DTU's Sustain Conference

Creating technology for a sustainable society.

Join the new yearly recurring conference for all research staff at DTU!

Time: All day December 17th. 2014.

Venue: Building 101 in Glassalen, and the meeting center.

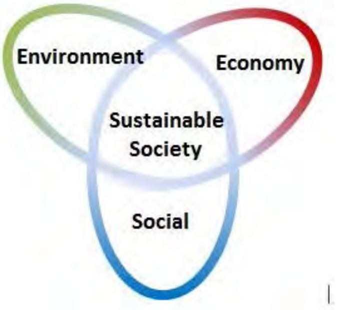
www.sustain.dtu.dk

Please see the website for time and location!

Table of Contents

Please see the website for time and location of talks and posters etc.

Sustainability



A sustainable society is considered to involve a balanced interplay of three main elements to meet the needs of present generations without compromising the possibilities of future generations to meet their own needs [1]:

- The environmental boundary conditions that set the limits on resource supply, waste disposal and environmental pollution;
- How the economy balances production and consumption processes within – or currently beyond - the environmental constraints;
- How society politically and culturally decides to manage the social effects of the above constraints given by the short and long term consequences of our activities.

Our developing knowledge of our own environmental impact imposes limits on our activities, while our expectations to the quality of life we wish to have requires expansion of activities.

Radically improved efficiency of our technologies are urgently needed in order to reduce both reliance on scarce resources and the long term effects on the environment and the climate, but also to handle the longer term demographic changes and the increase in material wealth in developing economies.

Society's growing awareness of the many challenges is causing a gradual but unavoidable change in our perspective on technology, from the traditional optimization of economic cost with the specific technological performance to a much broader view including environmental impact and performance in terms of resource efficiency etc.These considerations are becoming increasingly important in how we direct R&D and assess emerging technologies.

Both citizens and policies are evolving with this changing perspective. The EU Commission states that “Sustainable development will be an overarching objective of Horizon 2020” and allocates 60% of the budget to this [2]. The Danish Forsk2020 has also made the societal challenges in creating a sustainable society an important factor in their scope.

Sustain DTU is a conference where everyone involved in research at DTU from PhD students to Professors can meet to share their knowledge and inspire each other to create the best possible teams and solutions for solving the challenges.

The conference is divided into 5 tracks, and these broadly speaking cover the main societal challenges on sustainability and also involve the majority of DTUs many technology domains.

[1] United Nations General Assembly (1987) Report of the World Commission on Environment and Development: Our Common Future. http://www.un-documents.net/our-common-future.pdf
[2] “Horizon 2020 - The Framework Programme for Research and Innovation” Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 30.11.2011.

Plenum Talks

See schedule on
www.sustain.dtu.dk

Micro and nano structures for biosensing and oral drug delivery

Anja Boisen

DTU Nanotech

Corresponding author email: aboi@nanotech.dtu.dk

The optics and mechanics from a DVD player can be used to realize compact and sensitive sensor systems. By rotating a disc with integrated microfluidic channels it is possible to manipulate liquid samples such as blood – performing crucial operations like separation, valving and mixing. We integrate sensors such as cantilevers, nanoparticles and resonating strings with centrifugal microfluidics. The sensors are read out by a DVD pick-up head which can perform transmission/absorption measurements and which can detect nm deflections. Also, electrodes are integrated on a disc platform, facilitating electrochemical measurements.

In cantilever-based sensing, micrometer sized cantilevers are functionalized on one side with probe molecules. As target analytes bind to the probe molecules the cantilever deflects due to changes in surface stress. This deflection is typically in the nm range and normally only a few cantilevers can be read-out simultaneously. Using a rotating disc system hundreds of cantilevers can be read-out in one second. We will demonstrate how this approach can be used for detection of biomarkers. Hollow cantilevers will be briefly discussed as a new way of performing IR spectroscopy on picoliter amount of sample. Vibrating micrometer sized strings can be used for efficient and sensitive mass detection and for chemical analysis of single nanoparticles. We will show examples from drug characterization and illustrate how the strings can be read-out using blu-ray optics. Finally, we will show how agglutination based assays can be handled and read-out using the disc platform – here targeting biomarkers for rapid diagnostics and prognostics.

Micrometer sized containers can be used for oral drug delivery. The hypothesis is that oral drug delivery can be improved significantly by utilizing micrometer sized containers loaded with drug(s) and sealed by intelligent lids that open at specific locations in the body. The containers will, among other features, protect active pharmaceutical ingredients (APIs) during the passage through the stomach and facilitate adhesion to the wall of the intestine for controlled and unidirectional release, followed by absorption through the intestinal wall. We will show our recent findings and results.

Sustain DTU Plenum Talk Dec. 17. 2014

Enzyme technology: Key to selective biorefining

Anne S. Meyer, Center for Bioprocess Engineering

Dept. of Chemical and Biochemical engineering DTU

Development of selective biomass upgrading processes is a crucial prerequisite for unfolding the potential of biomass in biorefinery processes. The biorefinery concept designates that different value-added compounds are produced from the same crop or biomass stream. Selectivity with respect to the reaction is a unique trait of enzyme catalysis. Since enzyme selectivity means that a specific reaction is catalysed between particular species to produce definite products, enzymes are particularly fit for converting specific compounds in mixed biomass streams. Since enzymes are protein molecules their rational use in biorefinery processes requires an understanding of the basic features of enzymes and reaction traits with respect to specificity, kinetics, reaction optima, stability and structure-function relations – we are now at a stage where it is possible to use nature's enzyme structures as starting point and then improve the functional traits by targeted mutation of the protein. The talk will display some of our recent hypotheses related to enzyme action, recently obtained results within knowledge-based enzyme improvements as well as cast light on research methods used in optimizing enzyme catalysed biomass conversion processes.

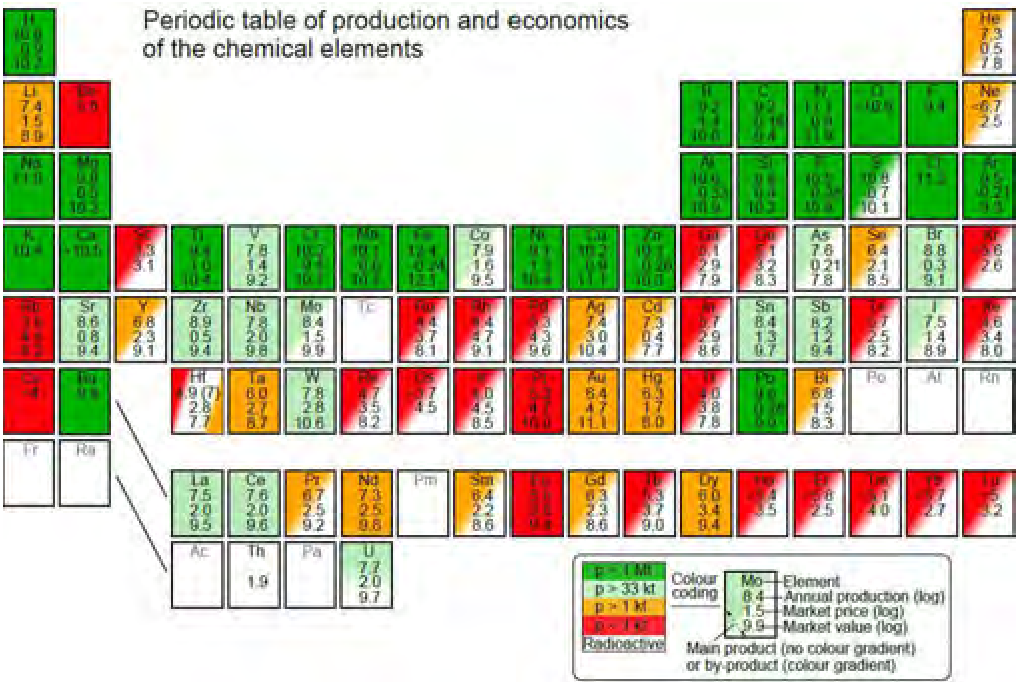
Can engineering solutions really provide a sustainable future?

Peter C.K. Vesborg[1*]
1: DTU Physics
*Corresponding author email: peter.vesborg@fysik.dtu.dk

Sustainability is a word which is very often (mis)used in various public debates. In engineering, however, it is perhaps easier to define the term, then in other academic fields.
We advocate the principle that only those activities, which can be sustained for at least a few centuries using known technology and resources, should be called sustainable.
Using this definition of sustainability one particularly big challenge field is energy supply, but the importance of the issue - "The energy problem" - is clear.

To illustrate one central aspect of the energy problem we introduce the "1 TW benchmark".
On this backdrop we proceed to discuss the practical availability of chemical elements for energy technologies and the implications this has for industrial scalability.
The issue will be exemplified by how some, otherwise promising, emerging technologies are limited in ultimate scale by scarcity of key elements. [1]

Finally, we discuss a few specific recent research highlights from DTU-Physics within the field of energy harvesting and conversion.



1 P.C.K. Vesborg & T. F. Jaramillo, RSC Advances, 2, p. 7933-7947 (2012), DOI: DOI: c2ra20839c

Future Solid State Lighting using LEDs and Diode Lasers

Paul Michael Petersen

DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Frederiksborgvej 399, 4000 Roskilde, Denmark;

Abstract

Lighting accounts for 20% of all electrical energy usage. Household lighting and commercial lighting such as public and street lighting are responsible for significant greenhouse gas emissions. Therefore, currently many research initiatives focus on the development of new light sources which shows significant savings. Solid state lighting (SSL) based on LEDs is today the most efficient light source for generation of high quality white light. Diode lasers, however, have the potential of being more efficient than LEDs for the generation of white light. A major advantage using diode lasers for solid state lighting is that the high efficiency can be obtained at high light lumen levels in a single element emitter and thus less light sources are required to achieve a desired light level. Furthermore, the high directionality of the generated light from laser diodes increases the energy savings in many applications.

Within the coming years, it is expected that the efficiency of blue laser diodes will approach the efficiency of infrared diode lasers. This will enable high efficiency white light generation with very high lumen per watt values.

SSL today is mainly based on phosphor converted blue light emitting diodes (LEDs). Blue emitting 445-460 nm LED chips with conversion in phosphorescent materials have undergone tremendous development in the last decade with ultra high efficiencies. However, the technology suffers from a decrease in efficiency at high input current densities, known as the “efficiency droop”. This efficiency droop restricts operation to relatively low output lumen levels for single element emitters. The cause of the efficiency droop is still not completely clear and thus a solution is not easily found. In the literature it has been suggested that carrier overflow in the quantum wells and non-radiative recombination could be the origins. Recently, Auger recombination was proposed as the dominant mechanism for efficiency droop.

In the talk we discuss the mechanisms of the efficiency droop in LEDs and we show how this problem can be eliminated in laser diodes. With the introduction of diode laser based lighting, high luminous flux levels and high efficiency can be available at the same time. Laser diodes operate in a fundamentally different regime using stimulated emission for light generation as opposed to spontaneous emission in LEDs

The recent progress in solid state lighting based on diode lasers will be reviewed and we will present a new diode laser architecture that emits as high as 2100 lumen green light with an efficiency of 70 lm/W

Put numbers on the sustainability

Michael Z. Hauschild*[1]

1: DTU Management

*Corresponding author email: mzha@dtu.dk

Sustainability is about meeting the needs of the present without compromising the possibilities for our future generations to meet their needs and is commonly perceived as comprising three dimensions – a social, an economic and an environmental dimension, e.g. in the triple bottom line thinking applied in many companies today. As engineers we need methods to analyze the sustainability performance of the technologies that we develop in order to create value for society. Quantitative methods allow us to benchmark alternative solutions against each other, to prioritize improvements and to document the sustainability performance. In this presentation the focus will be on the environmental dimension of sustainability and on methods for quantifying the environmental performance of products and technical systems. A product may cause environmental impacts when it is brought to use, but also when it is produced and disposed of at its end of life. The assessment therefore needs to take a life cycle perspective comprising all relevant activities from the extraction of resources over production, distribution and use, to the disposal and possible recycling of its constituents in new products (Figure 1).

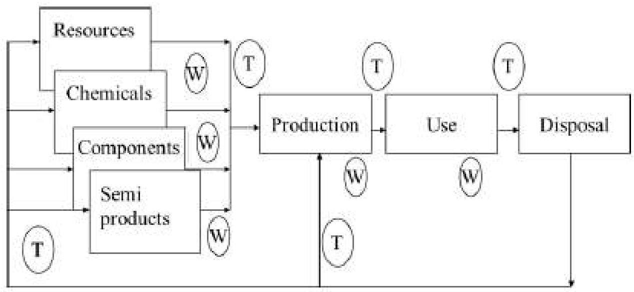


Figure 1. Product life cycle

Environmental sustainability encompasses multiple types of environmental impact ranging from the global scale like climate change and stratospheric ozone depletion over regional impacts associated with air pollution impacts causing acidification, photochemical ozone formation and particle exposure of humans, to the local impacts associated with physical transformation of land and extraction of water. Chemicals can cause toxic impacts to humans and ecosystems on all scales. All these impacts need to be quantified if we want to put numbers on sustainability.

The life cycle perspective on products and systems and the coverage of all relevant environmental impacts are combined in Life cycle assessment (LCA) which is introduced in the talk as the tool to put numbers on environmental sustainability. The basics of LCA are introduced, current applications are presented and a discussion of its possibilities and limitations in assessment of sustainability in relative and absolute terms is given.

Track 1

Sustainable Quality of life

Scientific Committee:

Coordinator: Ioannis S. Chronakis and Karen Boutrup Stephansen, DTU Food

Anne Marie Vinggaard (or Eva Bay Wedeby), DTU Food

Dennis Ringkjøbing Elema (and Jens-Peter Lynov), DTU Nutech

Tilmann Weber, DTU Biosustain

Ramneek Gupta, DTU Systemsbiology

Steering group contact person: Anders Baun, DTU Enviroment

Track 1
Talk
Presentations

See schedule on
www.sustain.dtu.dk

DTU's
Sustain
Conference

Sustainable strategies for treatment of bacterial infections

Søren Molin
Novo Nordisk Foundation Center for Biosustainability

Resistance to antibiotics and the consequential failures of treatment based on antibiotics makes microbial infections a major threat to human health. This problem combined with rapidly increasing life-style disease problems challenge our healtcare system as well as the pharma industry, and if we do not in a foreseeable future develop novel approaches and strategies to combat bacterial infections, many people will be at risk of dying from even trivial infections for which we until recently had highly effective antibiotics.

We have for a number of years investigated chronic bacterial lung infections in patients suffering from cystic fibrosis. These infections are optimal model scenarios for studies of antibiotic resistance development and microbial adaptation, and we suggest that this information should be useful when designing new anti-microbial strategies. In this respect it will be important to choose approaches which reduce as much as increases of the antibiotic resistance burden. Our approach is founded in molecular microbiology and microbial genomics.

Sustainable medication: Microtechnology for personalizing drug treatment

Adele Faralli[1], Fredrik Melander[1], Thomas L. Andresen[1], Niels B. Larsen *[1]

1: DTU Nanotech

*Corresponding author email: niels.b.larsen@nanotech.dtu.dk

Medication is an essential and costly part of global public health care, and the price of pharmaceuticals has increased steadily over the past decades. Recent statistics indicate that expenses may be stabilizing due to an increased public focus on the non-sustainable growth in total health care expenditure. Cost levels have stabilized by increasing competition between the pharmaceutical producers and through guidelines between hospitals on how to apply the most cost-effective medication for given disease conditions. Personalized drug treatment extends the latter concept by testing the effectiveness of candidate drugs on the individual patient prior to treatment. Thus, only useful medication is prescribed implying fewer societal expenses and better patient health. A large and growing number of specific biomarkers are developed to stratify patients into drug responders or non-responders based on one or more biochemical or genetic characteristics. However, stratification is typically a yes/no outcome that does not predict optimal drug dose or timing in the individual. Furthermore, existing biomarkers fair poorly in guiding patient treatment with combination drug regimens as commonly used, for example in cancer chemotherapy.

In the Danish Strategic Research Project "*IndiTreat - Individualized Treatment of colorectal cancer*" we pursue a radically different approach by testing all approved drug combinations on each patient's cells to predict the most optimal treatment. Massive drug testing calls for development of scalable nano- and microtechnologies suitable for culturing patient cells or cell clusters, and for easy and safe dosing of the patient cells with toxic drugs in normal hospital settings. Here, we will focus on easy scalable drug dosing of cells by introducing "digital drug dosing" using light-polymerizable polymer hydrogels as carriers for free or nanoparticle-encapsulated drugs. The total dose is simply controlled by the volume of drug-loaded cross-linked hydrogel defined by patterned light from a standard projector (Fig. 1). The concept enables simple immobilization of multiple drugs and triggered release of drugs from embedded liposome nanoparticles.

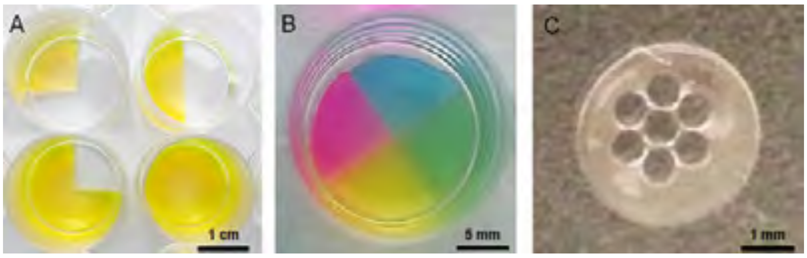
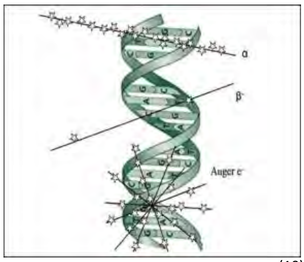


Fig. 1 Digital drug dosing. (A) Light-shaped hydrogels with a single embedded dye or (B) four different dyes as drug models. (C) Hydrogels can be shaped with high fidelity to enable massively parallel drug screening.

Auger Emitter Based Radiotherapy- A Possible New Treatment for Cancer


(10)

Pil M. Fredericia[1]; Groesser, Torsten[1]; Severin, Gregory[1]; Koester, Ulli[2]; Jensen, Andreas[1]; Mikael Jensen[1]

1: DTU Nutech 2:Institut Laue-Langevin, Grenoble, France
*Corresponding author email: kmje@dtu.dk

Cancer is a major cause of mortality worldwide (1). A large fraction of cancer patients undergo external radiotherapy, delivering a lethal dose of radiation to the patient's tumour(s). The main problem with this approach is the collateral damage caused to healthy, surrounding tissue and the side effects, which result.

Auger emitters decay by internal conversion (IC) or electron capture (EC) producing a number of Auger cascade electrons (5-8 electrons per decay). These electrons are so low in energy that their range in tissue is in the order of nm-µm. Due to this short range Auger emitters may be able to kill only the target cell while sparing the surrounding healthy tissue. In addition due to the multiple electrons released during the decay these emitters are more likely to produce at cluster of complex DNA damage which are considered to be much more harmful to the cell than dispersed DNA damage produced by Low-LET radiation used in current radiotherapy (2-3)

Considerable efforts have been made in the past twenty years to develop Auger emitter-based radiotherapy However, previous studies lack precise measurement of RBE, which is the fundamental factor defining the relationship between local radiation dose and biological damage done for the given Auger emitter, thereby brought the development to a halt. We believe we have the techniques to quantify the biological damage done for a given Auger emitter and thereby pushing the development of Auger emitter-based radiotherapy into reality (4-10)

References

1. WHO. Cancer. Fact sheet N°297. February 2012. Available from: http://www.who.int/mediacentre/factsheets/fs297/en/index.html.

2Kassis, A. I. (2004). The amazing world of auger electrons. *International Journal of Radiation Biology*, *80*(11-12), 789–803.

3Asaithamby, A., & Chen, D. J. (2011). Mechanism of cluster DNA damage repair in response to high-atomic number and energy particles radiation. *Mutation Research*, *711*(1-2), 87–99. doi:10.1016/j.mrfmmm.2010.11.002

4. Hoang B, Reilly RM, Allen C. Block copolymer micelles target auger electron radiotherapy to the nucleus of HER2-positive breast cancer cells. Biomacromolecules. 2012;13(2):455-65. Epub 2011/12/24.

5. Terry SYA, Vallis KA. Relationship Between Chromatin Structure and Sensitivity to Molecularly Targeted Auger Electron Radiation Therapy. International Journal of Radiation
Oncology Biology Physics. 2012;83(4):1298-305.

6. Kortylewicz ZP, Kimura Y, Inoue K, Mack E, Baranowska-Kortylewicz J. RadiolabeledCyclosaligenyl Monophosphates of 5-Iodo-2 '-deoxyuridine, 5-Iodo-3 '-fluoro-2 ',3 '-dideoxyuridine, and 3 '-Fluorothymidine for Molecular Radiotherapy of Cancer: Synthesis and Biological Evaluation. Journal of medicinal chemistry. 2012;55(6).

7. Liu X, Nakamura K, Wang Y, Cheng D, Liang M, Xiao N, et al. Auger-Mediated Cytotoxicity of Cancer Cells in Culture by an I-125-Antisense Oligomer Delivered as a Three-Component Streptavidin Nanoparticle. Journal of Biomedical Nanotechnology.
2010;6(2).

8. Nikjoo H, Girard P, Charlton DE, Hofer KG, Laughton CA. Auger electrons - A nanoprobe
for structural, molecular and cellular processes. Radiation Protection Dosimetry. 2006;1229

9. Pomplun, E., Booz, J., Dydejczyk, A., & Feinendegen, L. E. (1987).A microdosimetric interpretation of the radiobiological effectiveness of 125I and the problem of quality factor *. Radiation, 26, 181–188

10 .Jensen M, Köster U, Thisgaard H, editors. Experimental verification of auger emitter radiotoxicity using exotic radionuclides. Radiotherapy and Oncology; 2012

Green Toxicology – Application of predictive toxicology

Anne Marie Vinggaard, Eva Bay Wedebye, Camilla Taxvig, Nikolai G. Nikolov, Marianne Dybdahl & Terje Svingen

DTU Food, Molecular Toxicology
Mail: annv@food.dtu.dk

Humans are constantly challenged by exposure to a cocktail of chemicals that can have negative health effects, and fetuses and young children are particularly vulnerable. Therefore, we need safer chemicals in order to reduce any potential environmental and human hazards. A solid framework to design safer chemicals and to identify problematic compounds already in use such as industrial compounds, drugs, pesticides and cosmetics, is required. Green toxicology is the application of predictive toxicology to the production of chemicals with the specific intent of improving their design for hazard reduction. This objective is partly achieved through core principles of green chemistry. However, better utilization of existing predictive toxicological tools alongside new inventions is still required. For this, input from toxicologists early in the chemical enterprise is necessary to make informed choices on molecular design. Current tools, including (Quantitative) Structure-Activity Relationships ((Q)SARs) for predicting toxicity, Physiologically Based Kinetic (PBK) dynamic modeling for predicting absorption, distribution, metabolism and excretion, as well as human cell-based methods, deserve to be applied in chemical risk assessment to a greater extent than is currently the case. Greater focus on these tools, their strengths and weaknesses, should be part of chemistry training at the university level, thus ensuring constant focus on the issue and fostering new inventions into the future.

Zebrafish a new sustainable vertebrate model established at DTU Food to study immunotoxicology

Michael Engelbrecht Nielsen*[1] and Jacob Günther Schmidt[1]

1: DTU Food

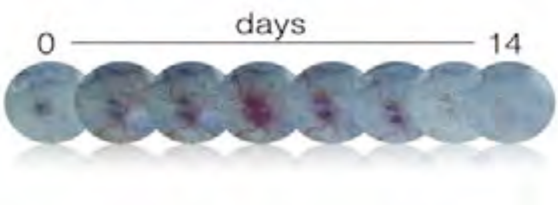
*Corresponding author email: mice@food.dtu.dk

Animal models are important tools in our combat against diseases as well as in screening for adverse effects of chemicals. As a supplement to the rodent models, which have been around for decades, the zebrafish provides new possibilities. The zebrafish have several practical characteristics, which enable new research possibilities:

- Small in size
- Short life cycle and generation time
- Good reproduction in captivity
- External fertilization
- Transparent embryos
- Rapid embryonic development
- Several transgenic strains e.g. with fluorescent cell types

We use zebrafish and carp as vertebrate models to investigate the immune system and adverse immunotoxicological effects of chemical substances. At DTU Food we have just invested in a State-of-the-art zebrafish facility with fully automated control of water parameters. We are currently working with the influence of chemicals on the allograft reaction (tissue transplants from one individual to another of the same species) in skin, where we measure angiogenesis (formation of new blood-vessels from pre-existing vessels) and expression of involved genes. The process of angiogenesis has proven to be a promising screening model, as angiogenesis can be followed by non-invasive imaging techniques and abrogates the need for time and cost consuming biochemical assays in a screening setup.

Progression of angiogenesis during an allograf reaction in common carp (Cyprinus carpio)



Genome Mining for antibiotics biosynthesis pathways with antiSMASH 3

Tilmann Weber[1*], Hyun Uk Kim[1], Kai Blin[1], Eriko Takano[2], Rainer Breitling[2], Marnix Medema[3]

1: DTU Biosustain; 2: Manchester Institute for Biotechnology, Univ. Manchester, UK; Max Planck Institute for Marine Biology, Bremen, Ger

*Corresponding author email: tiwe@biosustain.dtu.dk

Microorganisms are the most important source of natural products with antimicrobial or antitumor activity. These natural products are the main source for anti-infectives; 80% of antibiotics currently in medical use are derived from this class of compounds. In the past, functional screenings aiming directly to the substances or to putative targets were the only possibility to identify and isolate such compounds. With the recent progress of sequencing technologies, genome mining has become a very important method to complement the laborious and expensive experimental approach and to broaden the biological sources for novel drug candidates.

For high-throughput genome mining, sophisticated software is required, which allows the prediction of putative biosynthetic products based on genomic data. Here, we present the new version 3 of the software antiSMASH (http://antismash.secondarymetabolites.org). antiSMASH3 currently is the most comprehensive automated genome mining platform for natural product biosynthetic pathways.

It automatically screens genomic data of bacteria and fungi for the presence of 24 different types of secondary metabolite biosynthetic pathways. For different classes of secondary metabolites, detailed analyses on domain organization, enzyme active sites, and substrate specificities are integrated in the pipeline and allow the prediction of the biosynthetic core-products of the pathways.

In addition to tools focusing on the enzymes of the pathways, the identified gene clusters are searched compared against different integrated databases to identify homologous (often uncharacterized) gene clusters in other microorganisms, genes encoding the biosynthesis of conserved precursors or related experimentally validated gene clusters. A new module of antiSMASH3 now also provides a direct integration of metabolic modeling platform covering primary and secondary metabolism.

.
http://antismash.secondarymetabolites.org

References:

Blin, K., et al., 2014, PLoS ONE 9:e89420
Blin, K., et al., 2013, Nucleic Acids Res. 41:W204-W212
Medema, M. H., et al., 2011, Nucleic Acids Res. 39:W339-W346

The governmentalization of living: calculating health

Ayo Whalberg[1]*

1: Department of Anthropology, University of Copenhagen

*Corresponding author: Ayo.Wahlberg@anthro.ku.dk

The contemporary global health agenda has shifted emphasis from mapping disease patterns to calculating disease burden in efforts to gauge ‘the state of world health’. In this paper, we account for this shift by showing how a novel epidemiological style of thought emerged in the closing decades of the twentieth century. As is well known, the compilation and tabulation of vital statistics – death-rates, birth-rates, morbidity rates – contributed to the birth of the ‘population’ in the eighteenth and nineteenth centuries. The population is reformatted from the middle of the twentieth century by ‘modified life tables’ made up of disability weightings, health state valuations, quality of life scores, disease burden estimates, etc. The problem of morbid death gives way to that of morbid living, made calculable through a metrics of ‘severity’, ‘disability’ and ‘impairment’. A series of new indices and scales (e.g. the QALY and DALY) has contributed to a governmentalization of living, in the course of which the social and personal consequences of living with disease come to be an object of political concern, and made knowable, calculable and thereby amenable to various strategies of intervention. We conclude by showing how this style of epidemiological thought has generated a new global visibility for brain disorders as their impact on individuals, health care systems and nations are calculated in novel ways.

Track 1
Laptop
Presentations

See schedule on
www.sustain.dtu.dk

Sustainable nanomaterials? – How to apply "early warning signs" to screen nanomaterials for harmful properties

Anders Baun* and Steffen Foss Hansen

DTU Environment, Building 115, DTU.

*Corresponding author email: abau@dtu.dk

In 2001 the European Environment Agency (EEA) published a report that analyzed 14 cases of technological developments that later on turned out to have negative side-effects and they identified 12 "late lessons" for current and future policy-makers to bear in mind when initiating new technological endeavors. This presentation explores how the first lesson – "Acknowledge and respond to ignorance, uncertainty and risk in technology appraisal" could be applied to screen nanomaterials. In cases of ignorance, uncertainty and risk, the EEA recommends paying particular attention to important warning signs such as novelty, persistency, whether materials are readily dispersed in the environment, and whether they bioaccumulate or lead to potentially irreversible action. Through an analysis of these criteria using five well-known nanomaterials (titanium dioxide, carbon nanotubes, liposomes, poly(lacticco-glycolic acid) and nanoscale zero-valent iron), it was found that only nanoTiO2 fulfils all the five criteria. Depending on the length of the nanotubes, carbon nanotubes fulfil 3 or 4 criteria whereas liposomes, poly(lactic-co-glycolic acid), nanoscale zero-valent iron fulfil only one criteria. We will discuss how these warning signs can be used by different stakeholders such as nanomaterial researchers and developers, companies and regulators to design benign nanomaterials, communicate what is known about nano-risks and decide on whether to implement precautionary regulatory measures.

UV-Induced prevention of biofilm formation inside medical tubes and catheters

*Jens Mølgaard Pedersen[1], Kristian Nielsen[1] and Ole Bang[1]

1: DTU Fotonik

*Corresponding author email: jkmpe@fotonik.dtu.dk

Biofilm formation inside medical tubes and catheters may often cause unwanted infections, illness and impaired wound healing during medical treatment, resulting in extended hospitalization and - in worst case – life threatening conditions of the patients. In fact, it is estimated, that the infection risk connected with the use of medical tubes and catheters is the direct cause of more than 60% of all infections acquired in European hospitals [1]. Once formed, the biofilm is generally very tough to suppress by either the body's immunity system or by use of antibiotics, which may even favor the population of multi resistant bacteria cultures. Prevention of biofilm formation inside the tube or catheter, without risk of developing multi resistance, may be achieved by creating a UV-exposed environment in the interior. This may be realized by transforming the tube itself into an optical waveguide supporting UV-light propagation or by other means integrating optical fiber technology into the tube walls, such as to gradually release UV-light into the interior, efficiently killing off bacteria present inside.

This project is part of the innovation consortium BIOFORS, consisting of the research institutions DTU Fotonik, Rigshospitalet, Danish Technological Institute, Danish National Metrology Institute (DFM), together with the industrial partners OFS Fitel Denmark A/S, U-Vivo ApS, Palle Knudsen Kunststoffabrik ApS, Primasil Silicones Ltd. and Baxter-Gambro AB.

[1]: Lyytikanen O, Lumio J, Sarkkinen H, Kolho E, Kostiala A, Ruutu P, Clin Infect Dis 2002, 35(2)

Track 1
Poster
Presentations

See schedule on
www.sustain.dtu.dk

Innovative Solutions for Ostomy Care: Combining Consumer Insight and New Technologies

Bahar Bingöl,[1]*
1: Coloplast A/S, Global Research and Development Center for Adhesives, Holtedam 1 3050 Humlebæk, Denmark
*Corresponding author email: dkbbi@coloplast.com

2.5 million people live with an ostomy, which is a condition resulting from treatment of digestive and urinary diseases. They have a stoma, which is a surgically created opening in their body for discharging waste (Figure 1 a). A bag is attached to stoma to collect the waste (Figure 1 b). Coloplast is a medical device company, which aims at bringing new and innovative products to ostomy care market to sustain quality of life of people living with an ostomy and allow them to live a normal healthy life. To realize this goal at Coloplast, we are combining user insight with new technologies. We will share our activities and challenges in the area of translating consumer needs into innovative products. We carry out our activities in cooperation with industrial and academic partners such as DTU.


(a)


(b)

Figure 1: (a) An ostomy base plate on a consumer with stoma (b) A full ostomy device

Together with health care professionals, Coloplast has conducted a quality of life study in 11 countries with more than 4000 patients to understand the everyday challenges that people with stoma face and the impact of the challenges on everyday life. The results of this study show that leakage of body fluids from stoma bag is a major problem. Leakage usually leads to skin damage. Moreover, being worried about leakage, a large fraction of ostomy patients limit the choice of clothing, physical and social activities, how far they travel, while a smaller fraction of patients isolate themselves.

Coloplast is working towards new ostomy devices, which will reduce or eliminate leakage problem and protect skin. Success in this area requires an interdisciplinary team with expertise in material science, engineering, biology and design. Skin-friendly and processable polymeric materials are an important ingredient of ostomy devices. It is crucial to understand how these materials behave at rest as well as when they deform, and how they interact with skin. In addition, test methods are needed to evaluate the application related properties of ostomy devices. Moreover, understanding conditions leading to leakage is only possible by building simple systems that can follow and monitor the consumers while they use the products. In addition to these function related aspects, products are designed to be discrete.

Electrospun fish protein fibers as a biopolymer-based carrier – implications for oral protein delivery

Karen Stephansen[1,2], María García-Díaz[2], Flemming Jessen[1], Ioannis S. Chronakis[1], Hanne Mørck Nielsen*[2],

1: DTU FOOD; 2: Department of Pharmacy, University of Copenhagen

*Corresponding author: hanne.morck@sund.ku.dk

Purpose: Protein-based electrospun fibers have emerged as novel nanostructured materials for tissue engineering and drug delivery due to their unique structural characteristics, biocompatibility and biodegradability. The aim of this study was to explore the use of electrospun fibers based on fish sarcoplasmic proteins as an oral delivery platform for biopharmaceuticals, using insulin as a model protein.

Methods: Fish sarcoplasmic proteins (FSP) were isolated from fresh cod and electrospun into nano-microfibers using insulin as a model payload. The morphology of FSP fibers was characterized using scanning electron microscopy (SEM), and the conformational stability of insulin was confirmed by circular dichroism (CD). The *in vitro* release and enzymatic degradation of encapsulated insulin was measured in different buffers and quantified using RP-HPLC. The permeability of released insulin across differentiated Caco-2 cell monolayers was followed by RP-HPLC and ELISA, and the transepithelial electrical resistance (TEER) was measured before and after the experiment. Cell viability was assessed by the MTS/PMS assay.

Results: Insulin was encapsulated in the electrospun FSP fibers with high efficiency, high loading and without any effect on fiber morphology. Release of insulin *in vitro* was 75% after 3 h in simulated intestinal fluid. The secondary structure of insulin was preserved after release, and insulin functionality was confirmed by ELISA. Insulin permeability across Caco-2 cell monolayers was significantly enhanced when administered encapsulated in FSP fibers. The TEER was decreased after 4 h incubation, and no negative effect on cell viability was observed at any time.

Conclusion: In this work we present electrospun FSP fibers as a novel oral drug delivery system for biopharmaceuticals. The electrospinning process did not affect the functionality of the encapsulated insulin and it provided controlled release kinetics. The epithelial permeability enhancing effect and biocompatibility of the FSP fibers provide evidence for further investigating protein-based electrospun nanofibers for delivery of proteins and peptides.

QSAR pre-screen of 70,983 substances for genotoxic carcinogenicity, mutagenicity and developmental toxicity in the EU FP7 project ChemScreen

Eva B. Wedebye, Marianne Dybdahl, Nikolai G. Nikolov, Svava Ó. Jónsdóttir, Jay R. Niemelä

Department of Toxicology and Risk Assessment, National Food Institute,
Technical University of Denmark, Mørkhøj Bygade 19, 2860 Søborg, Denmark
e-mails: {ebawe,mdyb,nign}@food.dtu.dk

The focus of the EU FP7 project ChemScreen, which was completed by the end of 2013, was to generate alternative testing methods for reproductive toxicity under REACH. If found adequate, QSARs can be applied in REACH as a replacement for animal tests. As no testing for reproductive effects should be performed in REACH on known genotoxic carcinogens or germ cell mutagens with appropriate risk management measures implemented, a QSAR pre-screen for genotoxic carcinogenicity, germ cell mutagenicity and (limited) developmental toxicity was included in the project. Predictions for estrogenic and anti-androgenic activity (*in vitro*) were also included in the pre-screen. The prediction set comprised 70,983 of the 143,835 chemicals REACH pre-registered chemicals, for which structural information was found and was suitable for the applied QSAR models. The prediction set was run through 16 models and decision algorithms were applied to combine the predictions from the individual models to reach overall predictions for genotoxic carcinogenicity, germ cell mutagenicity and developmental toxicity. Furthermore, the full list of REACH pre-registered substances (143,835) was searched for substances containing certain known toxic heavy metals (Cd, As, Hg and Pb) and these were flagged as they may be assumed to possess the properties of the heavy metal part unless otherwise known. The QSAR pre-screen results were fed into subsequent ChemScreen activities to develop an *in vitro*/*in silico* screening system to predict human- and ecotoxicological effects.

1. http://www.chemscreen.eu/

POF based glucose sensor incorporating grating wavelength filters

*Hafeez Ul Hassan[1], Soren Aasmul[1], Ole Bang[2], Kristian Nielsen[2], Getinet Woyessa[2]

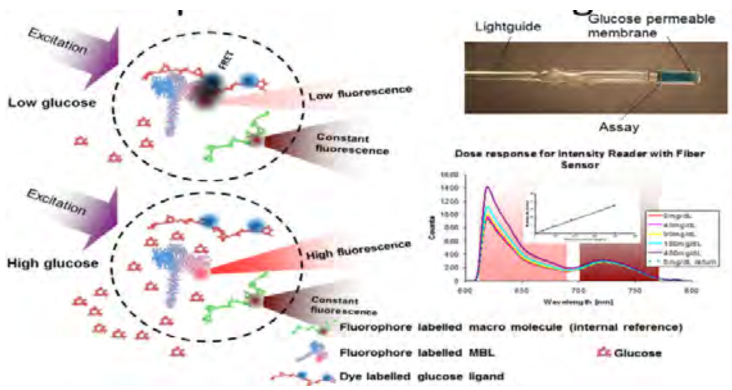
1: Medtronic R&D Diabetes Denmark A/S Agern Allé 1 | 2970 Horsholm, Denmark

2: DTU FOTONIK

*hafeez.ul.hassan@medtronic.com

Medtronic has already developed a plastic fiber based optical sensor to detect the concentration of glucose both in vivo and in-vitro.

The glucose sensor is based on a competitive glucose binding affinity assay consisting of a glucose receptor and glucose analog (ligand) contained in a compartment made up of permeable membrane for exchanging of only small molecules such as glucose, salts etc. (Fig 1).



The binding between the glucose binding protein labeled with flourophore and glucose like molecules labelled with dye, is reversible. In the presence of glucose, the glucose analog competes with the glucose on binding to the protein. The system reaches an equilibrium, which correlates with the glucose concentration.The assay chemistry makes donor and acceptor pair for FRET (Förster Resonance Energy Transfer). FRET results in decrease in donor emission intensity. Higher the concentration of glucose, more donor acceptor pairs got separated resulting in high intensity and vice versa. This change in optical signal is correlated to glucose concentration. (Fig.1)

Medtronic Diabetes and DTU FOTONIK has been working together under the consortium of Marie Curie Research Framework called TRAINING AND RESEARCH IN POLYMER OPTICAL DEVICES; TRIPOD.

Within the domain of TRIPOD, research is conducted on "Plastic Optical Fiber based Glucose Sensors Incorporating Grating Wavelength Filters".

Research will be focused to optimized fiber tips for better coupling efficiency, reducing the response time of sensor, improve the mechanical stabilization of assay compartment by exploring the side excitation and side coupling method, ease of manufacturing and feasibility of Polymer Fiber Bragg gratings as filters.

During the project, fibers will be drawn and fiber bragg gratings will be inscribed at DTU Fotonik and they will be characterized for glucose sensor at Medtronic Diabetes.

Supercontinuum based mid-IR imaging spectroscopy for cancer detection

Ole Bang*[1], Uffe Møller[1], Irnis Kubat[1], Christian Rosenberg Petersen[1]

1: DTU Fotonik

*Corresponding author email: oban@fotonik.dtu.dk

The mid-infrared (IR) spectral region is of significant technical and scientific interest because most molecules display fundamental vibrational absorptions in this region, leaving distinct spectral fingerprints. To date, the limitations of mid-IR light sources, such as thermal emitters, low-power laser diodes, quantum cascade lasers and synchrotron radiation, have precluded mid-IR applications where the spatial coherence, broad bandwidth, high brightness and portability of a supercontinuum laser are all required. In an international collaboration in the EU project MINERVA [minerva-project.eu] DTU Fotonik has now demonstrated the first optical fiber based broadband so-called supercontinuum light souce, which covers 1.4-13.3 µm and thereby most of the molecular fingerprint region [1]. This ultra-fast light source is the basic component in the mid-IR camera developed in MINERVA for early cancer detection with mid-IR imaging spectroscopy.

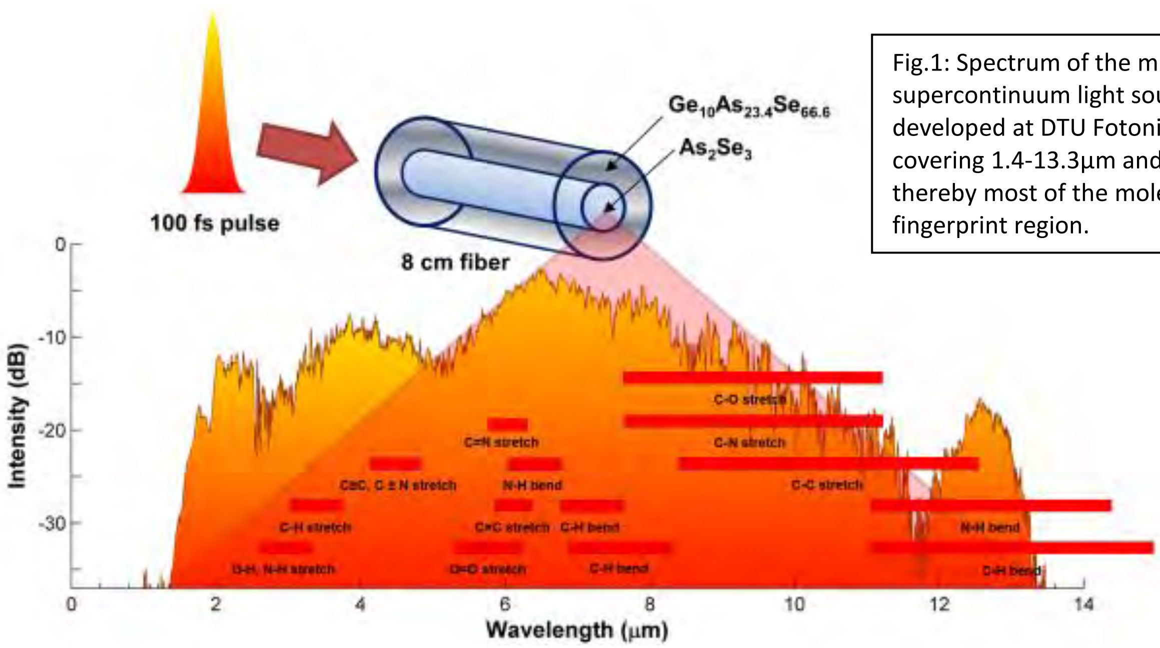


Fig.1: Spectrum of the mid-IR supercontinuum light source developed at DTU Fotonik, covering 1.4-13.3µm and thereby most of the molecular fingerprint region.

[1] C.R. Petersen, U. Møller, I. Kubat, B. Zhou, S. Dupont, J. Ramsay, T. Benson, S. Sujecki, N. Abdel-Moneim, Z. Tang, D. Furniss, A. Seddon, O. Bang, "Mid-infrared supercontinuum covering the 1.4–13.3 µm molecular fingerprint region using ultra-high NA chalcogenide step-index fibre", Nature Photonics **8**, 830–834 (2014)

Photo-acoustic imaging of coronary arteries with polymer optical fibers

Getinet Woyessa[*1], Christian, Broadway[2], Horacio Lamela[2], Guillermo Carpintero[2], Danie Gallegol[2], Ole Bang[1]

1: DTU Fotonik,

2: Optoelectronics and Laser technology group, Universidad Carlos III de Madrid

*Corresponding author email: gewoy@fotonik.dtu.dk

Coronary artery disease (CAD) is one of the most common types of heart disease which happens when the arteries that supply blood to heart muscle become hardened and narrowed. This is caused by the building of cholesterol plaques on the inner walls of arteries. The gradual growth of plaques cause less blood to flow through the arteries hence the heart muscle can't get the blood or oxygen it needs. Worse, a plaque can suddenly rupture. As a result, blood clot over the rapture and suddenly cut off the hearts' blood supply, causing permanent heart damage or stroke [1].

Photo-acoustic imaging is useful for detection of plaques for prevention of rupture of vulnerable plaques. These vulnerable plaques in the arteries can be distinguished using photo-acoustic imaging based on lipid accumulation with different characteristics of optical absorption. The basic principle of this imaging technique relies on exposing lipids to a laser capable of inducing photo-acoustic effect and a sensor affected by the induced pressure. Polymer optical fibre Bragg grating and Fabry-Perot sensors will be developed for detection of photo-acoustic signal in collaboration of Optoelectronics and Laser technology group, Universidad Carlos III de Madrid under the TRIPOD project.

TRIPOD (http://www.tripod-itn.eu) is a Marie Curie Initial Training Network located in the field of optical fibre sensors - an area where Europe has developed internationally competitive research and commercial activity. The aim is to significantly extend the range of application of optical fibre grating sensors by developing a mature version of the technology in polymer optical fibres and thereby increase European competitiveness.

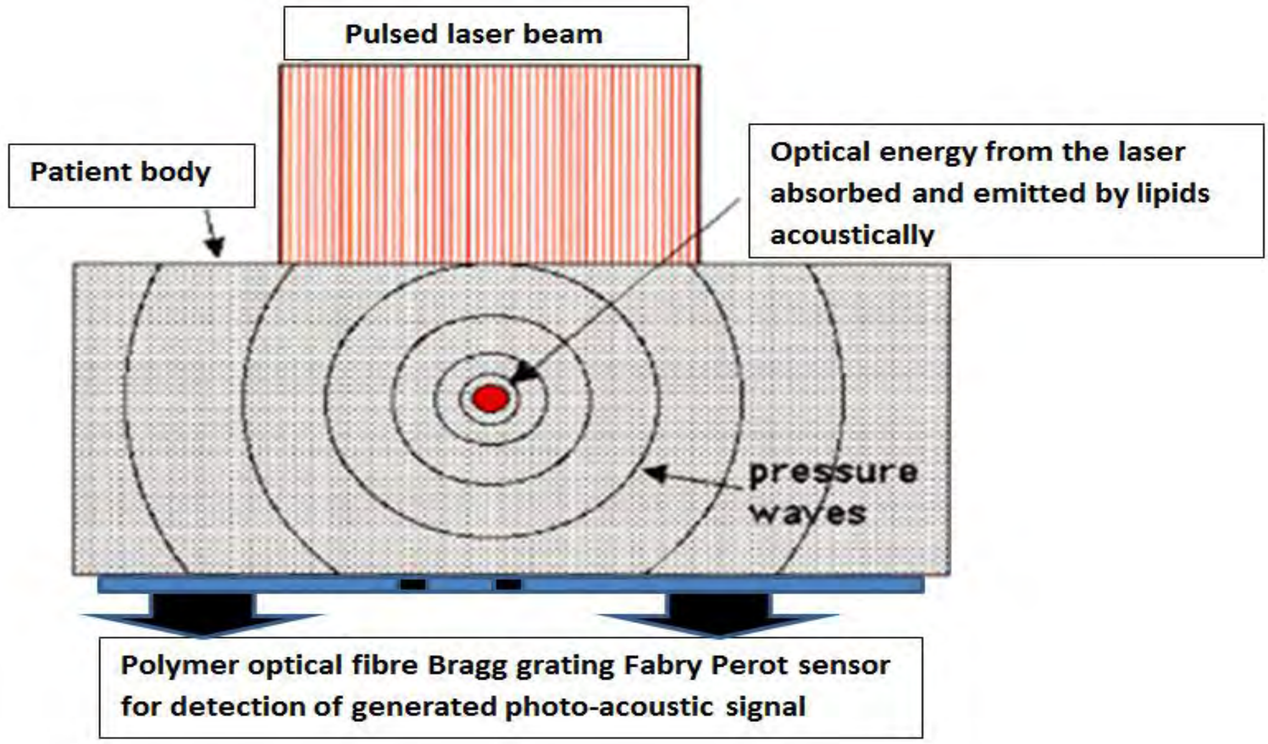


Figure 1: Photo-acoustic imaging of coronary arteries involves the generation of pressure waves by absorption of pulsed laser light by lipids

[1] Naghavi, M. Libby, P., Falk, E. et al., "From vulnerable plaque to vulnerable patient: a call for new definitions and risk assessment strategies: Part II," Circulation, 108(15), 1772-1778 (2003).
[2] Falk, E., Shah, P.K. and Fuster, V., "Coronary plaque disruption," Circulation, 92(3), 657-671 (1995).

Are structural analogs to bisphenol A a safe alternative?

Rosenmai, A.K.[*]; Dybdahl, M.[*]; Pedersen, M.[‡]; van Vugt-Lussenburg, B.[†]; Wedebye, E.B.[*]; Pedersen, G.A.[‡] & Vinggaard, A.M.[*]

[*]*Division of Toxicology & Risk Assessment and* [‡]*Division of Food Chemistry, National Food Institute, Technical University of Denmark, DK-2860 Søborg, Denmark.* [†]*BioDetection Systems b.v., Science Park 406, 1098 XH Amsterdam, The Netherlands*

Bisphenol A (BPA) is a chemical often integrated in impact-resistant plastics and surface coatings in canned foods as well as screw-on caps and cashier receipts. BPA is either intentionally added or appear as a consequence of recycling in materials with food contact, which leaves consumers at risk of exposure. BPA has known endocrine disrupting effects and is suspected to be a contributing factor in disorders such as overweight, diabetes, cardiovascular diseases, and behavioral changes in children. Thus, a need for developing alternatives to BPA exists. Structural analogues of BPA are already in use and have been detected in foods and in humans. Due to the structural analogy there is an inherent risk of similar effects as BPA.

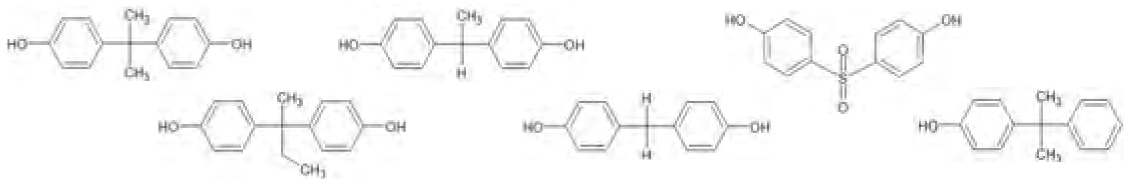


Fig. 1: Chemical structures from left to right for BPA, BPB, BPE, BPF, BPS, and HPP.

The aim of the present project was to assess whether BPB, BPE, BPF, BPS and HPP are safe BPA alternatives using eight *in vitro* assays covering potential to cause endocrine disruption, oxidative stress, genotoxicity and effects on metabolism.[1] Endocrine disruption was the main target of the test compounds. Besides ER and AR activity, alteration of steroidogenesis was observed which can add to the overall endocrine potential of the test compounds. A substitution of BPA with these structural analogues should be carried out with caution.

[1]Rosenmai AK, Dybdahl M, Pedersen M, Alice van Vugt-Lussenburg BM, Wedebye EB, Taxvig C, and Vinggaard AM. Are structural analogues to bisphenol A safe alternatives? *Toxicological Sciences* 2014; 139:35-47.

KirCII- promising tool for polyketide diversification

Ewa Musiol-Kroll*[1], Thomas Härtner[2], Andreas Kulik[2], Wolfgang Wohlleben[2], Tilmann Weber[1] and Sang Yup Lee[1]

* emmu@biosustain.dtu.dk

1: Technical University of Denmark, Novo Nordisk Foundation Center for Biosustainability, Kogle Allé 6, 2970 Hørsholm, Denmark

2: University of Tuebingen, Interfakultäres Institut für Mikrobiologie und Infektionsmedizin, Dpt. of Microbiology/Biotechnology, Auf der Morgenstelle 28, 72076 Tübingen, Germany

Kirromycin is produced by *Streptomyces collinus* Tü 365. This compound is synthesized by a large assembly line of type I polyketide synthases and non-ribosomal peptide synthetases (PKS I/NRPS), encoded by the genes *kirAI-kirAVI* and *kirB*. The PKSs KirAI-KirAV have no acyltransferase domains integrated into the PKS modules. This type of PKS is named trans-AT-PKS. The KirAVI belongs to the classical cis-AT-type PKS, where the ATs are part of the PKS protein. In the gene cluster of kirromycin two separate AT-like genes, *kirCI* and *kirCII*, were identified. The proteins KirCI and KirCII were characterized by genetic and biochemical approaches. While KirCI is a malonyl-CoA specific AT and loads malonate on the assembly line, the discrete AT KirCII is introducing ethylmalonate into the kirromycin structure.

Recently, the substrate preference of KirCII was described (1-3). *In vitro* assays showed that besides ethylmalonyl-CoA, KirCII accepts other non-malonyl-CoA substrates (e.g. allylmalonyl-CoA or propagylmalonyl-CoA). Feeding of the kirromycin producer strain carrying a Co-A-synthetase led to the production of kirromycin derivatives: allyl- and propagyl-kirromycin and demonstrate that KirCII is also introducing the non-native substrates in an *in vivo* context. Thus, KirCII represents a promising tool for polyketide diversification.

1. Musiol EM, et al. (2011) Supramolecular templating in kirromycin biosynthesis: the acyltransferase KirCII loads ethylmalonyl-CoA extender onto a specific ACP of the trans-AT PKS. Chemistry & biology 18(4):438-444.
2. Ye Z, Musiol EM, Weber T, & Williams GJ (2014) Reprogramming Acyl Carrier Protein Interactions of an Acyl-CoA Promiscuous trans-Acyltransferase. Chemistry & biology.
3. Koryakina I, et al. (2013) Poly specific trans-acyltransferase machinery revealed via engineered acyl-CoA synthetases. ACS Chem Biol 8(1):200-208.

Social LCA of maritime gardens and the concept of human capabilities

Arne Wangel[1]*

1: DTU Management Engineering * arwa@dtu.dk

The experiment in Copenhagen Harbour collapses a highly stratified production, distribution and consumption process into a much shorter and simplified life cycle situated in one locality only. As the oysters filter the polluted sea water, the regeneration of the water quality in the harbour accelerates and paves the way for new urban life spaces. The pioneers claim that their design provides a range of potentially positive social impacts: oysters at reasonable cost are a nutritious addition to the daily diet; the activities throughout the life cycle of oysters provide learning and recreation for the families involved; and also a sense of community and belonging develops in the process.
In terms of human capital development, aquaculture - in particular under experimental conditions - requires a high level of managerial skills. However, according to Sen, this will be included in his broader concept of capabilities. The concept of human capital focuses on *'the agency of human beings - through skill and knowledge as well as effort - in augmenting production possibilities'* (Sen 1997, 1959).Sen's concept of human capabilities has a wider scope; he points to *'their direct relevance to the well-being and freedom of people; their indirect role through influencing economic production; and their indirect role through influencing social change'* (Sen 1997, 1960). Tentatively, the list of ten central capabilities defined by Martha Nussbaum (2003) may be specified for the experimental oyster value chain. However, the actual specification of relevant capabilities and how measure these must – in accordance with Sen's concept – be performed by those involved on the basis of what they consider as valuable functionings. Thus, as suggested by several authors, e.g. by Syndhia Mathe (Mathe 2014), some form of participatory approach needs to be integrated into Social LCA to contextualize the assessment in terms of plurality of interests, local knowledge, diversity of social value judgements etc.
One important contribution towards the measurement of capabilities points the option for micro-foundations in normative assessments, *'the valuational foundation of the capability approach allows people to express their 'powers of discrimination' with regard to their well-being or to the good life'* (Comim et al. 2008, 180). For the oyster cas, it is proposed to apply Interactive Scenario Analysis, which is *'a method for creating scenarios that should be able to help stakeholders to navigate towards desirable futures'* (Baungaard Rasmussen 2011, 99). The suggestion is to integrate the assessment of social impacts as design criteria in the process of constructing the new oyster chain and its enabling context.

Baungaard Rasmussen, Lauge 2011. *Facilitating change : Using interactive methods in organizations, communities and networks*. [Kgs. Lyngby]: Polyteknisk Forlag.
Comim, Flavio., Qizilbash, Mozaffar.,Alkire, Sabina.,. 2008. *The capability approach: Concepts, measures and applications*. Cambridge, UK; New York: Cambridge University Press.
Mathe, S. 2014. Integrating participatory approaches into social life cycle assessment: The SLCA participatory approach. *International Journal of Life Cycle Assessment* 19 (8): 1506-14.
Nussbaum, Martha 2003. Capabilities as fundamental entitlements: Sen and social justice. *Feminist Economics* 9 (2-3): 2-3.
Sen, Amartya 1997. Editorial: Human capital and human capability. *World Development* 25 (12): 1959-61.

Track 2

Sustainable Bio & Food Resources

Scientific Committee:

Coordinator: Peter Ruhdal Jensen, DTU Food

Søren Aabo, DTU Food

Lone Gram, DTU Systemsbiology

Patrizio Mariani, DTU Aqua

Anna Rindorf, DTU Aqua

Steering group contact person: Michael Zwicky Hauschild, DTU Management

Track 2
Talk
Presentations

See schedule on
www.sustain.dtu.dk

DTU's
Sustain
Conference

Sustainable exploitation and management of aquatic resources

Stefan Neuenfeldt[1*], Friedrich W. Köster[2]

1,2: DTU Aqua

*stn@aqua.dtu.dk

DTU Aqua conducts research, provides advice, educates at university level and contributes to innovation in sustainable exploitation and management of aquatic resources. The vision of DTU Aqua is to enable ecologically and economically sustainable exploitation of aquatic resources applying an integrated ecosystem approach which utilizes synergies in natural and technical science disciplines. DTU Aqua advises the Danish Ministry of Food, Agriculture and Fisheries and other public authorities, the commercial fisheries, the aquaculture industry and international commissions.

DTU Aqua deals with all types of aquatic habitats – from the North Atlantic Ocean and European shelf areas to coastal areas and inner Danish waters, ecosystems in lakes and streams as well as aquaculture. European shelf seas, Danish coastal areas and freshwaters are our main working areas, but we also work on Arctic and sub-Arctic waters, in particular in the North Atlantic surrounding Greenland, and we are involved in research activities in other parts of the world. DTU Aqua's research is divided into the following fields:

Oceanography and climate focuses on understanding the interplay between physical, chemical and biological conditions in the ocean and how these factors impact the living conditions for marine organisms. **Population genetics** aims at gaining knowledge on how to preserve and manage biodiversity sustainably. **Individual biology** deals with the biology of aquatic organisms and their interaction with other organisms and with the surrounding environment.

Freshwater fisheries and ecology is devoted to looking at the behaviour of particular species of fish and their interaction with the environment. **Coastal ecology** deals with the structure and function of the ecosystems as a habitat for fish and shellfish as well as with coastal area management. **Marine ecosystems** aims at understanding the mechanisms that govern the interaction between individuals, species and populations in an ecosystem enabling us to determine the stability and flexibility of the ecosystem.

Marine living resources looks at the sustainable utilization of fish and shellfish stocks. **Ecosystem effects** expands from the ecosystem approach to fisheries management to an integrated approach where other human activities are taken into consideration. **Fisheries management** develops methods, models and tools for predicting and evaluating the effects of management measures and regulations applied by the authorities in fisheries management.

Fisheries technology focuses on the development of selective and low-impact fishing gear which can help limit unintended by-catches and minimize the impact on the marine environment. **Observation Technology** is concerned with research and development of systems for collecting data in support of marine research and management.

Shellfish aquaculture and fisheries focuses on production potential and resilience of coastal areas in relation to shellfish aquaculture and fisheries. **Aquaculture** covers a wide range of biological and technological aspects from fish nutrition and growth to environmental impacts of aquaculture.

Development of healthy marine ingredients from waste products from smoked rainbow trout

Charlotte Jacobsen*, Philipp Honold, Marie-Louise Nouard

DTU Food

*chja@food.dtu.dk

There is an increasing demand for healthy marine omega-3 oils as well as new functional proteins for human consumption. At the same time there is an increasing demand for fish oil as an ingredient in fish feed due to the growth in production of farmed fish. The aquaculture industry currently uses approx. 850.000 tons of fish oil per year, which is expected to increase significantly in the coming years. The demand for fish oil for human consumption has been estimated to 425.000 tons by 2017. The present production of fish oil from wild fish is 1 mio. tons/year. Due to sustainability issues it is not possible to increase the production of fish oil from wild fish further. A possible source of omega-3 oils for human consumption is waste products from the fish industry. At present only approximately 40 % of the fish is used for human consumption and the rest is turned into waste products.

Rainbow trout is the main species produced in Danish fresh water farming. By-products from the filleting process (head, bones, tail and intestine) are at present turned into ensilage and sold to the mink industry with low revenue. The aim of the DANFOMEGA project is therefore to use these waste products for the development of new high quality omega-3 oils and protein products and to evaluate the potential of these ingredients in a number of food applications. One of the challenges when producing and using fish oils is to obtain good sensory properties and high oxidative stability. Therefore, the process for extracting the fish oil as well as the addition of antioxidants to prevent oxidation must be optimized. This presentation will include results from our work on these challenges.

Integrated multi-trophic aquaculture (combined production of fish, mussels and seaweed)

Susan L. Holdt*[1], Goncalo S. Marinho[2], Irini Angelidaki[2]

1: DTU Food; 2: DTU Environment

*suho@food.dtu.dk

The Danish marine aquaculture has, despite the huge potential, only been slowly increasing the last 25 years because of the imposed limits to the nitrogen (N) released to the environment. Mussels, seaweed and other organisms have been successfully tested as biofilters in integrated multi-trophic aquaculture (IMTA) worldwide, where nutrients emissions (especially N) from e.g. fish production are assimilated and removed by valuable biomasses (crops; Fig.1). This IMTA production unit, and even spatial decoupling of the biofilter organisms from the fish, have been recognized by the Danish national authorities in off-shore fish farming. The bioremediation potential and yield of the "new" crop, seaweed (sugarkelp, *Saccharina latissima*) was monitored in a commercial off-shore IMTA system year round at Hjarnø Havbrug fish farm near Horsens. Furthermore, the year-round protein, amino acid, fatty acid, mineral and vitamin content and profiles were monitored to evaluate the nutritional value and harvest time of the seaweed biomass.

Sugarkelp showed to be efficient for bioremediation of nitrogen, with environmental and potentially economic benefits (e.g. waste water management and for production of valuable biomass). The seaweed protein content varied throughout the experimental period with the highest values recorded in November (14-20% of dry weight) and the lowest values recorded in May-July (2.8-6.7%). The lowest lipid content was observed in July, while the highest values were observed in November (approx. 4% of dw), with EPA (20:5(n-3)) and DHA (22:6(n-3)) accounting for 11.3-14.4% and 2.5-4.6% of total fatty acids, respectively.

This "new" Danish aquatic crop has potential applications. The harvest time should be settled around May for human consumption and September in order to achieve maximum biofiltration efficiency with harvested biomass for feed utilization. This considering both biology/life cycle, biofouling and yield, which may compromise with seasons with higher nutritional value of the produced biomass.

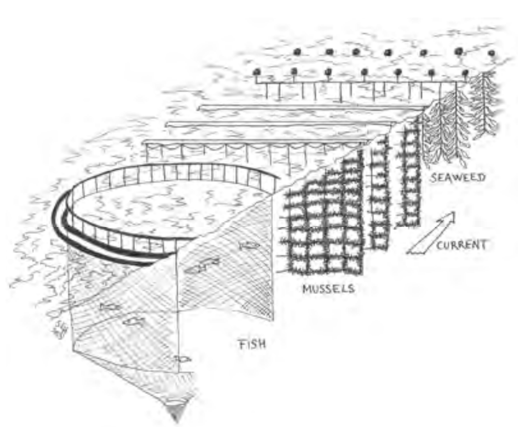


Fig. 1 Integrated Multi-trophic Aquaculture with the fed organisms (fish), filtrating (mussels) and assimilating (seaweed) organisms in a combined production unit (Holdt and Edwards, 2014).

Reference: Holdt, S.L., Edwards, M.D. (2014) Cost effective IMTA: Comparison between seaweed and mussel biofilter. *Journal of Applied Phycology,* 26, 933-945

Development of harvesting and up concentration technologies for microalgae as an ingredient in fish feed

Hamed Safafar [*1], Charlotte Jacobsen [1], Per Møller [2]

1: DTU Food; 2: Ecolipids;

The European Union has recently adopted an ambitious strategy for developing the Bio economy in Europe based on the innovative use of sustainable biological resources to cover the growing demand of the food, energy and industrial sectors. Despite their excellent nutritional quality of digestible protein, LC PUFAs and vitamin/ minerals, fish meal and fish oil are limited resources in aquaculture and alternatives are needed to support the fast growing aquaculture demand for high quality fish feed.

Micro algae represent an interesting reliable resource of great potential as an alternative to fish meal and fish oil. In applications of algae in fish feed, it is essential to produce a product comparable to fish protein and fish oil both in terms of quality and costs.

Downstream processing of microalgae includes harvest, dewatering, cell rupture, fractionation and drying. The dewatering and drying which involve separation of water from the algal suspension, account for the majority of total production costs.

This project investigate the effects of harvesting, dewatering, thermal treatments and drying on microalgae biomass composition and quality and suggests a set up suited for the production of algae ingredients for fish feed. Further we evaluate the chemical composition of six different microalgae species including; *Nanochloropsis limnethica, Chlorella sorokiniana, Phaeodactylum tinctorium, Dunaliella salina, Nannochloropsis salina* and *Nannochloropsis occulata .*

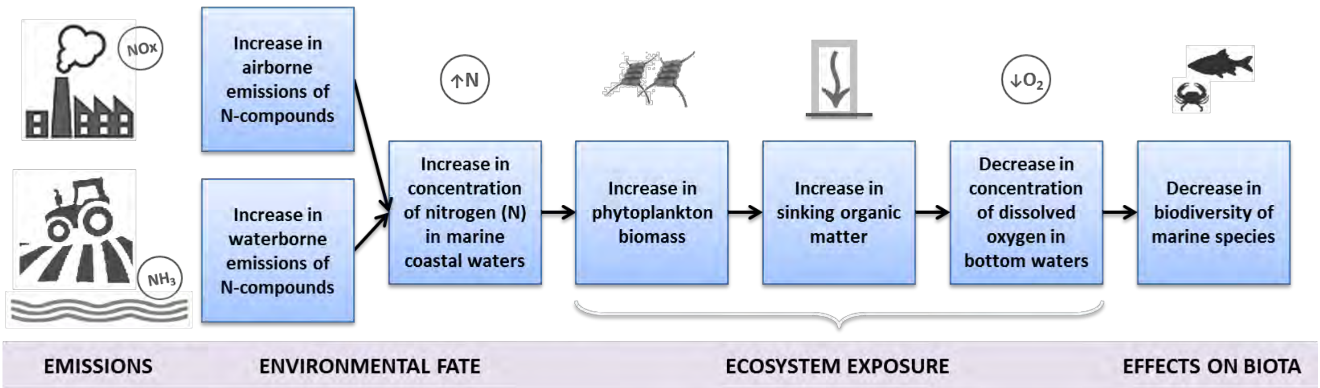
Spatially-explicit LCIA model for marine eutrophication as a tool for sustainability assessment

Nuno Cosme*, Michael Z. Hauschild

DTU Management

*Corresponding author email: nmdc@dtu.dk

The increasing emissions from human activities are overrunning the ecosystems' natural capacity to absorb them. Nutrient emissions, mostly nitrogen- and phosphorus-forms (N, P) from e.g. agricultural runoff and combustion processes, may lead to social-economic impacts and environmental quality degradation. Life Cycle Assessment (LCA) is as a tool to comparatively quantify the environmental impacts from product systems throughout their life cycle. Marine eutrophication is one of the LC Impact Assessment (LCIA) categories and it is still lacking an overall model linking nutrients over-enrichment to impacts on marine ecosystems. Emitted nitrogen reaches marine coastal waters where it promotes the growth of phytoplankton biomass in the surface photic zone from where it eventually sinks to bottom waters. This downward flux of organic matter is respired there by bacteria resulting in the consumption of dissolved oxygen. An excessive depletion of oxygen affects the exposed organisms and loss of species diversity may be expected. A model framework was built to estimate the potential impacts arising from N-emissions (see figure). It combines the fate of N in rivers and coastal waters, the exposure of receiving ecosystem to the N enrichment, and the effects of oxygen depletion on relevant species. The estimated impacts are quantified by means of substance-specific factors that translate the emission into potential impacts, i.e. Characterization Factors (CFs). These express the impacts to the ecosystem quality as potentially affected fraction of species (PAF) per mass of N emitted to the environment, volume and time integrated, or (PAF·)[$m^3 \cdot yr \cdot kg^{-1}$]. Preliminary results present spatially differentiated CFs for 214 country-to-ecosystem combinations and for 143 countries. Such CFs can be implemented into impact assessment methods in LCA to help characterizing the eutrophication impact of product systems related to agricultural production or involving combustion processes, and ultimately to assess the environmental sustainability of human activities.



Reducing antibiotic use in marine larviculture by probiotics

Lone Gram*, Paul D'Alvise, Torben Grotkjær and Mikkel Bentzon-Tilia

DTU Systems Biology, Matematiktorvet bldg 301, 2800 Kgs Lyngby.

*Corresponding author email: gram@bio.dtu.dk

Aquaculture is the fastest growing agricultural industry providing healthy food for mankind. In addition, culture of high valued marine fish, crustacean and mollusk species is financially attractive. However, diseases at the larval stages constitute a major bottleneck and cause economic losses to the industry. Vaccines are not effective at the larval stages and antibiotics are used for disease control, although there are serious concerns about development of bacterial antibiotic resistance and its transfer to human pathogenic bacteria. There is a strong need for development of non-antibiotic disease control strategies, especially at the larval stages.

The **objective** of our work is to reduce the need for antibiotics in marine larviculture by developing probiotic strategies; probiotics being defined by WHO as "live microbial cultures that excert a beneficial effect on the host". Rearing of marine larvae is difficult, as the larvae require live feed (*Artemia*, rotifers, copepods) which also requires live feed (algae). Larval pathogens can be introduced from the live feed and we work on applying our probiont strategy for pathogen control not only at the larval stage, but also in live feed cultures, hence targeting pathogen control at the very beginning of the production chain in a prophylactic strategy.

We collaborate with several aquaculture industries rearing turbot, sea-bass, sea-bream, oysters and flounder. We have at these sites isolated bacteria that are capable of antagonising fish larvae pathogens and that are not detrimental to the fish larvae. At all sites, bacteria belonging to the marine *Roseobacter*-clade have been isolated as strong pathogen-antagonising bacteria. We have demonstrated that these bacteria can antagonise pathogens (*Vibrio anguillarum* and *Vibrio harveyi*) in live feeds (algae, rotifers, *Artemia*) and that they have a dramatic and significant disease-reducing effect in turbot and cod larvae challenged with pathogenic *Vibrio*.

We are elucidating the mechanisms by which the probionts exert their effect, and have by mutagenesis identified tropodithietic acid (TDA) as an important molecule in the pathogen-antagonism. However, other molecules and mechanisms are likely also involved. Understanding the spectrum of mechanisms of action is important to determine where and how the probionts should be applied and also in determining potential side effects that could arise for the probiotic bacteria.

Other studies have focused on fish pathogens and it has been suggested that introducing lactic acid bacteria that are used as human probiotics (and have GRAS status) could be a way forward. However, we believe that re-introducing (or boosting) a potential probiotic bacterium already present in the fish larvae feed and rearing environments is likely a more successful strategy than introducing a foreign bacterium to this environment. Indeed, our results on disease prevention in model systems have been very convincing.

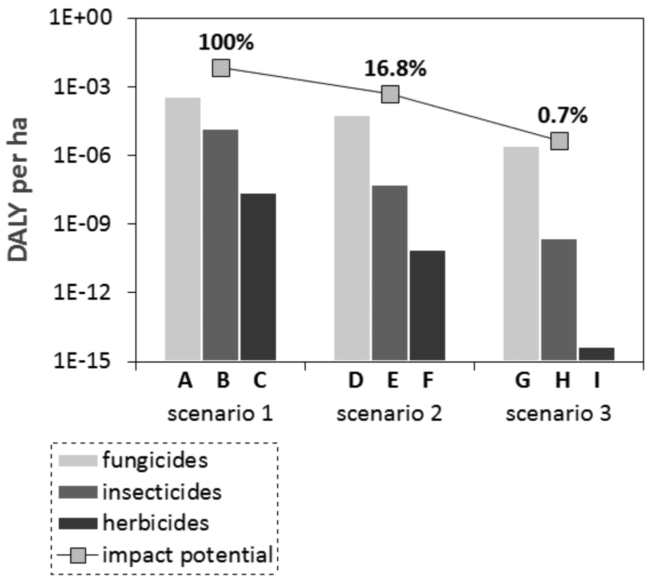
Substitution and food: Toward more sustainable pesticide use

Peter Fantke*[1], Olivier Jolliet[2]

1: Quantitative Sustainability Assessment Division (QSA), DTU Management; 2: School of Public Health, University of Michigan, United States

*Corresponding author email: pefan@dtu.dk

Pesticides authorized the EU are considered safe for humans, i.e. below thresholds of acceptable risk. However, pesticides nonetheless contribute to global human disease burden [1]. Comparative substitution scenarios combining crop-specific amount applied with pesticide-specific toxicity potential can help to characterize and minimize disease burden from pesticide exposure. We identified intake via food crop consumption as main exposure pathway to pesticides. For this pathway, we quantified health impacts in a dynamic crop uptake model, detailing how pesticides contribute to average burden of 2.6 hours lost per person over lifetime across Europe.



fungicides
A : azoxystrobin, cyproconazole
D : epoxyconazole, fenpropimorph, pyraclostrobin
G : chlorothalonil, mancozeb, tebuconazole

insecticides
B : β-cyfluthrin, carbaryl
E : cyhalothrin, esfenvalerate
H : α-cypermethrin, deltamethrin

herbicides
C : fenoxyprop-P, pendimethalin, prosulfocarb
F : glyphosate
I : iodosulfuron, propoxycarbazone-sodium

Figure 1. Human toxicity impact scores of different scenarios expressed in disability-adjusted life years (DALY) per ha of wheat treated with pesticides, and relative impact scores normalized to scenario 1.

Findings show that only 10% of all pesticides applied to grapes/vines, fruit trees, and vegetables account for 90% of total annual health impacts of around 2000 disability-adjusted life years. Main aspect driving crop residue dynamics and parameter uncertainty is thereby pesticide dissipation from crops. Combining improved dissipation data from two recent studies [2,3] with quantitative assessments, we demonstrate that health impacts can be reduced up to 99% by defining adequate substitution scenarios (Figure 1). We recommend that future work focuses on pesticides dominating human disease burden, which has policy implications.

Novel and improved yeast cell factories for biosustainable processes

Mhairi Workman*

DTU Systems Biology

*Corresponding author email: mwo@bio.dtu.dk

The utilization of an increasingly diverse range of cheap waste substrates will be an ongoing challenge for the bio-based economy, where the mobilization of nutrients from a variety of waste products will be necessary for realization of biosustainability on an industrial scale. Bioprocesses utilizing traditionally applied cell factories are generally based on a limited range of substrates (mainly glucose). However, a wider diversity in substrate range is highly desirable in developing biorefinery scenarios where feed-stocks containing a number of carbon sources are typically employed. In addition to plant biomass hydrolysates, glycerol is of interest here, being available in amounts relevant for industrial scale bioprocesses due to increased production of biodiesel.

The well characterised cell factory *Saccharomyces cerevisiae* exhibits a clear preference for glucose as a carbon source, and is highly adapted to its utilisation. Although there have been several studies on glycerol metabolism in *S. cerevisiae*, many industrially used strains grow poorly on glycerol ($\mu max = 0.01h^{-1}$). On the other hand, several non-conventional yeast species are efficient in utilization of glycerol, some with relevant applications as cell factories (including *Pichia* spp. and *Yarrowia lipolytica*) and other less well characterized strains (e.g. *Pachysolen tannophilus*).

This presentation will address how we evaluate cellular performance with a view to utilizing yeast species in industrial biotechnology applications. In addition, strategies for optimizing cellular performance based on either process engineering principles or genetic engineering will be presented. The work focusses on alternative substrates to glucose, the extension of substrate range in *S. cerevisiae* and an evaluation of non-conventional yeast species for industrial biotechnology applications.

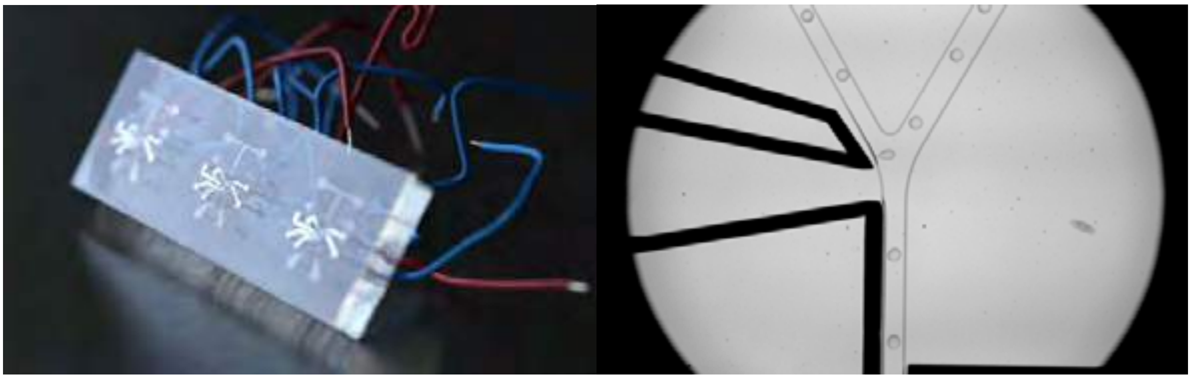
Development of droplets-based microfluidic systems for single-cell high-throughput screening

Jun Chen[1], Thomas Glasdam Jensen[2], Alexei Godina[3], Christian Solem[1], Martin Dufva[2], Peter Ruhdal Jensen*[1]

1: DTU Food; 2: DTU Nano; 3: ESPCI Laboratoire LBC

*Corresponding author email: perj@food.dtu.dk

High-throughput screening (HTS) plays an important role in the development of microbial cell factories. One of the most popular approaches is to use microplates combined with the application of robotics, liquid handling and sophisticated detection methods. However, these workstations require large investment, and a logarithmic increase to screen large combinatorial libraries over the decades also makes it gradually out of depth. Here, we are trying to develop a feasible high-throughput system that uses microfluidics to compartmentalize a single cell for propagation and analysis in monodisperse picoliter aqueous droplets surround by an immiscible fluorinated oil phase. Our aim is to use this system to facilitate the screening process for both the biotechnology and food industry.



Fly larvae as sustainable bioconverters of waste for feed in the future

Nordentoft S[1*], Aabo S[1]

1: DTU Food;

*snni@food.dtu.dk

How to provide enough food and feed for the growing population is a major challenge for the next generation. Improved economy in many developing countries increases the demand for protein from meat or fish. This may lead to depletion of the seas and overexploitation of agricultural land in the in search of obtaining sufficient food.

Traditional food production creates large amount of organic waste streams which are dumped or used for biogas production. Although some of these waste categories have large potential for upcycling to feed for animals or food for humans, then drivers for change have been hampered by low human perception, poor economy and regulations. This has delayed the biological and technological developments in the area.

Insects are natural converters of waste and have great potential for upcycling low value byproducts or waste materials as animal manure. They have much higher feed conversion rate compared to conventional livestock, low use of water and energy, and with at much lower requirements for production area. Furthermore the emission of greenhouse gases and ammonia compared to production with pigs and cattle is much lower. Harvested insects may be used direct as food or feed, or nutrients may be refined from processed insects, however there is a huge need for technological development in order to automate culture and harvest of the insects.

In nature insects and insect larvae are important feed sources for poultry and the larva of the common house fly (*Musca domestica*) have been shown to be especially rich in essential amino and fatty acids. At the Food institute we have investigated in feed safety of using these fly larvae as feed for egg laying hens. The larvae were reared on poultry manure which implies the risk of transmission of pathogenic microorganism between animals and to humans, as well as accumulation of chemical compounds from the manure. However, we found that the insects were able to actively degrade a number of important pathogenic bacteria during the conversion of the manure. Environmental pollutants as dioxins and PCB were higher in the larvae that in the manure, indicating that these substances could be accumulated in the larvae. Feeding trials of chickens and egg laying hens with insect supplements showed superior growth results compared to standard feed, showing inclusion of insects in future poultry diet is an sustainable and attractive alternative ot other protein soruces.

Acknowledgements
BioConval is an Organic RDD project. Organic RDD is financed by the Danish Ministry of Food, Agriculture and Fisheries and coordinated by ICROFS (International Centre for Research in Organic Food Systems).

Processing of biowaste for sustainable products in developing countries

Shruti Harnal Dantoft[1], Anders Cai Holm Hansen[1], Peter Ruhdal Jensen*[1]

1: DTU Food

Corresponding author email: perj@food.dtu.dk

The modern global society faces great challenges in supply of energy, feed, food, and other products in a sustainable way. One way to mitigate the negative effects of providing these local eco-services is to convert biomass – instead of petroleum or natural gas – into a variety of food, feed, biomaterials, energy and fertilizer, maximizing the value of the biomass and minimizing the waste. This integrated approach corresponds to the biorefinery concept and is gaining attention in many parts of the world (Kam & Kam 2004). Energy, food and feed production is the driver for development in this area, but as biorefineries become more and more sophisticated with time, other products will be developed. Today, almost all organic chemicals - and also fertilizer - are produced from crude oil and petroleum and technologies with are driven by fossil energy, thus referred to as petro-chemicals and fossil fertilizer. It is generally anticipated that white biotechnology, the use of fermentation and enzymatic processes will play a key role for future cleaner production of bulk chemicals, energy carriers as well as fertilizer from biomass sources by saving resources and reduce negative environmental impacts from the chemical production. In order to replace fossil based energy carriers, chemicals and fertilizer, cost is the critical challenge for success. Thus, easily accessible and low costs biomass feedstock is a prerequisite for making bio-based production economically feasible. Industrial, agriculture and municipal biowastes have the potential to be that resource. However, it is of great importance to be aware of how to utilize the different sources of biowaste and for which purpose.

In October 2012, a new EU project, funded under the FP7 programme was launched with partners from the EU, Africa and Malaysia. The objective of the proposed project is to show and demonstrate the technical roadmap - a strategy - for efficient technological utilization of selected significant biowaste in five African countries - Morocco, Egypt, Ghana, South Africa, and Kenya- derived from both the industrial and agricultural sector, thus, turning biowaste into a new resource for sustainable products. Our group is involved in developing strains and microbial fermentation processes for these bioconversions.

References:

Kam and Kam (2004) Principles of biorefineries, Appl. Microbiol. Biotechnol., 64, 137-145.

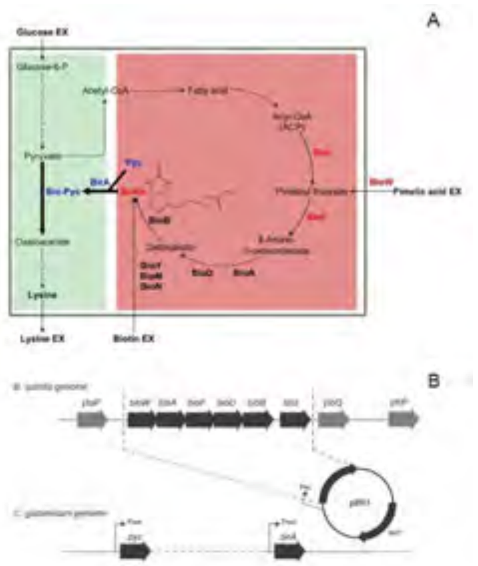
Microbial production of lysine from sustainable feedstock

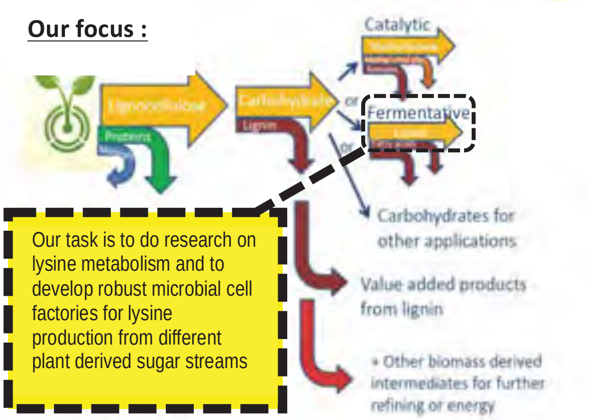
Zhihao Wang, Maria Grishkova, Christian Solem and Peter Ruhdal Jensen*

Systems Biotechnology and Biorefining, National Food Institute

*Corresponding author email: perj@food.dtu.dk

Lysine is produced in a fermentation process using *Corynebacterium glutamicum*, and even though production strains have been improved for decades, there is still room for further optimization. Production lysine from sustainable feedstock is an interesting topic for research and also a more economic strategy for industrial. Our research starts from a classical lysine-producing strain, through molecular cloning and systems biology to achieve our purpose. *C. glutamicum* is naturally a biotin auxotroph. We have introduced the biotin genes from *Bacillus subtilis* into that classical strain for creating a biotin protrotophic strain for cost saving. With the help of biotin biosynthesis operon, our *C. glutamicum* could grow on the minimal medium without biotin and produce the simial level of lysine compared to the optimal medium. However, a decrease in specific growth rate of 20% when the strains are cultivated without biotin, indicating a sub-optimal intracellular concentration of biotin. Pimelic acid, an early biotin precursor, was found that growth rate could be restored, which demonstrated that the bottleneck might be in pimeloyl-CoA formation. Meanwhile, over-expressing pyruvate carboxylase (*pycA*) and biotin ligase (*birA*), did have a positive effect on the lysine yield that was finally increased by 55% in the strain over-expressing both enzymes.





Track 2
Poster
Presentations

See schedule on
www.sustain.dtu.dk

DTU's
Sustain
Conference

A kinetic model of thiamine biosynthesis in *Escherichia coli*

Marta R. A. Matos*[1], Markus Herrgård[1], Mikael R. Andersen[2], Nikolaus Sonnenschein[1]
[1]The Novo Nordisk Foundation Center for Biosustainability, DTU
[2]DTU Systems Biology
*Corresponding author email: mrama@biosustain.dtu.dk

Thiamine can only be synthesized by prokaryotes and some eukaryotes, humans for example get it through their diet. Yet, it is key for the correct functioning of the carbohydrate and amino acid metabolism, and thiamine deficiency in humans can cause beriberi, which can result in muscle weakness or cardiovascular problems, among other symptoms. Nowadays it is common to add thiamine to commercial foods. Thus, it is important to produce it in a sustainable and efficient way. One approach to produce thiamine in a sustainable way is to use cell factories, and modeling of the metabolic network can be used to develop strategies for improved process efficiency. Constraint-based modeling methods [1] have been successfully used to increase cell factory productivity [2]. However, these approaches assume that the system is in a steady state, i.e., metabolite concentrations and reaction fluxes are constant along time. Therefore, kinetic models [3] are needed to understand the dynamics of metabolite concentrations and reaction fluxes. We have built a kinetic model for the thiamine biosynthesis pathway in *Escherichia coli*. So far we have used convenience kinetics rate laws [4] to describe the flux rates, but once more data has been collected, we will build enzyme modules where each elementary reaction step is explicitly modeled [5]. This model will be used to understand the pathway dynamics and ultimately suggest genetic manipulation strategies to optimize thiamine production in *E. coli*.

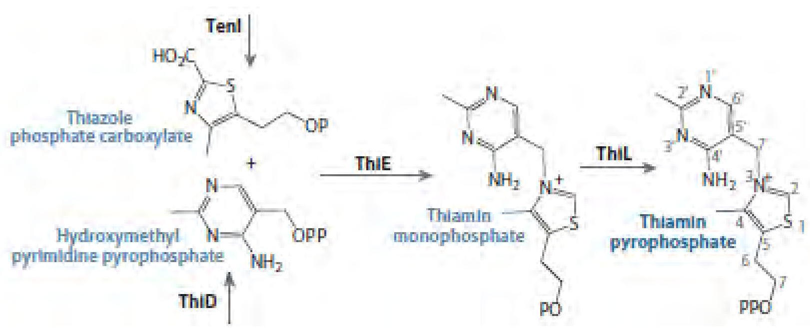


Figure 1: Part of the thiamine biosynthesis pathway in *E. Coli*.

[1] Price N D *et al*. Genome-scale models of microbial cells: evaluating the consequences of constraints. Nature Reviews Microbiology, 2004.
[2] McCloskey D *et al*. Basic and applied uses of genome-scale metabolic network reconstructions of escherichia coli. Molecular Systems Biology, 2013.
[3] Link H *et al*. Advancing metabolic models with kinetic information. Current Opinion in Biotechnology, 2014
[4] Liebermeister W and Klipp E. Bringing metabolic networks to life: convenience rate law and thermodynamic constraints. Theoretical Biology & Medical Modelling, 2006
[5] Jamshidi N and Palsson B. Mass action stoichiometric simulation models: Incorporating kinetics and regulation into stoichiometric models. Biophysical Journal, 2010.

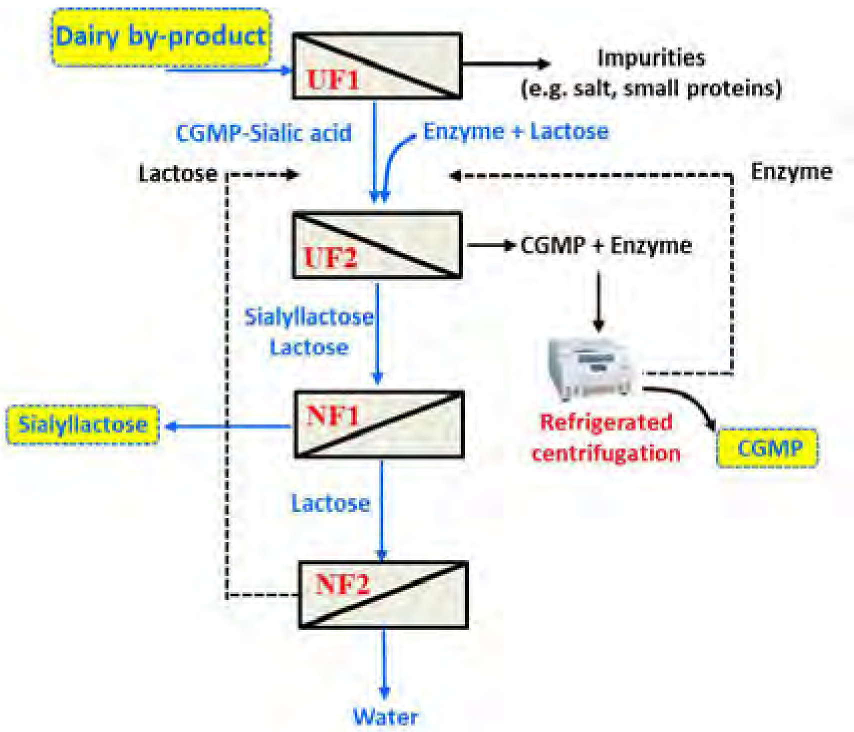
Reactive membrane technology: Two case studies

Birgitte Zeuner, Jianquan Luo*, Manuel Pinelo, Jørn D. Mikkelsen, Anne S. Meyer

Center for BioProcess Engineering, DTU Chemical Engineering.

*jluo@kt.dtu.dk

Enzymatic processes are generally sustainable processes that use mild conditions and natural substrates. Membrane technology can be employed for enzyme immobilization as well as for recycling free enzymes. Using alcohol dehydrogenase (ADH) as part of a process to recycle CO_2 to methanol, we investigated the effect of applied pressure, enzyme concentration, pH, and membrane properties on fouling-induced enzyme immobilization. In another study, the production of the human milk oligosaccharide 3'-sialyllactose by an engineered sialidase from *Trypanosoma rangeli* (Tr6) was significantly improved in an enzymatic membrane reactor. The entire process can be improved by employing a series of ultra- and nanofiltrations.



References:
Luo J, Marpani F, Brites R, Frederiksen L, Meyer AS, Jonsson G, Pinelo M. Directing filtration to optimize immobilization in reactive membranes. *J Membr Sci* 2014, 459, 1-11.
Luo J, Nordvang RT, Morthensen ST, Zeuner B, Meyer AS, Mikkelsen JD, Pinelo M. An integrated membrane system for the biocatalytic production of 3'-sialyllactose from dairy by-products. *Bioresour Technol* 2014, 166, 9-16.
Zeuner B, Luo J, Nyffenegger C, Aumala V, Mikkelsen JD, Meyer AS. Optimizing the biocatalytic productivity of an engineered sialidase from *Trypanosoma rangeli* for 3'-sialyllactose production. *Enzyme Microb Technol* 2014, 55, 85-93.

Enzymatic production of human milk oligosaccharides

Holck J*[1], Jers C, Michalak M[1], Zeuner B[1], Guo Y[1], Meyer AS[1] and Mikkelsen JD[1]

[1]DTU Chemical and Biochemical Engineering

*Corresponding author email: jeh@kt.dtu.dk

Human milk oligosaccharides (HMOs) are a group of complex glycans that are abundant in human breast milk [1]. Breastfeeding infants is linked to several beneficial effects like promotion of bifidogenic growth, anti-adhesive effects by blocking pathogens, and sialylated HMOs are moreover involved in infant brain development. Only trace amounts of these oligosaccharides are present in bovine milk-based infant formula. In order to produce genuine HMOs, this project explores a sustainable way to develop an enzymatic process capable of converting certain kinds of food materials into the desired products [2-6].

References
[1] Bode L. (2012) *Glycobiology* 22(9):1147-1162
[2] Jers C. *et al*. (2014) *Plos1* 9(1) e83902
[3] Michalak M. *et al.* (2014) *Process biochemistry* 49:265-270
[4] Zeuner B. *et al.* [2014) *Enzyme and microbial technology* 55:85-93
[5] Guo Y. *et al.* (2014) *journal of biochemistry* 170:60-67
[6] Holck J. *et al.* (2014) *New biotechnology* 31(2):156-165

AquaVir - Portable Analyzer for Water Borne Infectious Viruses

Noemi Rozlosnik*, Julie Kirkegaard, Mark Holm Olsen, Maria Dimaki and Winnie Svendsen

DTU Nanotech

*Corresponding author email: noro@nanotech.dtu.dk

Viral contamination in waters intended for human consumption or human contact poses a high health risk and can, in worst-case, lead to viral outbreaks. The waterborne virus, norovirus is a major cause of viral gastroenteritis [1]. Conventional detection methods of norovirus rely on microbiological methods like polymerase chain reaction and a variety of sample preparations [2][3]. These methods are time consuming, expensive and require highly trained personnel. Thus, viral surveillance cannot be done continuously and only provide an instant overview of the water quality.
We are developing an all polymer detection system for online viral surveillance of waters. The detection is based on differential impedance measurements between a reference and an electrode functionalized with a bio-recognition element. The bio-recognition element is an aptamer specific to the target virus. We have previously shown very low detection limits with influenza virus as proof of concept of the technology [4]. The electrode material is the intrinsic conducting polymer PEDOT:PSS screen-printed on TOPAS for easy up scaling of production. Finite element simulations of the electrode potential confirm the electrode viability in waters with conductivities similar to tap water, see figure 1.Substantial pre-concentration is required to reach the limit of detection needed in surface water. We employ both filter and on-chip based concentration techniques to accomplish this. In figure 2, virus presence and successful bio-recognition to the electrodes is established as an initial test. On-chip concentration is done by electric focusing of the virus particles. From extensive finite element modelling, we have designed dielectrophoresis channels with embedded microelectrodes to focus the virus particles in the center and thus facilitate concentration of the particles.

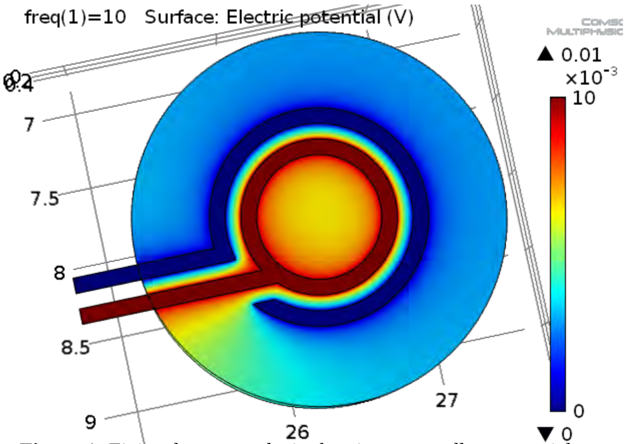


Figure 1: Finite element analysis showing an excellent potential distribution on our PEDOT:PSS electrode design in tap water when applying 10 mV. σ(PEDOT:PSS) = 2000 S/m, σ(tap water) = 10^{-3} S/m. Simulations are performed with Comsol Multiphysics 4.4.

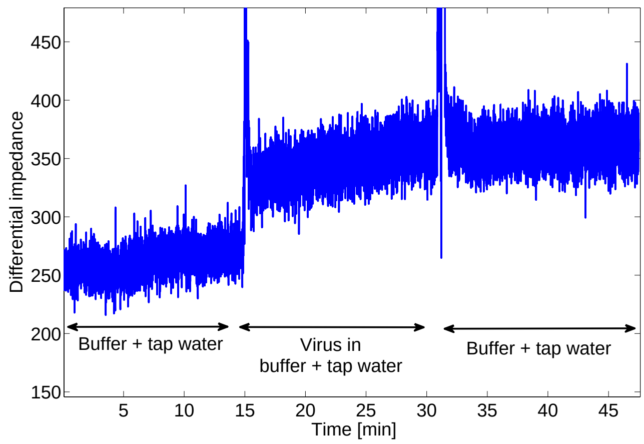


Figure 2: Post processed data of differential impedance measurements of norovirus in tab water and buffer.

We acknowledge financial support from the FP7-NMP-2013-SMALL-7 program under the grant agreement no. 604069 (AquaVir).

References:

[1] Teunis, P. F. M et al., (2008). Journal of Medical Virology, 80(8), 1468-76
[2] Faccin-Galhardi, Lopes, et al., (2013) Virus Rev & Res 18(1-2), online edition.
[3] Wyn-Jones, A. P et al., (2011). Water Research, 45(3), 1025-38
[4] Kiilerich-Pedersen et al., (2013) Biosensors and Bioelectronics, 49, 374-79

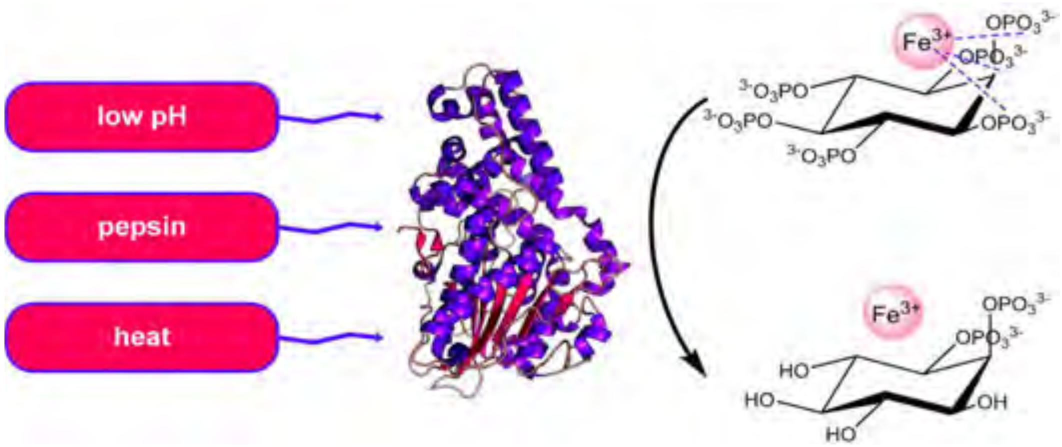
Phytases for Improved Iron Absorption

Anne Veller Friis Nielsen[1], Christian Nyffenegger[1], Anne S. Meyer*[1]

1: DTU Chemical Engineering

*Corresponding author email: am@kt.dtu.dk

Microbial phytases (EC 3.1.3.8) catalyse dephosphorylation of phytic acid, which is the primary storage compound for phosphorous in cereal kernels. The negatively charged phosphates in phytic acid chelate iron (Fe^{3+}) and thus retards iron bioavailability in humans [1]. Supplementation of microbial phytase can improve iron absorption from cereal-based diets [2]. In order for phytase to catalyse iron release *in vivo* the phytase must be robust to low pH and proteolysis in the gastric ventricle. Our work has compared the robustness of five different microbial phytases, evaluating thermal stability, activity retention, and extent of dephosphorylation of phytic acid in a simulated low pH/pepsin gastric environment. The five phytases responded differently to the robustness parameters: The *Peniophora lycii* phytase (Ronozyme NP) was the most thermostable, but the least robust enzyme at low pH, whereas the two tested *Aspergillus niger* phytases (SukaPhy phytase and a cloned *A. niger* enzyme), and an *Escherichia coli* phytase proved to be most resistant to low pH and pepsin hydrolysis. The phytase from *Citrobacter braakii* (Ronozyme HiPhos) showed intermediate robustness.



(1) Nielsen, A. V. F.; Tetens, I.; Meyer, A. S. Potential of Phytase-Mediated Iron Release from Cereal-Based Foods: A Quantitative View. *Nutrients* **2013**, *5*, 3074–3098.

(2) Sandberg, A.-S.; Hulthén, L. R.; Türk, M. Dietary Aspergillus Niger Phytase Increases Iron Absorption in Humans. *J. Nutr.* **1996**, *126*, 476–480.

Is Danish venison production sustainable?

*<u>Henrik Saxe</u>, **Q**uantitative **S**ustainability **A**ssessment, DTU Management Engineering*

It is a popular notion in Denmark that we should include more ingredients in our diet which are gathered, caught or hunted in nature rather than grown and harvested on farmed fields and waters. These ingredients include commodities like seafood, seaweed, mushrooms, herbs and venison (meat from free-ranging wildlife). In the recommendations for the New Nordic Diet, the Danish consumers are, among other recommendations advised to consume 35 % less meat, with more than 4 % of the consumed meat being venison (Meyer et al. 2011). This may be an impossible target. The "wild" ingredients in a modern diet are all *assumed* to be both healthy and environmentally sustainable. But is this always true? More research is needed!

The present study seeks to answer the question: *'Does venison have less impact on the environment than the organic and conventionally produced meat types they replace?'* Six types of venison are considered: Red deer, roe deer, fallow deer, wild boar, pheasant and mallard.

Is it more sustainable to consume venison from red deer than beef?

Is it more sustainable to consume venison from wild boar than pork?

Is it more sustainable to consume mallard than chicken?

The environmental impact related to the hunting-related infrastructure, fodder or game fields, hunting, transport, etc. is analysed by *consequential life cycle assessment* (cLCA). Monetizing the environmental impacts makes it possible to compare the environmental impact of the six types of venison with farmed and industrially produced meat. Venison of red deer, roe deer, fallow deer and wild boar are compared with beef, pork and lamb production. Mallard and pheasant are compared with chicken production.

Preliminary results suggest that red deer production is *twice as sustainable* as beef production, while wild boar production is *half as sustainable* as pork production.

One challenge in the environmental analyses of venison is that hunting typically has other purposes than food production. These include the recreational value of hunting, nature management and tourism. This study focuses on the meat produced commercially by one of two major Danish venison abattoirs – *Klosterhedens Vildt abattoir* in North Western Jutland – and their main suppliers.

This study is sponsored by: 15. Juni Fonden *(2014-2015)*

Resource use efficiency and renewability. Assessment of low-input agricultural production using eMergy.

Christina Wright[1] and Hanne Østergård[1*]

1: DTU Chemical Engineering

*Corresponding author email: haqs@kt.dtu.dk

Until now the demand for food has been met by the use of abundant and cheap fossil fuels; however we need to reconsider our modes of production to avoid a global environmental crisis. Food production systems should, therefore, increasingly rely on renewable inputs and increase their stability by reducing dependency on external input. We apply the emergy approach to evaluate resource use efficiency of two low-input innovative farms while distinguishing between use of renewable and non-renewable resources as well as local and global origin of resources. This study is a part of the SOLIBAM (www.solibam.eu) project funded by the European commission under the Seventh Framework Programme.

We apply an approach where we include efficiency in resource use to produce food energy joules sold while distinguishing between use of renewable and non-renewable resources as well as on-site, local and non-local resources. Result shows that the large farm (75 ha) had an input of renewable resources of 32% while the small (6 ha) had a renewable fraction of 26%. The latter is based on assuming that the firewood used is 50% renewable. If this percentage is increased to 100% then both farms have a renewable fraction of resource use of about 39%.

In conclusion, especially fuels and machinery may be subject to management improvements as these represent a large fraction of the total eMergy use. Further, they are characterized by being mainly non-renewable. The larger resource inputs per food Joule to the small farm compared to the larger farm may be an economy-of-scale consequence. The larger farm can grow more crops on-site reducing the external inputs. Also the larger farm area may reduce the input of machinery per ha of cultivated area, reducing this part of the total use per food Joule produced.

Supercontinuum light sources for food analysis

Uffe Møller[1]*, Christian R. Petersen[1], Irnis Kubat[1], Ole Bang[1]

1: DTU Fotonik

*Corresponding author email: ufmo@fotonik.dtu.dk

In *Light & Food*, a 30M DKK project funded by Innovationsfonden where DTU Fotonik has joined forces with University of Copenhagen, Aarhus University, FOSS and NKT, the vision is to develop a platform of analytical solutions to optimization of sustainable food production, both in the field and in the factory. These solutions will combine bright and broadband infrared light sources, so-called supercontinuum light sources, with spectroscopy, chemometrics and processing expertise and thereby contribute to increased food quality through faster and more precise analysis of grains, soils and dairy products.

One track of *Light & Food* will target the mid-infrared spectral region. To date, the limitations of mid-infrared light sources, such as thermal emitters, low-power laser diodes, quantum cascade lasers and synchrotron radiation, have precluded mid-IR applications where the spatial coherence, broad bandwidth, high brightness and portability of a supercontinuum laser are all required. DTU Fotonik has now demonstrated the first optical fiber based broadband supercontinuum light souce, which covers 1.4-13.3 µm and thereby most of the molecular fingerprint region [1].

Figure 1: Illustration of supercontinuum generation in the mid-infrared ‘fingerprint’ region. Nonlinear optical processes in an optical fiber generate broadband light that can then be used for e.g. food analysis. The most common vibrational resonances in organic molecules are in the wavelength range from 2 to 10 µm. The example spectrum shown is for acetone, which is the top left molecule in the sample area. Figure adapted from [2].

[1] C.R. Petersen, U. Møller, I. Kubat, B. Zhou, S. Dupont, J. Ramsay, T. Benson, S. Sujecki, N. Abdel-Moneim, Z. Tang, D. Furniss, A. Seddon, O. Bang, “Mid-infrared supercontinuum covering the 1.4–13.3 µm molecular fingerprint region using ultra-high NA chalcogenide step-index fibre”, Nature Photonics **8**, 830–834 (2014).

[2] G. Steinmeyer and J. S. Skibina, “Supercontinua: Entering the mid-infrared”, Nature Photonics **8**, 814–815 (2014).

Marine Microplastics - Method development for detection of plastic particles from sea water down to 10 µm

Robin Lenz*[1], Kristina Enders[2],

1: DTU Aqua

*Corresponding author email: roble@aqua.dtu.dk

During the past few years and especially in 2014, plastic pollution has gained a lot of media attention and public awareness is rising. Management plans and policies start to adopt strategies for mitigating effects and reducing entry of marine litter and beached plastic. Strangled seals or plastic ingesting seabirds are perceived easily by the broad public through emotionally charged photographs and personal experiences on beaches all around the globe. Monitoring programs, beach clean-ups, source elimination, and societal changes such as local bans of single-use plastic bags or out-phasing of microbeads in personal care products are being talked of frequently. All together, this increases the acceptance of allocation of public resources on environmental programs. In contrast it is hard to draw someones attention to possible effects of microplastics on community structures of organisms on the bottom of the food web, whose existence and importance we are rarely aware of. There are chances for severe impacts in plastic accumulating ocean gyres which are of oligotrophic nature and consequently low food availability.

So far the concentrations, biological impact and the fate of disintegrating plastics in the marine environment are still not enough understood, especially with perspective on the ecosystem as a whole. Zooplankton, free-floating animals that often live of single-celled algae, form the link between primary production and higher trophic level organisms, including commercially important fish species and therefore human food resources. Microplastic, either as degradation product from plastic litter or directly introduced as microfibres, microbeads or plastic resin pellets, have been found by many studies down to sizes of a few micrometres, which is in the food size range of most zooplankter. The physical and chemical harm from ingestion can not be quantified yet, and also data on distribution of particles smaller than 300 µm is sparse. The handling and analysis of those small microplastics is still difficult and no working standard methods are in place. Here we show our ongoing work on a sample set from a cross Atlantic transect to estimate the concentration of microplastic from 10 µm and larger based on visual identification supported by Raman microspectrometry.

Gasification biochar as soil amendment for carbon sequestration and soil quality

(Veronika Hansen)

Abstract

Thermal gasification of biomass is an efficient and flexible way to generate energy. Besides the energy, a valuable by-product, biochar, is produced. Biochar contains a considerable amount of recalcitrant carbon that has potential for soil carbon sequestration and soil quality improvement if recycled back to agriculture soils. To determine the effect of gasification biochar on soil processes and crop yield, a short-term incubation study was conducted and a field trial has been established.

Track 3
Sustainable Energy & Transportation

Scientific committee

Coordinator: Hans Hvidtfeldt Larsen, DTU Natlab

Sune Ebbesen, DTU Energyconversion

Tian Zhang, DTU Biosustain

Jan Rossmeisl, DTU Fysik

Jens Juul Rasmussen, DTU Fysik

Rasmus Fehrmann, DTU Chemistry

Poul Norby, DTU Energyconversion

Henrik Gudmundsson, DTU transport

Brian Elmegaard, DTU Mek

Steering group contact person: Kristian Mølhave, DTU Nanotech

Track 3
Talk
Presentations

See schedule on
www.sustain.dtu.dk

DTU's
Sustain
Conference

Overview of the Sustainable Energy Research at DTU

Author[1], Hans Hvidtfeldt Larsen

1: DTU National Laboratory for Sustainable Energy; * Corresponding author email: hala@dtu.dk

Most of the Danish expertise in sustainable energy is found at the Technical University of Denmark, where approximately 1,000 staff members are carrying out research into sustainable energy. The research activities cover a broad area of scientific fields, from production, conversion, systems and transport to storage and end-use consumption. DTU places great emphasis on this research taking place in close cooperation with internationally leading institutions and experts.

Wind energy for a sustainable development

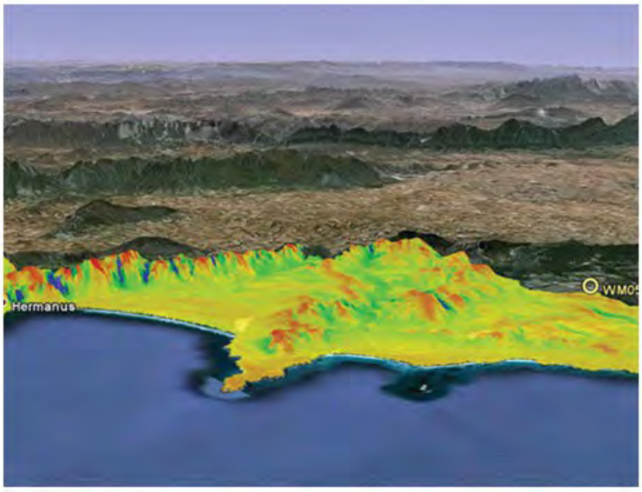
Ioanna Karagali*[1], Charlotte B. Hasager[1], Anna Maria Sempreviva[1], Hans E. Jørgensen[1], Peter Hauge Madsen[1]

1: DTU Wind Energy

*Corresponding author email: ioka@dtu.dk

Wind energy is on the forefront of sustainable technologies related to the production of electricity from green sources that combine the efficiency of meeting the demand for growth and the ethical responsibility for environmental protection. The last decades have seen an unprecedented growth of both the wind energy related research activities and the wind energy industry, as installed capacity has been increasing in most of the developed and developing countries.

The DTU Wind Energy department carries the heritage of the Risø National Laboratory for Sustainable Energy by leading the research developments in all sectors related to planning, installing and operating modern wind farms at land and offshore. With as many as 8 sections the department combines specialists at different thematic categories, ranging from meteorology, aeroelastic design and composite materials to electrical grids and test and measurement techniques. Five research facilities provide the scientific playground for full and reduced scale research opportunities at a departmental, national and international level. The department develops and maintains software products to support not only research but also commercial activities related to the design, sitting and operation of wind farms. As member of the European Energy Research Alliance (EERA) and coordinator of the associated joint programme, DTU Wind Energy leads the coordination of research and educational activities in wind energy for a low carbon Europe, in a sustainable manner.



Wind Atlas for South Africa

The National Test Centre for Large Wind Turbines

Catalytic routes from biomass to fuels

Anders Riisager*

DTU Kemi, Centre for Catalysis and Sustainable Chemistry

*ar@kemi.dtu.dk

The carbon-based chemicals and fuels that are necessary to meet the energy demand for our society originate presently almost exclusively from inexpensive fossil resources – coal, oil and natural gas. The forecast of diminishing and more expensive petroleum reserves has, however, engaged the chemical industry to find new feasible chemocatalytic routes to convert the components of lignocellulosic plant biomass (green biomass) as well as aquatic biomass (blue biomass) into potential platform chemicals that can replace the fossil based chemicals in order to leave the chemical supply and value chain unaffected.

This presentation will survey the status of biofuels production from different sources, and discuss the sustainability of making transportation fuels from biomass. Furthermore, recently developed chemocatalytic technologies that allow efficient conversion of lignocellulosic biomass components into transportation fuels and fuel additives will be highlighted.

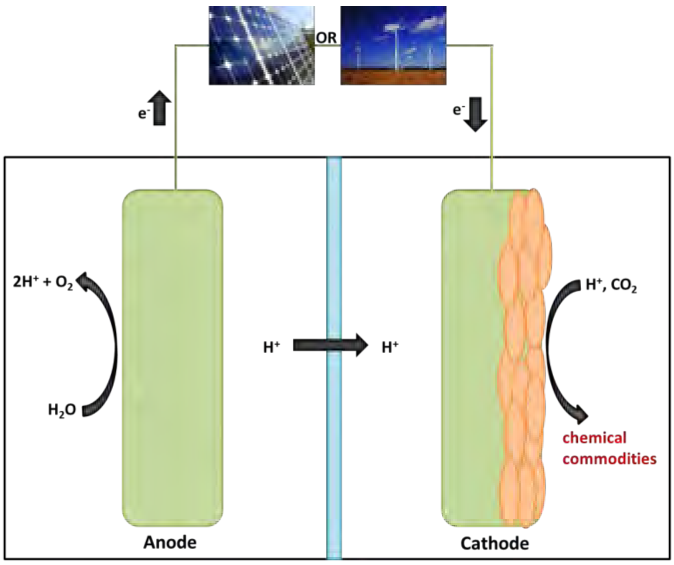
Microbial electrosynthesis: a novel strategy for flexible energy storage from electricity surplus and greenhouse gas

Tian Zhang[1]*

1: DTU Biosustain

*Corresponding author email: zhang@biosustain.dtu.dk

Abstract: Energy storage and distribution is a particular concern for solar or wind energy within the existing power grid infrastructure. This spurs the search for solutions to convert electrical energy produced from these renewable sources to chemical compounds or liquid transportation fuels, which can readily be stored and consumed on demand or if necessary converted again to electricity. Microbial electrosynthesis (MES), the process in which microbes accept electrons from an electrode directly to reduce CO_2 to chemical commodities such as biofuels, is a particularly attractive option to take advantage of the fluctuating electricity generated from renewable sources and to mitigate the release of greenhouse gases in the atmosphere. Although MES is attracting a lot of attention and has been studied intensively during the last five years, advances related to the engineering and the biology of this process are required for pilot plant scale and commercialization. If MES reaches its full potential, it will serve as a highly flexible and tunable approach for the conversion of electrical energy into chemical energy, generating valuable products especially from surplus electricity and CO_2.



Flue Gas Cleaning

Rasmus Fehrmann

Centre for Catalysis and Sustainable Chemistry, DTU Chemistry, DTU

Abstract.

Flue gases from industrial sources like power, waste incineration, glass manufacturer and cement plants as well as ships meet increasingly stricter regulations regarding emission of several pollutants in particular nitrogen and sulfur oxides. These pollutants lead to formation of nitric and sulfuric acid in the atmosphere causing precipitation of acid rain resulting in death of forests and destruction of buildings and monuments in addition to human health problems.

The most common state-of-the-art methods applied today industrially for cleaning of flue gases will be addressed, including wet and dry scrubbing for sulfur oxides (SO_2) and catalytic removal of nitrogen oxides (NO_x).

There is however, a desire of increasing the energy produced in electrical power plants by firing CO_2-neutral biomass/waste or biomass/waste in combination with fossil fuels. Thus, the EU reached agreement in March 2007 specifying that 20 % and recently in 2014 this was increased to 40 % of the energy should be produced from renewable fuels by 2020 and 2030, respectively to cut emissions of the greenhouse gas CO_2. This, however, challenges not only the power plant itself due to enhanced slagging, fouling and corrosion, but also the downstream cleaning of the flue gas for nitrogen oxides (NO_x) which is almost exclusively carried out using selective catalytic reduction (SCR) with ammonia (NH_3) as reductant. It is now well known that the traditional industrial catalyst used for SCR of NO_x by ammonia is severely deactivated by the aggressive flue gas, originating from the high content of potassium salts found in the biomass compared to fossil fuels. Also the formation of large amounts of more or less useful gypsum by the traditional lime scrubbing for sulfur oxides in the flue gas pose an increasingly new waste problem.

In Centre for Catalysis and Sustainable Chemistry, DTU Chemistry we are carrying out research dedicated to solve this problem not only by traditional catalytic routes where we from a molecular understanding of the catalyst performance try to improve the composition and catalyst life-time. But the problems may also be attacked by new materials like supported ionic liquid phase (SILP) gas absorbers where the pollutants may be selectively absorbed, desorbed and finally converted to useful mineral acids of commercial grade – really a green waste-to-value approach that we persue instead of the traditional cleaning processes that use chemicals to form new wastes.

Environmental sustainability of electricity supply in the world between 1980 and 2011: Lessons learnt and perspectives

Alexis Laurent[1]*, Nieves Espinosa[2]

1: DTU Management Engineering; 2: DTU Energy Conversion and Storage

*Corresponding author email: alau@dtu.dk

The generation of electricity is known to cause important damages to environment and human health. The political awareness of the global challenges posed by climate change and resource depletion has guided several countries to gradually move from a dominant use of fossil fuels towards more utilisation of renewables. However, has such moves led to burden-shifting from these environmental impacts to others as relevant? Considering the whole spectrum of environmental problems, are there any identifiable patterns across regions or impact categories that could serve to draw recommendations for energy planning? To address these questions, we collected annual data on electricity generation for 199 countries and territories for the period 1980-2011, differentiated per types of energy sources. These data were combined with region-specific life cycle inventories of pollutant emissions and resource consumptions to assess ten environmental impact categories, e.g. climate change, water use or chemical pollution. The results show that, for several regions, the majority of these impacts have increased between 1980 and 2011. Asia and the Middle East – and to a lesser degree, Africa and Latin America – thus show steep increase, up to more than one order of magnitude, in nearly all indicators when compared to their 1980-baseline values. To estimate the "environmental cleanness" of the grid mixes over time, the impact scores were normalized by the electricity generated yearly within each country. This revealed burden-shifting occurrences in almost all regions within the period 1980-2011. For example, in Asia, normalized impacts of particulate matters on human health have more than doubled, while increase in climate change scores have been limited to ca. 35%,. Based on our findings, we therefore recommend that electricity planning be accompanied with quantification of all relevant environmental impacts of the foreseen energy systems to prevent or minimise problem-shiftings ensuring an environmentally-sound energy transition.

Utilization of low-temperature heat sources for heat and power production

Fredrik Haglind*, Brian Elmegaard

DTU Mechanical Engineering

*Corresponding author email: frh@mek.dtu.dk

Low-temperature heat sources are available in many applications, ranging from waste heat from marine diesel engines, industries and refrigeration plants to biomass, geothermal and solar heat sources. There is a great potential for enhancing the utilization of these heat sources by novel thermodynamic cycle and cycle design, and use of multi-component working fluids. These advancements will not only improve the performance of existing technologies, but also enable the utilization of low temperature heat sources, which are currently not utilized due to technical or economical infeasibility.Both power production and heat pumps may benefit from the development as both technologies utilize a heat source. This makes it possible to cover the complete temperature range of low temperature sources. The development may contribute to significantly lower energy consumption in Danish industry and shipping. This will provide the scientific basis and devise potential innovations needed for implementation of technologies utilizing low-temperature energy sources in Denmark. Thereby, contributing to the development of the future society with no use of fossil fuels and with high shares of intermittent, renewable energy sources with electricity being the main energy carrier.

Power to fuel using electrolysis and CO_2 capture

Mogens B. Mogensen, **Christopher Graves, Christodoulos Chatzichristodoulou, Sune Dalgaard Ebbesen, Søren Højgaard Jensen**

Department of Energy Conversion and Storage, DTU Risø Campus, 4000 Roskilde

Abstract
Conversion of renewable electricity to synthetic fuel using electrolysis to produce at H_2 and CO, which is further used to form liquid or gaseous fuel, called "power to fuel" or "power2fuel" has got a lot of attention recently. This is because synthetic fuels (synfuels) in the form CO_2 neutral "green" hydrocarbon fuels seem particularly benign to replace the fossil fuels, and electrolysis seems to be a feasible step in production of green fuels. In particular, synthetic hydrocarbon based fuel will be necessary for the heavy transportation vehicles such as airplanes, ships, and trucks.
More than 65 % of the cost of H_2 produced by electrolysis originates from electricity cost. How much more depends on the actual electricity price and depends further on efficiency, investment cost and lifetime of electrolyzer. Investment costs are inversely proportional the current density at a given cell voltage, to lifetime and directly proportional to materials cost.
The solid oxide electrolyser cell has probably the biggest potential for a low cost electrolysis system, but there are issues of performance and lifetime that must be solved before it will become an affordable technology. Other electrolyzer cells, alkaline electrolyte and polymer electrolyte electrolyzer cells are also under development. The technical status will be described and necessary further work will be discussed.
Sources and techniques for capture of the necessary CO_2 will be presented briefly in order to explain how to get enough concentrated CO_2 for large scale fuel production.

The perspectives of fusion energy: The roadmap towards energy production and fusion energy in a distributed energy system

Volker Naulin*,[1], Jens Juul Rasmussen[1] and Søren B. Korsholm[1]
1: PPFE, DTU Physics, Bldg 309, Technical University of Denmark

*Corresponding author email: vona@fysik.dtu.dk

Controlled thermonuclear fusion has the potential of providing an environmentally friendly and inexhaustible energy source for mankind. Fusion energy, which powers our sun and the stars, is released when light elements, such as the hydrogen isotopes deuterium and tritium, fuse together. This occurs at very high temperature where all matter is in the plasma state as the involved energies are orders of magnitude higher than typical chemical binding energies. It is one of the great science and engineering challenges to construct a viable power plant based on fusion energy.

Fusion research is a world-wide international collaboration and is in a crucial new phase with the construction of the international fusion experimental reactor, ITER, in Cadarache, France, which will be largest energy experiment in the world, and a milestone on the way to fusion energy. The recently adopted European Roadmap to fusion energy aims at feeding the first energy into nets by 2050.The section for Plasma Physics and Fusion Energy, PPFE, at DTU Physics is a partner in the European fusion program: EUROfusion, which is organized and funded through the Horison2020. PPFE also delivers specific diagnostic equipment to ITER

The presentation will discuss the present status of the fusion energy research and review the EU Roadmap towards a fusion power plant. Further the cost of fusion energy is assessed as well as how it can be integrated in the distributed energy system

Criteria for Sustainable Transport Planning - what, how and why to measure?

Henrik Gudmundsson [1],

1, DTU Transport

*Corresponding author email: hgu@transport.dtu.dk

Sustainability has become a key concern for transport policy and planning, not only in terms of reducing impacts like climate change or developing specific solutions such as electromobility, but also as a strategic overarching policy framework rooted in sustainability science and governance for a sustainable society. Criteria for sustainability need to be adapted to the transport system specific context and to distinct policy applications such as problem identification, goal setting, ex ante assessment, monitoring and ex post evaluation for accountability, while maintaining a holistic overarching perspective.

The research project SUSTAIN has the double aim to help establish National Sustainable Transport Planning as an international research topic connecting transportation engineering and governance scholars around the world, and to develop a practice framework for National Sustainable Transport Planning in Denmark. The presentation will focus on the conceptual and operational aspects of measuring sustainability in the transport sector, and how to select indicators for sustainable transport planning and policy making. Some of the existing indicator systems for sustainable transport will be examined, and an outline of a national system will be proposed.

Apart from representing research in the SUSTAIN project an additional aim is to invite a discussion on how to connect transport system related research methods and findings across DTU under a sustainability perspective. Can information form somewhat disconnected research topics like alternative fuel systems, engine optimization, green logistics, infrastructure design, life cycle analysis, and other transport related features contribute to a system for measuring the sustainability of urban, national or global, transport systems?

Green Maritime Logistics

Harilaos N. Psaraftis[1*]

1: DTU Transport

*hnpsar@transport.dtu.dk

Typical problems in maritime logistics include, among others, optimal ship speed, ship routing and scheduling, fleet deployment, fleet size and mix, weather routing, intermodal network design, modal split, transshipment, queuing at ports, terminal management, berth allocation, and total supply chain management. The traditional analysis of these problems has been in terms of cost- benefit and other optimization criteria from the point of view of the logistics provider, carrier, shipper, or other end-user. Such traditional analysis by and large either ignores environmental issues, or considers them of secondary importance. Green maritime logistics tries to bring the environmental dimension into the problem, and specifically the dimension of emissions reduction, by analyzing various trade-offs and exploring 'win-win' solutions. This talk takes a look at the trade-offs that are at stake in the goal of greening the maritime supply chain and takes stock at models that can be used to evaluate these trade-offs. The talk is based on recent research of the author and his colleagues.

Track 3
Laptop
Presentations

See schedule on
www.sustain.dtu.dk

DTU's
Sustain
Conference

Microchip systems for imaging liquid and high temperature processes in TEM & SEM

Eric Jensen[1], Silvia Canepa[1], Rolf Møller Nielsen[1], Simone Lagana[1], Kristian Mølhave[1*].
[1]DTU Nanotech.
*Corresponding author email: Kristian.molhave@nanotech.dtu.dk

Microchips systems have found their way into electron microscopes in order to make miniature platforms for controlled liquid and gaseous environments that also begin to include electrical contacts and other types of interactions with the sample, such as application of forces and irradiation with light.

This presentation will explain the different types of microchip systems and give examples of some of the results we have achieved with our devices and examples of how such devices can be used for research related to energy storage and conversion.

Heaters can be made in several ways, and monocrystalline silicon cantilever heaters have successfully been used to grow silicon nanowires in-situ TEM to create an electrically contacted nanowire bridge between to cantilevers. This makes it possible to make IV measurements of the pristine wires [1]. Such heaters might find use for heated and electrically contacted measurements on high temperature fuel cell systems.

For imaging processes in liquids, our SEM system enables imaging on-chip microelectrodes and using standard built-in reference electrodes [2]. To get higher resolution in TEM, we have created a monolithic chip system with suspended microfabricated channels [3]. Both systems will allow high resolution imaging of heterogeneous electrochemical processes such as those in batteries. Based on the suspended microfluidic channels, we are also developing microchips that enable ultrafast freezing of processes in liquids.

[1] Kallesøe C, Wen C-Y, Booth TJ, Hansen O, Bøggild P, Ross FM, et al. In Situ TEM Creation and Electrical Characterization of Nanowire Devices. Nano Lett. 2012 Jun 13;12(6):2965–70.
[2] Jensen E, Købler C, Jensen PS, Mølhave K. In-situ SEM microchip setup for electrochemical experiments with water based solutions. Ultramicroscopy. 2013 Jun;129:63–9.
[3] Jensen E, Burrows A, Mølhave K. Monolithic Chip System with a Microfluidic Channel for In Situ Electron Microscopy of Liquids. Microscopy and Microanalysis. 2014 Apr;20(02):445–51.

Renewables in Electricity Markets

Christos Ordoudis, Athanasios Papakonstantinou, Pierre Pinson

Energy Markets and Analytics Group, Centre of Electric Power and Energy, DTU Electrical Engineering

Electricity is nowadays commonly exchanged through electricity markets, designed in a context where dispatchable generators, with non-negligible marginal costs, were dominating. By depending primarily on conventional (fossil, hydro and nuclear) power generation based on marginal pricing, deterministic market designs were considered adequate with straightforward setups consisting of a forward optimal allocation accompanied by a real-time balancing mechanism. However, as the share of renewable sources of energy (RES) increases, such market designs tend to become inefficient since they were not designed to take into account the uncertainty brought by the substantial variability and limited predictability associated with stochastic sources, most notably wind power and solar energy.

Due to these developments, the need for decision making models able to account for the uncertainty introduced by high shares of renewable sources and for new market designs has emerged. Consequently, the research vision of our research group focuses on the large scale integration of RES in the power system under a liberalized market environment by providing a set of methods and tools for forecasting power generation from renewables, and on the adaption of electricity market designs and power system operations to the aforementioned characteristics of renewables. Additionally, the aim of the research group is supplemented by providing the appropriate frameworks for secure future investments in the field of renewables being in line with the worldwide environmental concern to reduce carbon emissions and for the economic energy system integration.

In this context, the central objective of the group is to deal with the uncertainty in energy systems and to rethink electricity markets design by taking uncertainty into consideration. This is accomplished by bridging the gap between relevant expertise in power systems, data mining and optimization, meteorology, as well as energy economics.

As the name of the group suggests, the specific areas of research of its members are divided in two groups: i) Energy Analytics and ii) Markets. In Energy Analytics we focus on forecasting the various quantities of energy systems, such as wind power, energy consumption and the corresponding prices, and on developing decision making tools in a market environment. This is supported by a serious commitment in data mining and analysis of increasing quantity of power and meteorological data with high spatial and temporal resolutions. While research on Markets considers the development of new systems and market models that will be able to accommodate high shares of RES. These designs are tested under various uncertainties both from the generation and the demand side. The aim is to propose various approaches to market settlements (i.e. joint spot and balancing markets), define new market products and accomplish the efficient coordination of market and system operators. Furthermore, we follow closely the recent trends in EU which involve coupled day-ahead markets for the member states and co-ordination for balancing, by looking into coupling mechanisms that promote the effective cooperation between the power systems of various countries.

Solar Fuels: Photocatalytic Water Splitting Using a 2-Photon Approach

Brian Seger[1], Bastian Timo Mei[1], Dowon Bae[1], Mauro Malizia[1], Thomas Pedersen[2], Peter Vesborg[1], Ole Hansen[1], Ib Chorkendorff*[1]

1: DTU Physics; 2: DTU Nanotech

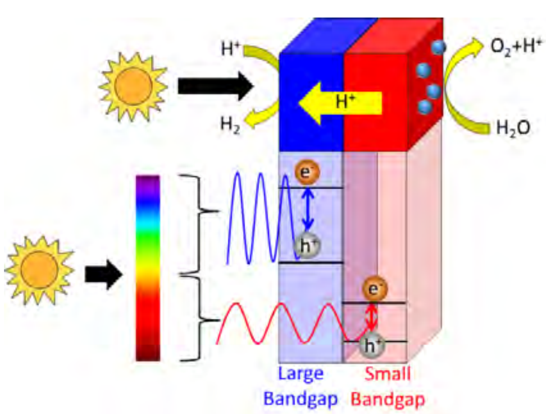
*Corresponding author email: ibchork@dtu.dk

While the sun provides orders of magnitude more energy than we consume on earth, it is intermittent, and thus we must have storage reservoirs for when it is dark. Plants have realized early on that storing this energy in the form of molecular fuels is quite effective. In our work, we take a similar approach and look to use solar cells to electrolyze water into hydrogen fuel and an oxygen byproduct.

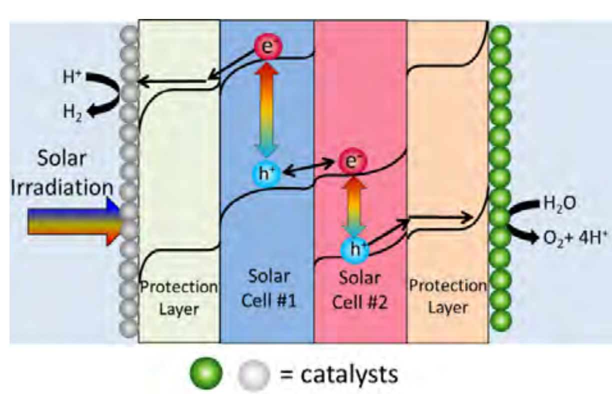
Modelling has shown that to optimize photoelectrolysis efficiency, a 2 photon tandem device (back to back solar cells) should be used. The underlying principle is that one solar cell should absorb high energy photons while the other absorbs the low energy photons. This is demonstrated in Figure 1A. While the concept seems relatively simple, no one has yet been able to full optimize this system.

2-photon water splitting devices have many issues that need to be optimized. Both solar cells need to be optimized as well as the H_2 evolution and O_2 evolution catalysts. Figure 1B shows a diagram of our device design. Furthermore all of these materials must be stable in the extremely corrosive environment needed for water splitting. At DTU Physics we have the critical mass which enables us to look at each one of these issues and how to integrate them seamlessly together. In this talk I will discuss a) our optimizations of our solar cell, b) how we protect the solar cells from corrosion and c) our H_2 and O_2 evolution catalysts. The talk will focus on what areas of the device we think are highly optimized and what areas need to be improved to get us to a point where we can become highly efficient and economically competitive.

1 A)



1 B)



Track 3
Poster
Presentations

See schedule on
www.sustain.dtu.dk

Novel catalysts for methanol synthesis from CO_2 and H_2

C.D. Damsgaard *[1,2], I. Sharafutdinov[2], E.M. Fiordaliso[1], D. Gardini[1], J.B. Wagner[1], I. Chorkendorff[2]

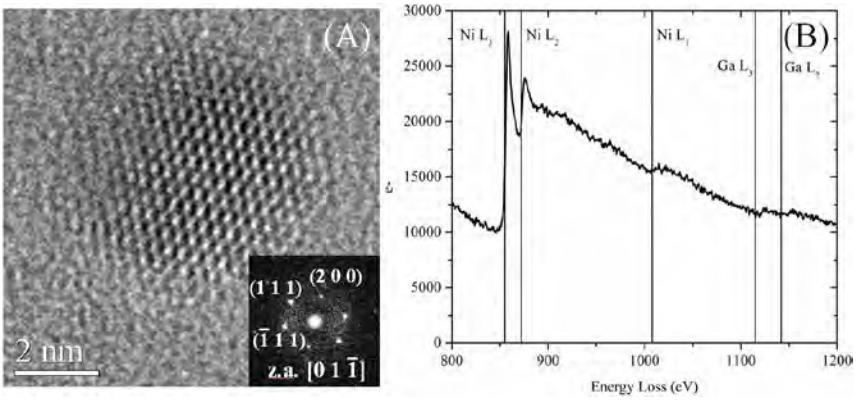
1: DTU Cen; 2: DTU Physics

*Corresponding author email: cdda@dtu.dk

Catalysis will play a crucial role in all technologies, which potentially could be used for producing sustainable chemical fuels from solar energy. One specific challenge concerns energy conversion based upon decentralized hydrogen production. One solution could be to store hydrogen on location by methanol synthesis under lower pressure conditions. In the search of catalysts that might open up new processes, studies based on density functional theory (DFT) calculations have predicted a nickel gallium alloy to be active for this reaction [1].

δ-Ni_5Ga_3 catalysts prepared by incipient wetness impregnation on a high surface area silica support, have shown comparable turn over frequencies to the preferred commercial $Cu/Zn/Al_2O_3$ catalyst system [2]. The catalysts have been studied and characterized extensively by activity measurements, in situ XRD and Environmental Transmission Electron Microscope (ETEM) [3] during nanoparticle formation, methanol synthesis [2], and accelerated aging experiments. For the optimal Ni:Ga ratio of 5:3 in situ XRD and ETEM studies confirms the formation of the δ-Ni_5Ga_3 phase nanoparticles at temperatures above 600°C in H_2 [4].

On-going work at DTU Cen and DTU Physics is focused on development of the promising NiGa catalyst for methanol synthesis in order to increase the long-term stability of catalytic activity.



(A) High-resolution TEM image of a nanoparticle (NP) after reduction as well as a fast Fourier transform (FFT) of the NP region reveals an orthorhombic structure resembling the Ni–Ga δ-phase. The crystal is viewed along the [01-1] zone axis. (B) STEM-EELS of single NP. The Ni $L_{2,3}$, Ni L_1 and Ga $L_{2,3}$ ionization edges are clearly visible.

References:
[1] F. Studt et al., Nature Chemistry 6(2014), p. 320.
[2] I. Sharafutdinov et al., Journal of Catalysis, 320(2014), p. 77
[3] T.W. Hansen et al., Materials Science and Technology 11(2010), p. 1338.
[4] C.D. Damsgaard et al., Microscopy 63(2014), p. 397.

EASETECH Energy: Life Cycle Assessment of the Danish Electricity System

Roberto Turconi, Thomas Astrup

DTU Environment

*Corresponding author email: robt@env.dtu.dk

The need for reducing dependency on fossil resources and decrease greenhouse gas (GHG) emissions is pushing many countries towards the implementation of low-carbon electricity systems. In this study the environmental impact of a future (2030) possible low-carbon electricity system in Denmark was assessed, and compared with the current situation and an alternative 2030 scenario using Life Cycle Assessment (LCA). The influence in modeling of: (i) electricity import, (ii) biomass resources and (iii) cogeneration of heat and power on the final results are discussed. Results showed that consumption of fossil resources and global warming impacts from the Danish electricity sector can be significantly reduced compared to 2010 status, nevertheless reduction of GHG may be at the expenses of other impact categories, i.e. increased impacts on abiotic resources and freshwater eutrophication. Results are very dependent on biomass origin: if Land Use Change and transportation are included, GHG emissions from energy crops might be comparable to those of fossil fuels. Electricity trading and cogeneration of heat and power are expected to grow in the future: LCA guidelines at the moment fail to address these issues, and specific guidelines are needed to ensure transparency and comparability of LCA studies. By providing impact assessment for Danish power plants in 2010 and 2030 (and the corresponding electricity supply mixes), this study enables performing LCA of present and future products involving consumption/production of electricity.

Mo- and V- catalyzed transformation of biomass into high-value chemicals.

L. B. Nielsen *, J. R. Dethlefsen, D. Lupp, P. Fristrup

Technical University of Denmark, Department of Chemistry, 2800 Lyngby, Denmark

*Corresponding author: lbni@kemi.dtu.dk

The possibility of converting biomass into higher-value chemicals has received increased attention over the last few years. If biomass could be converted into biofuels or platform chemicals, then it could constitute a large source of renewable energy and economy for society. We have focused on homogeneous catalysis by molybdenum and vanadium complexes through deoxydehydration (DODH) reactions of vicinal diols as these are good model compounds for glucose, the major component of all biomass [1]. The main problem with glucose is the high oxygen content which need to be removed if glucose derived chemicals is to be turned into chemicals of higher value [2]. Our experiments have been conducted in an autoclave at 230 °C and 15 bar initial pressure. We have found that $[NH_4]_6Mo_7O_{24}\cdot 4H_2O$ and $(NH_4)VO_3$ give yields close to 50% of the reduced alkene. Sadly, half of the initial diol is spend on reducing the metal, thus seriously limiting the possible yield. We have investigated the possibility of circumventing this problem by applying H_2 gas, different solvents and by the addition of other possible reductants. The experiments have also shown that water is a serious inhibitor of the DODH reactions even in small amounts and thus need to be removed. We conclude that the V and Mo compounds are promising catalysts in DODH reactions, but that further optimization is needed.

Acknowledgments

We thank Sapere Aude for financing.

References

[1] A. M. Ruppert and K. Weinberg and R. Palkovits, *Angew. Chem. Int. Ed.* **51**, 2564 (2012).

[2] P. N. R. Vennestrøm and C. M. Osmundsen and C. H Christiansen and E. Taarning, *Angew. Chem. Int. Ed.* **50**, 10502 (2011).

Towards fusion energy as a sustainable energy source: Activities at DTU Physics

J. Rasmussen*[1], A. Christensen[1], M. Dam[1], A. Jacobsen[1], T. Jensen[1], M. Jessen[1], S. Korsholm[1], F. Leipold[1], J. Madsen[1], M. Magnussen[1], V. Naulin[1], A. Nielsen[1], S. K. Nielsen[1], S. Nimb[1], J. J. Rasmussen[1], M. Salewski[1], M. Stejner[1], L. Tophøj[1]

1: DTU Physics

*Corresponding author email: jeras@fysik.dtu.dk

Nuclear fusion – the process from which the Sun derives its energy – holds the potential to become a clean, safe, highly efficient, and virtually inexhaustible energy source for the future. To mimic this process on earth, experimental fusion devices seek to heat gas to millions of degrees (creating a fusion plasma) and to confine it within magnetic fields. Learning how such plasmas behave and can be controlled is a crucial step towards realizing fusion as a sustainable energy source.

At the Plasma Physics and Fusion Energy (PPFE) section at DTU Physics, we are exploring these issues, focusing on areas of high priority on the way towards a working fusion power plant. On the theoretical front, we are simulating plasma turbulence and transport of heat and particles in fusion plasmas (**Fig. 1a**). These issues play a key role in determining how the plasma behaves globally and how well it remains confined in the magnetic field of the fusion device. Understanding this is important for optimizing plasma performance and for controlling the heat load onto the walls of the confining vessel.

Experimentally, we operate equipment to measure key plasma properties in experimental fusion devices such as *ASDEX Upgrade* in Germany (**Fig. 1b+c**). Using a technique called collective Thomson scattering (CTS), we can infer the plasma composition and the dynamics of energetic ions in the plasma. Control of these parameters is vital for achieving a high fusion yield in future power plants. We are also designing CTS equipment for the next-step fusion device *ITER* (**Fig. 1d**), in which plasma temperatures will exceed 200 million C. This machine is currently being built in France in a large international effort to experimentally demonstrate fusion as a viable energy source and pave the way for the first fusion power plant.

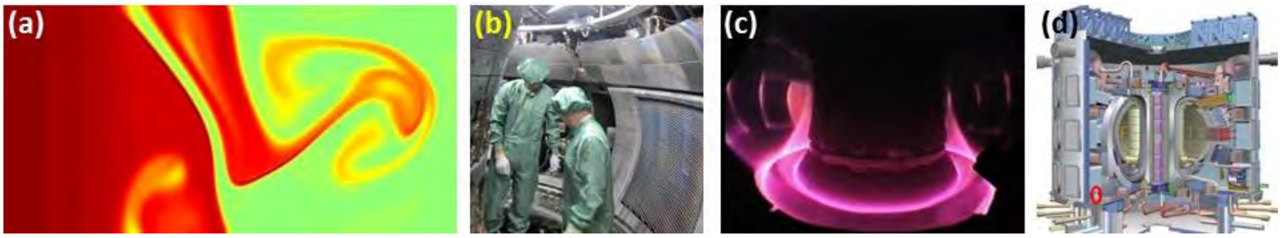


Fig. 1. (**a**) Simulation snapshot revealing turbulent structures in the plasma pressure at the plasma edge in the *ASDEX Upgrade* (AUG) fusion device. Red is high plasma pressure, green is low. (**b**) PPFE employees working inside AUG in preparation for experiments. (**c**) AUG with plasma (seen glowing in pink). (**d**) Cross-section of *ITER* (www.iter.org). Note person drawn to scale at bottom left, circled in red.

TinyPower – Power conversion on a tiny scale

Anpan Han, Anders M. Jorgensen*

DTU Danchip

*Corresponding author email: AJOE@Danchip.dtu.dk

The world surrounding us is filled with devices relying on electrical power and the rise of internet-of-things will mean that powering devices will remain important in the future. The size and cost of the power supply has become a dominant factor in many applications. At the same time, most of the power supplies have large electrolytic capacitators, which are expensive, bulky and often limit the product lifetime. The ambition of the TinyPower project is to develop an integrated switch-mode power supply consisting of an integrated circuit (IC) where only a few external components need to be added to achieve a complete product.

One of the key external components is an inductor. This inductor must operate at the switch frequency of the IC, be able to carry the current needed, be small and not have stray magnetic fields causing problems in nearby circuitry. The switch frequency of the IC will be in the ultra-high frequency, UHF range (300 MHz to 1 GHz) which means that skin effects, Eddy current and nonlinear behavior of magnetic materials are highly important[1]. At least two different inductor structures will be realized and tested, one with a magnetic core and one with a non-magnetic core.

A separate effort is placed on assembling the integrated circuits and passive components. This will most likely be based on a interposer, a miniature circuit board which must account for not only the electrical signals but also the magnetic fields, so as not too reduce conversion efficiency too much.

The Tinypower project is an ambitious approach to taking miniature power converters into a new domain and the trickle-down effect on micro fabricated inductors can hopefully benefit other projects.

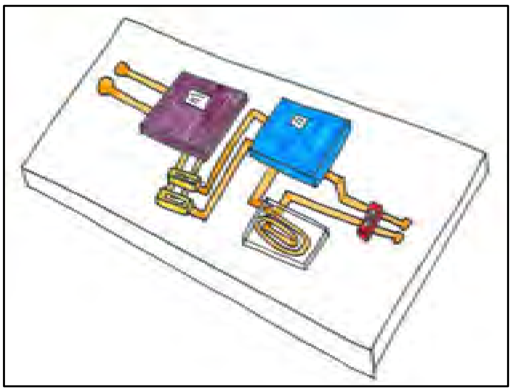


Figure 1: Sketch of a possible realization of the Tinypower system. The racetrack structure in the middle is the inductor.

[1] "Integrating Magnetics for On-Chip Power: A Perspective", C. R. Sullivan *et al.*, IEEE Trans. Power. Elec. Vol 28 No 9, 2013, pp. 4342-4353

Photovoltaic building blocks

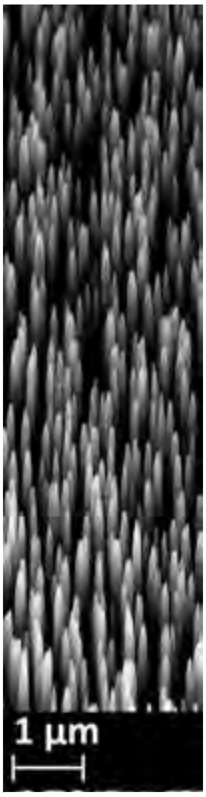
Jesper Hanberg[1] and Anders M. Jørgensen*[1]

1: DTU Danchip

*Corresponding author email: ajoe@danchip.dtu.dk

Photovoltaics (PV), better known as solar cells, are now a common day sight on many rooftops in Denmark. The installed capacity of PV systems worldwide is growing exponentially[1] and is the third most important renewable energy source today. The cost of PV is decreasing fast with ~10%/year but to make it direct competitive with fossil energy sources a further reduction is needed. By increasing the efficiency of the solar cells one gain an advantage through the whole chain of cost. So that per produced Watt of power less material is spent, installation costs are lower, less area is used etc. With an average efficiency of about 15% for commercial Silicon solar cells there is still much to gain.

DTU Danchip provides research facilities, equipment and expertise for the building blocks that comprises fabricating the efficient solar cell.
In order to get more of the sun light into the device we provide thin film coating tools to deposit and develop anti-reflection filters by means of sputtering or e-beam evaporation. To reduce the area taken up by metallic contacts transparent conducting oxides like Aluminium doped Zinc Oxide (AZO) and Indium Tin Oxide (ITO) can be deposited. We also support research and development of new 2D materials like graphene that is a promising candidate for cheap highly transparent contacts. Another way to increase efficiency is to structure the active layers in device so that more light is absorbed. This can be done in one of our advanced dry etching machines either mask-less to form so-called Black Silicon or using micro- or even nano-structured masks to form pyramids or similar structures. These facilities support both the predominant silicon technology but also competing new technologies like thin film solar cells and organic photovoltaics. They can further benefit from our resources within spin- and spray-deposition techniques and a newly installed Atomic Layer Deposition chamber that brings layer thickness control down to the atomic level. Even more advanced multi-junction devices based on compounds from group III and V has brought the world record efficiency up to 44.7%[2]. Such efforts we also provide service for through our tools designed for this material system.



Electron microscope image of Black Silicon

Our team of process generalists can guide and advice you to utilize our clean room facilities most efficiently while our process specialists can help you to develop new processes and fabrication recipes. Our dedicated technical staff supports the infrastructure and keeps the facilities running for your development or research efforts with an uptime of tools of more than 85%.

[1] SETIS: Technology Information Sheet: "Solar Photovoltaic Electricity Generation".
[2] NREL: Best Research-Cell efficiencies: find the newest chart at http://www.nrel.gov/ncpv/

Thin films of absorber material Cu_2ZnSnS_4 for solar cells

Andrea Cazzaniga*, Rebecca Bolt Ettlinger, Jørgen Schou

DTU Fotonik

Corresponding author: andcan@fotonik.dtu.dk

Pulsed Laser Deposition technique is applied to the production of thin films of CZTS (Cu2ZnSnS4). This vacuum technique has proven to be particularly successful in the production of films with a complex stoichiometry, as in the case of high temperature superconductors. The material ablated by the laser pulse is transferred to the substrate at very high kinetic energy (~ keV), thus resulting in high mobility of the adsorpted atoms yet at low substrate temperatures. Since the reaction of decomposition of CZTS via S and SnS evaporation is the main problem all vacuum techniques have to deal with, it is of interest to see here how the crystallinity develops out of such high energetic, stoichiometric transfer.

We investigate the optical and structural properties of thin films produced in high vacuum ($p < 10^{-6}$ mbar) with a single target made with sintered powder with stoichiometry: Cu2ZnSnS4. The films are deposited on Mo coated SLG in the temperature range from 25C to 500C. X-ray diffraction patterns show an increase in the intensity of main peak associated to kesterite CZTS up to a substrate temperature of 300 C, then secondary phases start to show up and the main peak associated to kesterite drops down in intensity. Optical measurements (direct and diffuse reflectance) and ellipsometry analysis are used to investigate the optical constants of the films produced and to estimate the bandgap, while AFM images are used to investigate the roughness.

The same measurements are carried out on the same samples after annealing at 500 C for 20 mins in N2 + S atmosphere and the results are compared.

The films produced are in the thickness range 600 – 1000 nm, the excimer laser used is a Lambda Physik filled with KrF working at 248 nm, with pulse length of 20 ns. Pulse repetition rate was set at 10 Hz, the deposition process was lasting 1 hour.

Waste Water Treatment Plants and the Smart Grid

Rasmus Halvgaard*[1], Peter Tychsen[2], Thomas Munk-Nielsen[2], Morten Grum[2], Henrik Madsen[1]

1: DTU Compute; 2: Krüger A/S *Corresponding author email: rhal@dtu.dk (www.compute.dtu.dk/~rhal)

Denmark's political ambitions of a fossil fuel free energy system by 2050 calls for more renewable energy sources such as wind and solar. These green energy resources fluctuate and the transition to a green energy system requires a Smart Grid with flexible consumers that balance the fluctuating power production. The energy-heavy processes for waste water transport and treatment could potentially provide a flexible operation with storage capabilities and be a valuable asset to a Smart Grid.

In order to enable Waste Water Treatment Plants (WWTPs) as flexible prosumers in the future Smart Grid, we must update their process control system to model based predictive control that monitors the changed flexible operation and plans ahead.

The primary aim of a WWTP is to treat the incoming waste water as much as possible to ensure a sufficient effluent water quality and protect the environment of the recipient. The secondary aim is to treat the waste water using as little energy as possible. In the future waste water will be considered an energy resource, that contains valuable nutrients convertible to green biogas and in turn electricity and heat. In a Smart Grid consuming or producing energy at the right time is key to both lower plant electricity costs and actively help to balance the energy system.

Predictions of the WWTP and sewer system operation could help a model based controller to adapt power consumption and production according to the energy system flexibility needs; incentivized through energy markets and prices.

We are in the process of upgrading the current control system to prepare a flexible operation and Smart Grid market integration. The prototype system will be tested online at a plant in Denmark, that in the current market could save up to 300.000 DKK/year in electricity costs. The solution is based on existing available online plant sensors and is expected to be part of Krüger's advanced process control software *STAR control*® already used at plants worldwide.

H_2CAP - Hydrogen assisted catalytic biomass pyrolysis for green fuels

Trine Marie Hartmann Arndal[1*], Martin Høj[1], Peter Arendt Jensen[1], Anker Degn Jensen[1], Lasse Røngaard Clausen[2], Jan-Dierk Grunwaldt[3], Jostein Gabrielsen[4] and Felix Studt[5].

1: DTU Chemical Engineering, 2: DTU Mechanical Engineering, 3: Karlsruhe Institute of Technology (KIT), 4: Haldor Topsøe A/S, 5: Stanford University.

*trina@kt.dtu.dk

Pyrolysis of biomass produces a high yield of condensable oil at moderate temperature and low pressure. This bio-oil has adverse properties such as high oxygen and water contents, high acidity and immiscibility with fossil hydrocarbons[i]. Catalytic hydrodeoxygenation (HDO) is a promising technology that can be used to upgrade the crude bio-oil to fuel-grade oil[ii]. The development of the HDO process is challenged by rapid catalyst deactivation, instability of the pyrolysis oil, poorly investigated reaction conditions and a high complexity and variability of the input oil composition[ii]. However, continuous catalytic hydropyrolysis coupled with downstream HDO of the pyrolysis vapors before condensation shows promise (Figure 1).

A bench scale experimental setup will be constructed for the continuous conversion of solid biomass (100 g /h) to low oxygen, fuel-grade bio-oil. The aim is to provide a proof-of-concept for the proposed process (Figure 1), to understand the reaction mechanisms of HDO, to develop highly active and durable catalysts for hydropyrolysis and HDO and to optimize the operating conditions; all in order to develop a sustainable production of green transportation fuels from biomass.

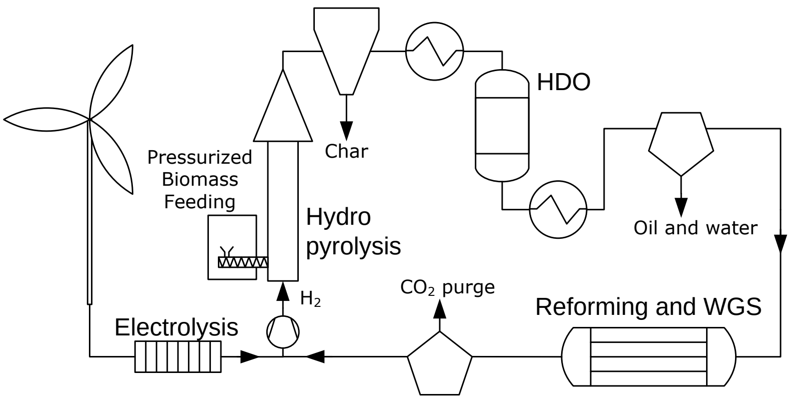


Figure 1 *Proposed process diagram including catalytic hydropyrolysis, char separation, temperature adjustment, deep HDO, liquid separation, pyrolysis gas reforming and water gas shift. Additional hydrogen is obtained from water electrolysis.*

To support the process development, the conversion of different bio-oil model compounds over a wide range of catalyst classes (reduced types, oxides, phosphides and sulfides) will be investigated. Special attention will be paid to operating conditions (e.g. temperature, H_2 partial pressure, residence time) and to tolerance against water, sulfur, chlorine and potassium which are abundant in bio-oil.

i) A.V. Bridgwater, Biomass and Bioenergy, 38 (2012), pp. 68-94. ii) P. M. Mortensen, J.-D. Grunwaldt, P.A. Jensen, K.G. Knudsen, A.D. Jensen, Appl. Catal. A: General, 407 (2011), pp. 1-19.

Bioelectrochemical reduction of carbon dioxide by pure culture at the cathode.

Nabin Aryal[#], Pier-Luc Tremblay[#], Leifeng Chen[#], Daniel Höglund[#], Tian Zhang#*

Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Kogle Allè 6 DK-2970 Hørsholm

***** Corresponding author; Dr. Tian Zhang, zhang@biosustain.dtu.dk,

Microbial electrosynthesis (MES) is an innovative approach in which microbes use electricity to reduce carbon dioxide and produce chemical commodities. This process relies on the ability of electroautotrophic microbes to accept electron from an electrode. The concept of MES has already been demonstrated with pure cultures of acetogenic bacteria such as *Sporomusa ovate* DSM-2662 and *Clostridium ljungdahlii*. Until now, electron transfer rates from the cathode to the best electroautotroph, *S. ovata*, are still orders of magnitude lower than what is observed in bioanodic processes with electrigenic bacteria. Hence, we are screening other pure cultures for better MES activities. These bacterial species were pre-selected based on several criteria such as their presence in enrichments of environmental samples in MES systems, their capacity to fix CO_2, their incapacity to sporulate, and their ability to form robust biofilms. In preliminary results, 171.9mM of acetate per day per m^2 was produced by a previously uncharacterized strain of *Sporomusa ovata* which is approximatively 1.4 times better than *S. ovata* DSM-2662[1]. This demonstrates that better electroautotrophic bacteria can still be uncovered leading to more productive MES process.

Reference:

1-Nevin et al., 2010; mBio 1:e00103-10.

Assessing the environmental impacts of using demineralized coal for electricity generation

Morten Ryberg[*1], Mikolaj Owsianiak[1], Alexis Laurent[1]

1: DTU Management

*Corresponding author email: moryb@dtu.dk

The energy sector is the source of two-thirds of global greenhouse-gas emissions, and is the main target of climate policies among authorities and governments. The share of fossil coals (hard coal and lignite) in world total net electricity generation is 40% in 2010. Demineralization or ash removal of the coal is thought to be beneficial for reducing ash-related problems, such as slagging and fouling in the combustion chamber, increasing the heating value, increasing thermal efficiency and reducing airborne emissions.

A novel method for removing ash is alkali-acid leaching where the coal is washed in alkaline and acidic solution to dissolve and remove the ash. This process is well-studied on lab scale but has only to a small extent been tried on a full scale. This assessment is conducted as an aid for further developing the technology, allowing for early identification of environmental impacts and possible improvements. Experimental studies conducted so far have shown better performance of demineralized coal than its original raw coal during combustion, gasification, and coke making process. However a thorough analysis of the impacts from demineralization has not yet been conducted. We take a life cycle perspective, to assess the environmental impacts from removing ash in coal, and assess how this affects the combustion in terms of higher thermal efficiency. We assess 260 different data points applying alkali-acid leaching or acid leaching and assess how the treatment and subsequent energy generation will affect the environment.

The results showed that demineralization in some cases were beneficial for regional impacts such as particulate matter formation because emission of particles and SO_2 were reduce. In the contrary global impacts such as climate change did not benefit from demineralization because of the large energy use for running the demineralization process. Local and regional environmental impacts were shown to improve from demineralization for low ranking coals or lignite where the ash content is above ≈25 % and the carbon content is less than ≈50 %. Overall, it can be concluded that demineralization of coal is not advised for high quality coals as the additional energy required for removing the ash outweighs the benefits from the increase thermal efficiency.

Sustainability assessment of two chains of biomass supply from field to bioenergy

Fabiana Morandi[1], Hanne Østergård*[1]

1: DTU Chemical Engineering

*Corresponding author email: haqs@kt.dtu.dk

LogistEC, "Logistics for Energy Crops biomass", is an FP7 Project aiming at developing new or improved technologies of the biomass logistics chains (http://www.logistecproject.eu/). Sustainability assessment of different biomasses is being performed by studying the environmental, economic and social impacts, based on the supply chain of two existing bioenergy plants, located in France (Bourgogne) and Spain (Extramadura), respectively.

Our contribution to the project is part of the environmental impacts analysis and it is divided into two steps: 1) sustainability assessment of the systems by using emergy analysis, a method that accounts for all forms of energy, resources and human services that contribute to the system; 2) combination of all assessment results (coming from emergy, LCA, economic and social evaluations) in a Sustainability Multi-criteria Multi-scale Assessment (SUMMA) framework.

We present some results of the emergy evaluation for the French scenario, where *Miscanthus* is the energy crop used to produce pellet. In particular, results for each phase (i.e., growing, harvesting, transportation and pelletization of Miscanthus) are described.

Production of butyrate and caproate from a coculture of *Sporomusa ovata* and *Clostridium kluyveri* during MES

F. Ammam*, *PL. Tremblay, N. Faraghi, T. Zhang and K. Zengler*

The Novo Nordisk Foundation Center for Biosustainability, 2970 Hørsholm, Denmark,
*corresponding author: faram@biosustain.dtu.dk

Microbial electrosynthesis (MES) is the process in which microorganisms use electrons derived from an electrode to reduce carbon dioxide via the Wood-Ljungdahl pathway to form organic compounds. *S. ovata*, a Gram-negative acetogenic bacterium is the best electrotroph organism reported to date. The lack of a genetic system for *S. ovata* represents an obstacle that hampers engineering of this organism for the production of organic compounds other than acetate by MES. In this study, we attempted to produce longer and valuable compounds during MES by deploying a coculture of *S. ovata* and *C. kluyveri* to bypass the lack of genetic tools. *S. ovata* is able to produce ethanol and acetate while *C. kluyveri* uses these two compounds as carbon source and produces butyrate and caproate.

The first step was to optimize the growth medium for *S. ovata* to increase ethanol production. The effect of trace metal ions such as SeO_4^- and WO_4^-, as well as Ni^{2+}, Zn^{2+}, Cu^{2+}, and Fe^{2+} on growth and ethanol production was investigated. Growth and ethanol production under autotrophic conditions (H_2/CO_2) were improved by increasing tungstate and nickel (WO_4^- and Ni^{2+}) concentrations in the medium. The coculture *S. ovata* and *C. kluyveri* was thereafter tested under autotrophic condition (H_2/CO_2) using the optimised medium. A maximum of 6.0 mM and 2.0 mM of butyrate and caproate, respectively were produced after 18 days of incubation. In MES, only traces of butyrate were detected after 20 days. These results suggest that the amount of ethanol produced in MES by *S. ovata* is not sufficient to support *C. kluyveri* growth; butyrate and caproate production. Further optimization of MES process is needed to increase ethanol production from *S. ovata* and subsequently increase butyrate and caproate production from *C. kluyveri*.

Utilization of low temperature heat for environmentally friendly electricity production

Jesper Graa Andreasen*[1], Brian Elmegaard[1], Fredrik Haglind[1]

1: DTU Mechanical Engineering

*Corresponding author email: jgan@mek.dtu.dk

The focus on reduction of fossil fuelled electricity generation has increased the attention on exploitation of low grade heat as the energy source for electricity producing power plants. Low grade heat is heat, which is available at a low temperature, e.g. from waste heat from marine diesel engines and industrial processes or from geothermal and solar heat sources. Utilization of such heat sources makes it possible to produce electricity with no additional burning of fossil fuel, and does therefore represent an environmentally friendly alternative to fossil fuel based electricity production.

Utilization of low grade heat is not feasible with conventional steam Rankine cycles (steam engines) due to undesirable properties of steam. Instead the organic Rankine cycle is typically used, since it enables the choice of a working fluid, e.g. hydrocarbons or refrigerants, with desirable properties. One of the key issues for improving the performance of organic Rankine cycles is to optimize the heat transfer processes for adding and removing heat from the cycle, which can be achieved by employing a working fluid consisting of a mixture of two or a number of pure fluids.

This project is aimed at quantifying the benefits of using mixtures compared to pure fluids as working fluids in organic Rankine cycles. In order to do so, thermodynamic and economic analyses are carried out, first on an overall cycle level, and next on component level including detailed modelling of heat exchangers, pumps and expanders involving project collaborators with expertise in these areas. In addition to this, novel innovative cycle layouts are developed with the aim of increasing the economic feasibility of utilizing low temperature heat. As an example, this can be achieved by implementing separators in the power cycle to create optimal variations in mixture composition throughout the cycle (equivalent of combining a power cycle with a distillation process). In collaboration with DTU Chemical Engineering, a search for novel pure fluids and mixtures are initiated in order to develop working fluids that are tailored for maximizing the profitability of the power cycles; both the organic Rankine cycle and the novel power cycles.

Track 4

Sustainable Production and Materials

Scientific Commitee

Coordinator: Peter Andreas Sattrup, DTU byg

Kim Pilegaard, DTU chemical engineering

Morten Willatzen, DTU Photonics

Hanne Thomasen, DTU Space

Jochen Förster, DTU Biosustain

Steering group contact person: Steffen Foss Hansen, DTU Environment

Track 4
Talk
Presentations

See schedule on
www.sustain.dtu.dk

Integrated Resource Management and Recovery

Thomas Fruergaard Astrup*

DTU Environment

*Corresponding author email: thas@env.dtu.dk

A significant part of the environmental consequences related to activities in society is associated with our consumption of resources. Modern products become more and more complex and rely on more complex sets of resources than before. This emphasizes the need for continuous access to high quality resources, i.e. security of supply, but also the need for efficient recovery of the same resources after the use-phase of the products. While this recovery may appear simple, considerable challenges exist.

Management and recovery of resources in waste materials, or in general residual streams in society, depends on the quality of these resources and technological abilities to extract resources from mixed materials, e.g. mobile phones, solar cells, or mixed domestic waste. The "effort" invested in recovery of secondary resources should not be more than the "benefit" associated with the secondary resources.

Over the recent decades, DTU Environment has worked extensively both with resource recovery technologies and life cycle assessment (LCA) models (www.EASETECH.dk) dedicated to evaluating resource management and recovery systems. Advanced sustainability assessments of resource recovery and utilization have been carried out e.g. in relation to household and industrial waste systems, biomass residues from agriculture and forestry, energy producing technologies as well as entire energy systems.

The presentation provides an introduction to key challenges in relation to sustainability assessment of resource recovery as well as examples of recent research.

Understanding Eco-innovation and Green Business Models

Maj Munch Andersen

DTU Management

mmua@dtu.dk

Eco-innovation is considered a still more important competitive strategy to maintain production in high cost economies such as the Danish one. Within the studies of economics of technological change only little research has been undertaken on the dynamics of eco-innovation. Rigorous statistics and definitions of eco-innovation are lacking leading to much confusion and methodologically weak empirical analyses. This paper seeks to remedy this by offering a definition and taxonomy of eco-innovations and discussing the implications for green business model thinking, bringing in examples of Danish successful and less successful green business models.

The taxonomy entails seven main types of eco-innovations which are defined by the role these innovations play on the market, i.e. they represent different ways to attract green value. The categorization hence differs markedly from existing taxonomies of environmental technologies which has taken a starting point in the environmental effects of varies technologies. The seven categories are:

1. Curative eco-innovations - add-on (clean-up, recycling and resource handling)
2. Integrated continuous process and product eco-innovations (cleaner production and products)
3. User-oriented product eco-innovation (enables cleaner consumption)
4. Discontinuous product eco-innovations (alternative green trajectories)
5. General purpose eco-innovations - enabling pervasive eco-innovation (ICT, biotech, nano)
6. Macro-organizational eco-innovations - reorganizing production and consumption patterns (cities/communities, physical planning, symbiosis)
7. Business model eco-innovation (green value creation by novel financing or ownership modes)

(See also Andersen 2006, 2008 for earlier versions).

The taxonomy may be used to understand the conditions for creating green value for different types of companies and industries and how this is changing over time as the green economy matures. The complementarities and competition between these eco-innovations are significant for determining the rate and direction of green economic change. Understanding these processes is essential in developing efficient green business models and even advanced green Danish companies struggle with this.

References:

Andersen, M M. (2006). *Eco-innovation indicators. European Environment Agency, Copenhagen*.

Andersen, M M. (2008). Eco-innovation. Towards a taxonomy and a theory. In *DRUID Conference 2008 - Entrepreneurship and innovation - organizations, institutions, systems and regions*.

Andersen, M M. (2009). Combating Climate Change through Eco-innovation - Towards the Green Innovation System. In *Innovative Economic Policies for Climate Change Mitigation* (1st ed., pp. 37–58). Lulu.com.

Urban and Building Design Methods for Resource Management

Peter Andreas Sattrup*,

DTU Civil Engineering, Section of Building Design

*pans@byg.dtu.dk

Design has great impacts on resource use. For instance, the demand for transportation is dependent on the design of cities, the demand for energy is dependent on the design of buildings, which in turn affect the health and well-being of citizens, society's human resources and social capital, to name but a few dimensions. Engineers may influence decision making at all levels, and do in many instances have direct responsibility for decision making, - however many (Civil) engineers don't really think of themselves as designers. However this perception is changing. Engineering is fundamentally a design discipline.

Having a structured approach to design methods, a design methodology, is a fundamental aid in decision making and resource management through design. At DTU Civil Engineering experiments are made in cross disciplinary collaboration between engineers of different specializations and outside collaborators. Design methodologies are invented addressing urban and building design issues, making performance, resource use and environmental impacts transparent.

This talk discusses how design methods can be used for decision support in urban and building design, based on quantitative modelling and qualitative research. Examples from practice will serve as cases, where research based design methods have been developed into innovative design tools and services.

The discussion is taken further as there is a pressing demand for further cross disciplinary integration and collaboration on developing tools and methods for resource management and decision support regarding the development of the built environment towards a sustainable future.

EASETECH – A LCA model for assessment of environmental technologies

Anders Damgaard [1]*, Hubert Baumeister[2], Thomas F. Astrup[1], Thomas H. Christensen[1]

1: DTU Environment, 2: DTU Compute

*Corresponding author email: adam@env.dtu.dk

EASETECH is a new model for the environmental assessment of environmental technologies developed in collaboration between DTU Environment and DTU Compute. EASETECH is based on experience gained in the field of waste management modelling over the last decade and applies the same concepts to systems with different kinds of material flows, such as sludge, wastewater, biomass for energy production and treatment of contaminated soil.

The primary aim of EASETECH is to perform life cycle assessment (LCA) of complex systems handling heterogeneous material flows. The main novelties of the model compared to other LCA software are as follows. The focus is put on material flow modelling. This means that each material flow is characterized as a mix of material fractions with different properties. Flows in terms of mass and composition are computed throughout the integrated system including rejects, slags, ashes and products as a basis for the LCA calculations. These flows are handled as a matrix of waste fractions and material properties, and each fraction can be handled independently or grouped based on general similarity (e.g. PE bottle and plastic waste) in different processes. This is very important because different materials have different chemical compositions, and the optimal treatment for one material fraction might be suboptimal for another fraction. It is therefore critical that the starting point of the modelling process is a composition matrix where each material fraction is specified in terms of chemical, as well as fraction-specific parameters (e.g. water content, heating value).

The presentation will cover the main novelties of the model as well as examples of recent research carried out with the model.

For more info on the model see www.easetech.dk

Biotechnology for renewable chemicals

Irina Borodina*[1], Kanchana R Kildegaard[1], Niels B Jensen[1], Svetlana Sherstyk[1], Jérôme Maury[1], Jochen Forster[1], Markus Herrgård[1] and Jens Nielsen[1,2]

1: DTU Biosustain

2: Chalmers University of Technology, Sweden

*Corresponding author email: irbo@biosustain.dtu.dk

The majority of the industrial organic chemicals are derived from fossil sources. With the oil and gas resources becoming limiting, biotechnology offers a sustainable alternative for production of chemicals from renewable feedstocks. Yeast is an attractive cell factory for sustainable production of chemicals, due to its safe use status, tolerance of low pH and inhibitors, and amenability to large-scale fermentations. There are examples of commercial processes for production of organic acids such as lactic and succinic acids in yeast.[1]

Examples of chemicals produced by yeast fermentation

We have engineered baker's yeast *Saccharomyces cerevisiae* for the production of non-native 3-hydroxypropionic acid (3HP).[2,3,4] 3HP can be chemically dehydrated into acrylic acid and thus can serve as a biosustainable building block for acrylate-based products (diapers, acrylic paints, acrylic polymers, etc.)

[1] Borodina I & Nielsen J (2014) "Advances in yeast metabolic engineering for production of chemicals". *Biotechnol J*, 9(5):609-620
[2] Borodina *et al.* (2014) "Genetically engineered yeast". WO 2014/067036 A1
[3] Kildegaard *et al.* (2014). "Evolution reveals a cyclic glutathione-dependent mechanism of 3-hydroxypropionic acid detoxification". *Metab Eng*, 26:57-66
[4] Borodina et al. (2015) "Establishing a synthetic pathway for high-level production of 3-hydroxypropionic acid in Saccharomyces cerevisiae via b-alanine". *Metab Eng*, 27:57-64

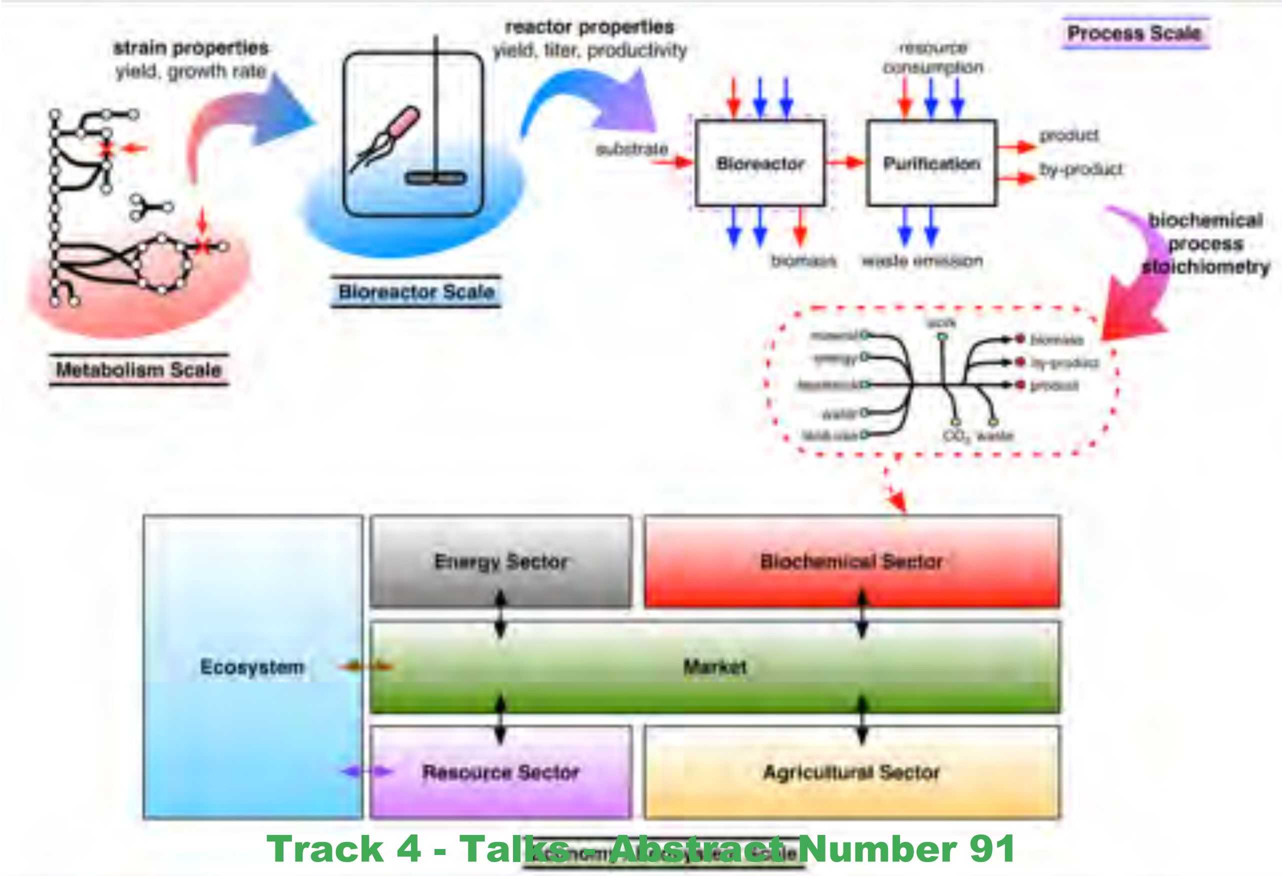
Multi-scale Exploration of the Technical, Economic, and Environmental Dimensions of Bio-based Chemical Production

Kai Zhuang[1], Markus J. Herrgård[1]

1:Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Kogle Alle 6, DK-2930 Hørsholm, Denmark

*Corresponding author email: kazh@biosustain.dtu.dk

In recent years, bio-based chemicals have gained traction as a sustainable alternative to petrochemicals. In order to maximize the impacts of researches and investments, there is a need to focus on the most promising combinations of feedstocks, biochemical products, and bioprocesses. To address this issue, we developed a multiscale framework that integrates modeling approaches across scales of cellular metabolism, bioreactor, bioprocess, and economy/ ecosystem, and is able to simultaneously assess biological, technological, economic and environmental feasibility of different production scenarios. Using our framework, we assess the production of two major polymer precursors (1,3-propanediol and 3-hydroxypropionic acid) from two biomass feedstocks (corn-based glucose and soy-based glycerol) using two host organisms (*E. coli* and *S. cerevisiae*). We explore the sustainability and economic impacts of a variety of policies and practices (e.g. land-usage, energy source mixture, CO_2 emission cap), as well as tradeoffs between different objectives (e.g. profits for different sectors, emission minimization) for key stakeholders involved in the biochemical value chain (agriculture, energy, and biotechnology sectors).



Landfill methane emission mitigation – How to construct and document a full-scale biocover system

Peter Kjeldsen* and Charlotte Scheutz, DTU Environment

*Corresponding author email: pekj@env.dtu.dk

Landfills receiving organic wastes produce biogas (landfill gas – LFG) containing methane (CH4). Landfills are significant sources of methane, which contributes to climate change. As an alternative to gas utilization systems or as a follow-on technology when a gas utilization system gets non-cost-effective, bio-mitigation systems may be implemented. Bio-mitigation systems are defined here as systems based on microbial removal processes implemented at landfills to reduce emission of methane (or other harmful substances). In respect to CH_4, experiments have documented that a very high methane oxidation rate can be obtained in soils, compost and other materials, high enough to significant reduce the methane emission from landfills. The process has been scaled up by DTU Environment to a full-scale implemented technology at two Danish landfills. Now the Danish government has decided to establish bio-mitigation systems at up to 100 closed and old Danish landfills.

The presentation will introduce the technology and methodologies for documentation of the gained greenhouse gas mitigation.

Hierarchical nanoreinforced composites for highly reliable large wind turbines: Computational modelling and optimization

Leon Mishnaevsky Jr.*

DTU Wind Energy *mailto:lemi@dtu.dk

The major precondition for the successful development of wind energy in Europe is the high reliability of wind turbines, in particular, large off-shore turbines. The qualitative enhancement of the reliability of wind turbine blades can be achieved by the development of new highly damage materials, with modified, hybrid or nanomodified structures [1]. In this project, we seek to explore the potential of hybrid (carbon/glass), nanoreinforced and hierarchical composites (with secondary CNT, graphene or nanoclay reinforcement) as future materials for highly reliable large wind turbines [2-4]. Using 3D multiscale computational models of the composites, we study the effect of hybrid structure and of nanomodifications on the strength, lifetime and service properties of the materials (see Figure 1). As a result, a series of recommendations toward the improvement of composites for structural applications under long term severe service conditions have been developed [1].

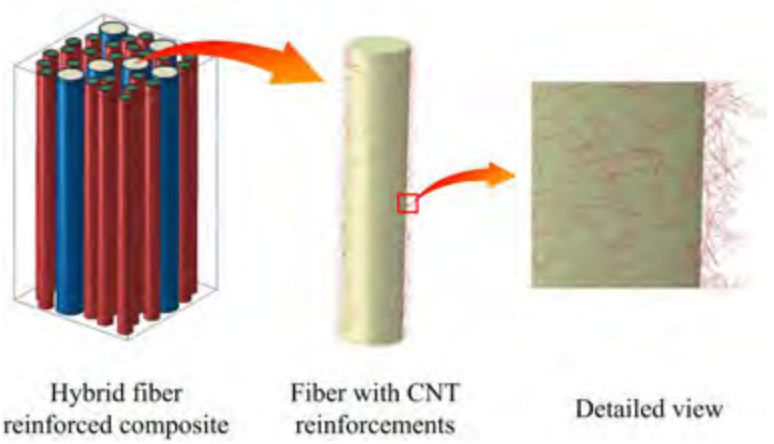


Figure 1. Schema of the multiscale modelling of CNT reinforced hybrid composites

References:

1. L. Mishnaevsky Jr. et al, Materials of large wind turbine blades: Recent results in testing and modelling, *Wind Energy*, Vol. 15, No.1, pp, 83–97, 2012
2. L. Mishnaevsky Jr et al., Microscale damage mechanisms and degradation of FRC for wind energy applications, *J. Composite Materials,* 2014, Vol. 48(24) 2977–2991
3. L. Mishnaevsky Jr., G.Dai, Hybrid and hierarchical nanoreinforced polymer composites, *Composite Structures, 117 (2014) 156–168*
4. G.M. Dai, L. Mishnaevsky Jr., Graphene monolayer nanocomposites: 3D simulation of damage and fracture, *Computational Materials Science,* Vol. 95, 2014, Pages 684–692

Small and smart magnet design

Cathrine Frandsen*[1], Marco Beleggia[2,3], Erik Brok[1,2,§], Jelena Jordanovic[1], Takeshi Kasama[2], Jacob Larsen[1], Steen Mørup[1], Jakob Schiøtz[1], Miriam Varon[1]

1: DTU Fysik; 2: DTU Cen; 3: HZB Berlin; §: Now at NIST Gaithersburg

*Corresponding author email: fraca@fysik.dtu.dk

Society faces an accumulated need to find ways to produce super strong magnets that can fulfill the growing demands for green technology products such as compact and efficient generators and motors. Next-generation magnets could very likely be composite materials built bottom-up from nanoparticles. However, combining the nanoparticles into a compact magnetic material where all magnetic moments are aligned is an engineering challenge. We investigate - with nanoparticle-resolution – principles of assembly-processes and particle arrangements that can generate optimal magnetic order in new materials (see e.g. Fig. 1). These studies are enabled by advanced transmission electron microscopy, magnetic modelling and new synthesis protocols. Examples of magnetic ordering and self-organization will be given.

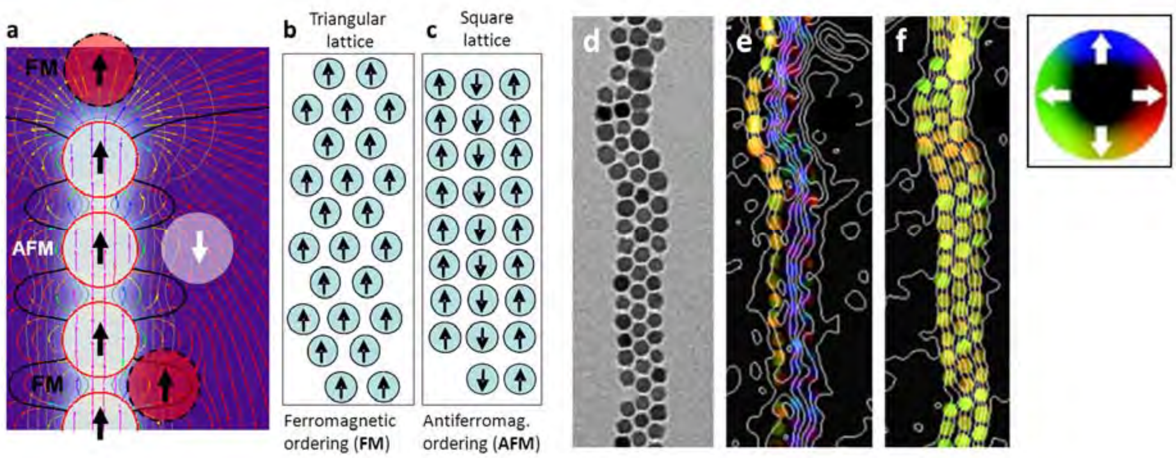


Figure 1: Dipolar magnetic ordering of nanoparticles. a) Particles (red) attached at the end of the chain or in the strong near-field between two particles in the chain favor ferromagnetic (FM) alignment, while antiferromagnetic (AFM) alignment will occur otherwise (white particle). b,c) Examples of resulting magnetic ordering for different nanoparticle lattices. d) Electron micrograph of a chain of self-assembled ~15 nm Co particles. e-f) Electron holography mapping of the magnetic order in the chain: e) initial state; f) after application of a field of 2 T. The contours and the colors (described using the color wheel to the right) provide a measure of the magnitude and direction of the magnetic field in the plane of the particles with a spatial resolution of 6 nm. Figure adapted from M. Varon et al. Scientific Reports 3 (2013) 1234.

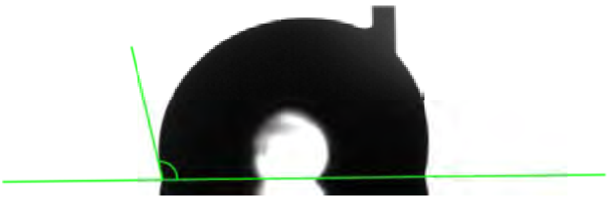
TransForm: Injection moulded 3D superhydrophobic surfaces

Carl Esben Poulsen[1], Kasper Kistrup[1], Nis Korsgaard Andersen[1], Rafael Taboryski[1], Mikkel Fougt Hansen[1], Anders Wolff*[1]

1: DTU Nanotech

*Corresponding author email: Anders.Wolff@nanotech.dtu.dk

Fluorinated coatings are widely used for non-stick cooking utensils, as spray-on for stain prevention on fabrics and for single use laboratory utensils such as sample tubes and pipette tips. In the latter examples, the superhydrophobic surface is of high importance since it ensures high dosing precision and reduces waste due to the high contact angle between the sample and the fluorinated coating. Unfortunately, the applicability of fluorinated compounds is limited due to the acute or long term toxic effects when inhaled[1], [2] or ingested[3]. Alternatively, a superhydrophobic Cassie-Baxter state can be achieved by introducing micro- and nano-structures on a hydrophobic substrate[4]. However, no micro- and nano structuring methods for modifying commercial relevant mould materials, such as tool steel, exist.
We have developed a patent pending method for selective 3D-structuring conventional moulds for polymer injection moulding such that injection moulded pieces possess localised superhydrophobic wetting properties. We have demonstrated our technology in several aluminium alloys, as well as tool steel, that are typical for mould making - and superhydrophobic polymer pieces have been injection moulded, see below:



Flat polypropylene piece

- Contact angle= 104°
- Contact angle hysteresis =21°

Polypropylene piece from modified mould

- Contact angle= 160°
- Contact angle hysteresis < 5°

[1] G. M. F. Wallace and P. H. Brown, “Horse rug lung: toxic pneumonitis due to fluorocarbon inhalation.,” *Occup. Environ. Med.*, vol. 62, no. 6, pp. 414–6, Jun. 2005.

[2] C. J. Johnston, J. N. Finkelstein, P. Mercer, N. Corson, R. Gelein, and G. Oberdörster, “Pulmonary effects induced by ultrafine PTFE particles.,” *Toxicol. Appl. Pharmacol.*, vol. 168, no. 3, pp. 208–15, Nov. 2000.

[3] M. Sakata, H. Kazama, A. Miki, A. Yoshida, M. Haga, and M. Morita, “Acute toxicity of fluorocarbon-22: Toxic symptoms, lethal concentration, and its fate in rabbit and mouse,” *Toxicol. Appl. Pharmacol.*, vol. 59, no. 1, pp. 64–70, Jun. 1981.

[4] E. Puukilainen, T. Rasilainen, M. Suvanto, and T. a Pakkanen, “Superhydrophobic polyolefin surfaces: controlled micro- and nanostructures,” *Langmuir*, vol. 23, no. 13, pp. 7263–8, Jun. 2007.

Screening of waste for use in clay-based bricks in the Arctic

Belmonte, L.J.*[1], Ottosen, L.M.[1], Kirkelund, G.M.[1], Erland Jensen, P.[1] and Vestbø, A.P.[2]

1: DTU Civil Engineering; 2: Danish Technological Institute

*Corresponding author email: lojon@byg.dtu.dk

Clay-based ceramics, such as bricks, are heterogeneous materials, which can incorporate raw materials of wide ranging compositions, without impairing their technical properties (Dondi et al., 1997a,b). Due to this ability, bricks have become a popular material in waste management research worldwide and several studies have demonstrated that clay-based bricks and tiles can successfully accommodate waste types, such as incineration ashes, mine tailings and dredged harbour sediments (Zhang et al., 2011; Roy et al., 2007; Mezencevova et al., 2012). In the vulnerable Arctic environment, the impact of especially hazardous wastes can have severe consequences (Lemly, 1994) and the reduction and safe handling of these waste types are therefore an important issue in the Arctic nations. In comparison to other parts of the world, the Arctic region imports most of its construction materials and does not have a strong tradition for masonry structures. In Greenland, for example, bricks are neither currently produced locally nor frequently applied for construction purposes. Recent studies have, however, established that deposits of marine glaciogene clay, which are found throughout the former glaciated areas of the northern hemisphere, are suitable for brick production (Belmonte et al., 2014, a; Belmonte et al., 2014, b). This provides an excellent opportunity to test whether bricks produced locally in the Arctic could also help to solve issues regarding waste handling and disposal.

In this study, two types of hazardous waste, municipal solid waste incineration (MSWI) ashes and mine tailings from Greenland, were investigated in order to determine their potential suitability for incorporation in the production of clay-based bricks. Furthermore, the MSWI fly ash was subjected to two remediation techniques (electrodialytic treatment and washing) with the purpose of studying the effects of these treatments on the leaching behaviour.

Belmonte, L. J., Ingeman-Nielsen, T. and Foged, N.N. (2014, a) Characterisation and weathering properties of fine-grained marine sediments from West Greenland. Submitted.

Belmonte, L. J., Ottosen, L. M., Kirkelund, G. M. and Villumsen, A. (2014, b) Use of a typical marine clay from Greenland for the production of red bricks. Submitted.

Dondi, M., Marsigli, M. and Fabbri, B. (1997, a and b) Recycling of industrial and urban wastes in brick production – a review (part 1 and 2). Tile and Brick International, 13 (3 and 4), pp. 218-225 and pp. 302-315.

Lemly, A.D. (1994) Mining in Northern Canada: Expanding the industry while protecting the Arctic Fishes – a review. Ecotoxicology and environmental safety, 29, pp. 229-242.

Mezencevova, A., Yeboah, N. N., Burns, S. E., Kahn, L. F. and Kurtis, K. E. (2012) Utilization of Savannah Harbor river sediments as the primary raw material in production of bricks. Journal of Environmental Management, 113, pp. 128-136.

Roy, S., Adhikari, G.R. and Gupta, R.N. (2007) Use of gold mill tailings in making bricks: a feasibility study. Waste Management and Research, 25, pp. 475-482.

Zhang, H., Zhao, Y. and Qi, J. (2011) Utilization of municipal solid waste incineration (MSWI) fly ash in ceramic brick: Product characterisation and environmental toxicity. Waste Management, 31, pp. 331-341.

Track 4
Laptop
Presentations

See schedule on
www.sustain.dtu.dk

DTU's
Sustain
Conference

NanoRiskCat and nanodb.dk – Advancing Sustainability through Safety and Risk Evaluation of Nanomaterials and Products in Europe

Steffen Foss Hansen[1,*], Aiga Mackevica[1], Laura Roverskov Heggelund[1], Alexander Newcombe[1,2], Anders Baun[1]

1: DTU Environment, 2: DTU Wind Energy

*Corresponding author email: sfha@env.dtu.dk

Assessment of safety and risks play an important role when it comes to advancing sustainability, but has been very challenging when it comes to complex technical, environmental and societal issues such as nanotechnology, chemicals and fracking. We have developed a systematic tool called NanoRiskCat that can support companies and regulators in their first-tier assessment and communication on what they know about the hazard and exposure potential of consumer products containing engineered nanomaterials (see Hansen *et al.* 2014. J Nanopart Res 16:2195). The final outcome of NanoRiskCat is communicated in the form of a short-title describing the intended use and five colored dots (see figure 1).

Figure 1: Example of a NanoRiskCat evaluation on exposure and hazard potential for a given nanoproduct

The first three dots refer to the qualitative exposure potential for professional end-users, consumers and the environment, whereas the last two refers to the hazard potential for humans and the environment. Each dot can be assigned one of four different colors, i.e. red, yellow, green, and gray indicating high, medium, low, and unknown, respectively. In this paper, we first introduce the criteria used to evaluate the exposure potential and the human and environmental hazards of specific uses of the nanoproduct. We then apply NanoRiskCat to the more than 1300 different nanoproducts that we have identified to be available on the European marked and which we have recorded in the European nanoproduct database available at http://www.nanodb.dk. The human and environmental exposure potential was found to be high (i.e., red) for many of the products due to direct application on skin and subsequent environmental release. In the NanoRiskCat evaluation, many of the nanomaterials achieve a red human and environmental hazard profile as there is compelling in vivo evidence to associate them with irreversible effects, e.g., carcinogenicity, respiratory, and cardiovascular effects, etc., in laboratory animals. A significant strength of NanoRiskCat is that it can be used even in cases where lack of data is prominent such as in the case of nanomaterials and we strongly believe that our approach can be used in other areas of risk as well for the evaluation of the relative merits of various options for managing risk and understanding aspects of sustainability in complex, real-world situations.

Hot asphalt recycling using rejuvenators

Presentation theme: “From black roads today – to greener roads tomorrow”

Mingaudas Kalvaitis[1]

1: DTU Transport, FH Erfurt Civil Engineering, VGTU Civil Engineer (roads)

Millions tons of old asphalt are being thrown away all around the world. Asphalt recycling benefits the environment in many ways. In particular, it reduces quarrying, mining and oil consumption. The practice of incorporating reclaimed asphalt pavement into hot mix asphalt are slowly gaining speed all around the word. Concrete asphalt is made from aggregates combined with binder – usually bitumen. During years bitumen get aged and of the particles – maltenes get lost from the asphalt. This is the place, where rejuvenators could be the most useful. It resets the balance of maltenes and asphaltenes. Recent research shows that by improving quality of rejuvenators, more reclaimed asphalt pavement can be used when constructing or repairing roads. This has huge effect to the environment. Stocking piles of asphalt can affect ground water. So the faster it is possible to get rid of the reclaimed asphalt – the better for environment. Also it is very important to save our natural resources. It is crucial to reduce the consumption of virgin aggregates and oil. Increased use of reclaimed asphalt and rejuvenators would save the materials and also reduce the cost. In this research I am focusing on performance of AC 16 BN pavement. Virgin materials are mixed with the reclaimed asphalt pavement (from 20 to 100%) simulating hot-in-plant recycling technology. Various aggregates temperatures are selected and different rejuvenators with different proportions are used. Asphalt and bitumen performance are measured by making standard tests. Research shows that by selecting optimal temperatures and appropriate rejuvenator it is possible to use high amounts of reclaimed asphalt and reach the optimal performance.

Pictures (from personal archive)

Picture 1. Rejuvenators

Picture 2. Asphalt specimens

Bibliography

Huang, S.-C. et al., 2014. Ageing characteristics of RAP binder blends – what types of RAP binders are suitable for multiple recycling? *Road Materials and Pavement Design*, 15(sup1), pp.113–145. Available at: http://www.tandfonline.com/doi/abs/10.1080/14680629.2014.926625 [Accessed November 14, 2014].

Mogawer, W. et al., 2012. Performance characteristics of plant produced high RAP mixtures. *Road Materials and Pavement Design*, 13(sup1), pp.183–208. Available at: http://www.tandfonline.com/doi/abs/10.1080/14680629.2012.657070 [Accessed November 14, 2014].

Moghadas Nejad, F. et al., 2014. Rutting performance prediction of warm mix asphalt containing reclaimed asphalt pavements. *Road Materials and Pavement Design*, 15(1), pp.207–219. Available at: http://www.tandfonline.com/doi/abs/10.1080/14680629.2013.868820 [Accessed November 14, 2014].

Sias Daniel, J. et al., 2013. Effect of long-term ageing on RAP mixtures: laboratory evaluation of plant-produced mixtures. *Road Materials and Pavement Design*, 14(sup2), pp.173–192. Available at: http://www.tandfonline.com/doi/abs/10.1080/14680629.2013.812840 [Accessed November 14, 2014].

Vargas-Nordcbeck, A. & Timm, D.H., 2012. Rutting characterization of warm mix asphalt and high RAP mixtures. *Road Materials and Pavement Design*, 13(sup1), pp.1–20. Available at: http://www.tandfonline.com/doi/abs/10.1080/14680629.2012.657042 [Accessed November 14, 2014].

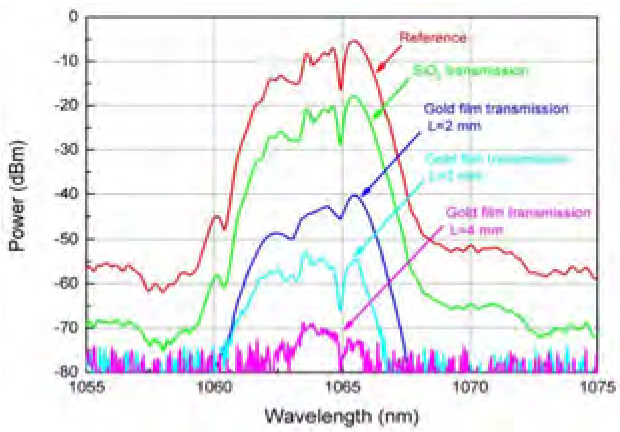
Nanoplasmonic solution for nonlinear optics

M. Bache, A. Lavrinenko, O. Lysenko*, R. Malureanu
DTU Fotonik
*Corresponding author email: ollyse@fotonik.dtu.dk

Nonlinear optical properties of dielectric waveguides are well known and are widely used in modern telecommunication systems [1]. However, the fundamental law of diffraction imposes physical limitation for integration of dielectric photonics and semiconductor electronics [2]. A possible way to combine the high speed of a photonic device with the compact size of an electronic device is to produce a nanoplasmonic device based on metal waveguides. The successful solutions can be used for future sustainable technologies. In meantime, nonlinear optics of metal waveguides is not fully understood and is being under investigation in recent years [3].

The purpose of our research is to study nonlinear optical properties of gold waveguides embedded into dielectric medium (silicon dioxide) using picosecond laser spectroscopy. The work includes modeling of optical properties of gold waveguides, fabrication of prototype samples, and optical characterization of samples using a picosecond laser source.

The prototype samples of gold waveguides embedded into silicon dioxide were fabricated at DTU Danchip. A silicon wafer with pre-made 6.5 µm layer of silicon dioxide was used as a substrate and gold waveguides (films) with the thickness of 35 nm were deposited using the sputter-system (Lesker). The waveguides have different width in the range of 1 µm to 100 µm. A cladding layer of silicon dioxide of about 5 µm was deposited on top of the gold waveguides using the plasma-enhanced chemical vapor deposition (PECVD) method. The quality of samples was inspected using the optical microscope, scanning electron microscope, atomic force microscope, and ellipsometer. The ready wafer was diced into several rectangular sliced with the fixed width of 15 mm and the different length from 2 mm to 6 mm for optical characterization in the laboratory.



Picture 1. Transmission spectra measurements

The samples were characterized using the picosecond laser source (NKT Photonics) with the peak wavelength of 1064 nm. The relevant spectra are shown on picture 1. The red curve corresponds to the reference measurement of the laser spectrum. The green curve is the transmission spectrum for the silicon dioxide cladding. The blue, cyan and magenta curves correspond to the transmission spectra for the gold waveguides with the width of 10 µm and length of 2, 3, and 4 mm. The polarization of laser beam was tuned to match the transverse magnetic mode of surface plasmon polaritons in the gold waveguides.

The propagation loss per unit length and coupling loss for the gold waveguides were calculated. The average propagation loss was 14 dB/mm and the average coupling loss was 6 dB. The obtained results showed a capability of the prototype samples to guide surface plasmon polaritons and their potential for the further investigation of nonlinear properties.

References

[1] G. Agrawal, “Nonlinear fiber optics”, fifth edition, Academic Press (2013).
[2] M. Brongersma, V. Shalaev, “The case for plasmonics”, Science, 328, 440 (2010).
[3] M. Kauranen, A. Zayats, “Nonlinear plasmonics”, Nature Photonics, 6, 373 (2012).

Architectural Design in Arctic Regions
Issue of wind-driven snow in a built environment for sustainable urban planning

Jennifer Fiebig, M.A. Architecture, Research Assistent*[1], H.Holger Koss Associate Professor[2]

1: DTU Civil Engineering; 2: DTU Byg Arctic Technology Center

*Corresponding author email: jenfi@byg.dtu.dk

Figure: Sisimiut, Greenland, Jennifer Fiebig, April 2014

The extreme climate is a growing problem caused by climate change in many parts of the world. Research in Arctic regions offer a great potential for adaptation for other extreme climates. The issue of snow drift and accumulation in north European and arctic regions exists since the first human settlements in this areas. The need to adapt to the extreme climatic conditions lead to specific traditions of construction forms and development concepts utilizing the available resources. Focuses of the research will be the relation between the architectural design of buildings as individual units or as arrangement in an urban grid and the dominating climatic boundary conditions of snow and wind in arctic regions. Especially the accumulation of wind-driven snow on building roofs and on the ground around and between buildings has caused damages of roof structures and blockage of accumulation in arctic urban roads. Densification of urban areas in snow prone regions of extreme climates imposes another problem on the city infrastructure functionality. Climate change also affects the usage of the urban realm in nordic cities. The densification of urban area allows rethinking the potential of communal space for city life and human comfort. Increasing temperatures in summer season give the incentive for human activities as known from more temperate climate zones. Such activities can be supported by enhancing the urban microclimate though sheltering measures. These shelters might in winter season increase the issue of snow accumulation. City planning in arctic regions faces the challenge to accommodate for snow drift and accumulation during winter season and sheltering in summer season.

´…, the most important principle is to integrate, rather than isolate, people with their environment. Living with winter not spite of it should be the planner's motto`(N.E.P. Pressman)[1]

---

[1] SUSTAINABLE WINTER CITIES: FUTURE DIRECTIONS FOR, PLANNING, POLICY AND DESIGN, NORMAN E.P.PRESSMAN, Urban & Regional Planning, Faculty of Environment Studies, University of Waterloo, Waterloo, Canada, Atmospheric Environment, 1996

Sustainable packaging: from eco-efficiency to eco-effectiveness

Monia Niero[1]*, Simon H. Boas[2], Stig I. Olsen[1]

1: DTU Management; 2: Carlsberg Breweries A/S

*Corresponding author email: monni@dtu.dk

According to Verghese et al (2012) sustainable packaging should be: effective in delivering its functional requirements, efficient in its use of materials, energy, and water throughout its life cycle, cyclic in its use of renewable materials and recoverability at end-of-life, and safe for people and the natural environment.

Companies in the packaging sector have traditionally been using the Life Cycle Assessment (LCA) methodology to fulfill these requirements. However, being inspired by the eco-efficiency principle, LCA aims to reduce the negative environmental footprint of human activities by optimizing product system individually, without considering multiple future uses of resources in continuous loops.

A broader approach oriented towards product quality and innovation is the Cradle to Cradle® (C2C) design framework. C2C aims to increase the positive footprint of products by designing "eco-effective" solutions, i.e. maximizing the benefit to ecological systems. C2C is based on three key principles "waste equal food", "use solar energy income" and "celebrate diversity" (McDonough and Braungart, 2002). The first principle calls for eliminating the concept of waste by designing systems where waste and emissions can be taken up as nutrients by other processes instead of reducing the amount of waste as eco-efficiency advocates.

From a company point of view, LCA and C2C are complementary approaches to develop sustainable and innovative solutions for packaging, see Figure 1. We will illustrate the challenges and opportunities emerging from the case study of Carlsberg Circular Community, a cooperation platform where Carlsberg (http://www.carlsberggroup.com/investor/news/Pages/Carlsbergjoinsforceswithsupplierstoeliminatewastebydevelopingnextgenerationofpackagingforhigh-quality%E2%80%98upcycling%E2%80%99.aspx) and some global partners are joining forces to reduce the reliance on raw materials, involving consumers and customers, and creating new types of cooperation among partners to generate resource effective products.

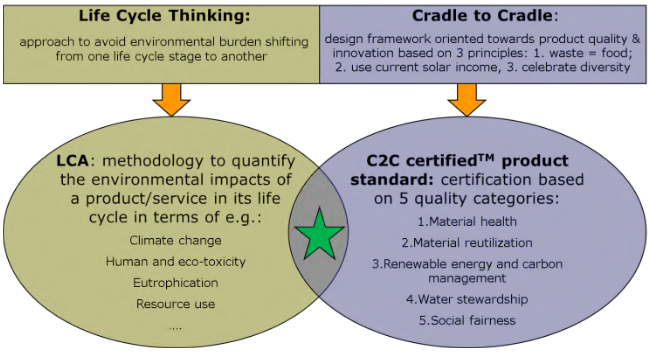


Figure 1. Possible integration between LCA and C2C.

References:
McDonough W., Braungart M. (2002) Cradle to cradle—Remaking the way we make things. New York, NY, USA: North Point Press.
Verghese K, Lewis H, Fitzpatrick L (2012) Packaging for Sustainability. Springer-Verlag London Limited.

Tunable exchange bias effect in $BiGdFeTiO_3$ mutlferroic nanoparticles

Duc-The Ngo[1,2,*], Mohammed Abdul Basith[3], Quang-Hung Tran[1,4], and Kristian Mølhave[1]

1: DTU Nanotech; 2: DTU Energy Conversion; 3: Bangladesh University of Engineering and Technology (Bangladesh); 4: DTU Food

*Corresponding author email: dngo@dtu.dk

Multiferroic materials show coexistence of ferroelectric and magnetic ordering. They exhibit unusual physical properties owing to the coupling between their ferroic orderings. The coupling between magnetic and ferroelectric orderings in multiferroics, which causes novel composite properties, is known as magnetoelectric coupling. Due to the composite properties of magnetic and ferroelectric orders, multiferroic materials are highly attractive for a wide range of applications such as magnetoelectric memory, sensing, and energy conversion.[1,2] Particularly, multiferroic materials would bring a revolution in environmental-friendly magnetic refrigeration technology by exploiting the electrical-field-assisted control of magnetism.[3]

We have prepared mutltiferroic nanoparticles of $BiGdFeTiO_3$ by simply ultrasonicating the powder of bulk ceramics in isopropanol.[4] The obtained materials after sonication consist of ultrafine monodisperse single-crystalline nanoparticles and show enhanced ferromagnetism at room temperature. Especially, by cooling the nanoparticles in magnetic field, exchange bias effect, which is manifested by the shift of the magnetic hysteresis loop along the applied field [Fig.1(c)] due to the exchange coupling between antiferromagnetism and ferromagnetism, has been established and appears to vary with the cooling field and the temperature. This finding is very crucial for application of multiferroic nanoparticle in spin-electronic technology, and clean-tech energy conversion.

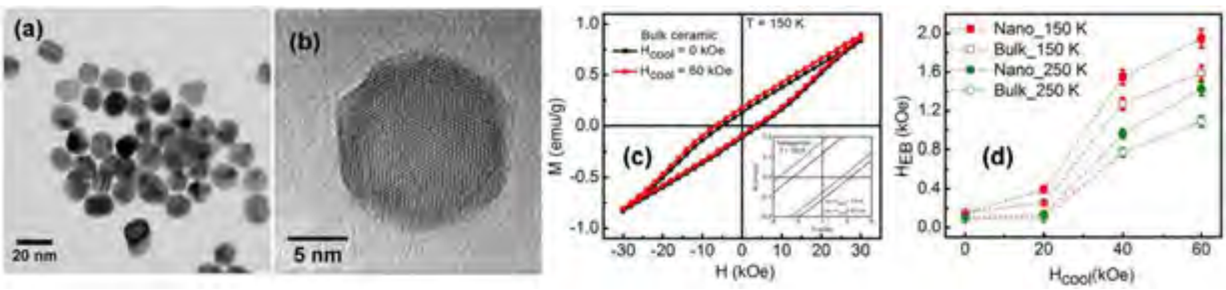


Fig. 1. (a,b) TEM and HRTEM images of $BiGdFeTiO_3$ multiferroic nanoparticles, and (c) exchange bias effect measured at low temperature, and (d) the exchange bias field varies with the cooling field.

References

[1] H. Schmid, Multi-ferroic magnetoelectrics, *Ferroelectrics* **162,** 317–338 (1994).
[2] S. H. Baek*et al.*, *Nat. Mater.* **9**, 309–14 (2010).
[3] J. Ma *etal.*, *Adv. Mater.* **23**, 1062 (2011).
[4] M. Basith *et al.*, *Nanoscale* **6**, 14336 (2014).

Abstract

Development of Graphene-based novel cathode material in MES system

Leifeng Chen, Nabin Aryal, Fariza Ammam, Pier-Luc Tremblay, Tian Zhang*,

The Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark, Hørsholm, Denmark.

Corresponding author: Tian Zhang, Zhang@biosustain.atu.dk.

It has been reported that physical contact between unique nanostructures of electrode and bacteria is important for microbial electrosynthesis. The higher specific surface area of cathode can increase contact interface area with bacteria and enhance electron-exchange at the electrode surface.

The graphene (GP) has outstanding electrical conductivity, extremely high specific surface area, mechanical robustness and flexibility, chemical inertness, and biocompatibility. These special properties of GP can provide excellent opportunity to improve the performance of MES. Gram negative microorganisms like Sporomusa ovata (S.O) typically have a negative outer-surface charge. The graphene oxide (GO) is the acceptor of the electron. If the GO accept electrons from the Sporomusa ovata and the GO can be reduced to graphene. This will lead to in situ construction of a bacteria/graphene network in the cathode. This enable the incorporation of a large amounts bacteria into the biofilm matrix, and form multiplexed conductive pathways, thus facilitating electron exchange between bacteria and electrode. The images of GO, the R-GO, can be characterized and analyzed by SEM or AFM. We can also use the methods of XRD, XPS and Raman Spectrum to character the GO and R-GO. The density of the Sporomusa ovate on the R-GO cathode can be charactered by the confocal laser-scanning fuorescence microscopyer. Acetate is measured via high performance liquid chromatography (HPLC).The images of R-GO/Sporomusa ovate can be characterized and analyzed by SEM or AFM.

Thanks to the high surface area for graphene, superior conductivity, biocompatibility, the incorporation of the large amount bacteria into the biofilm matrix, and forming multiplexed conductive pathways, so the hybrid biofilm can facilitate electron exchange between bacteria and electrode. It will be expected that R-GO can improve microbe–electrode electron exchange and can effectively enhance microbial electrosynthesis rates.

References

1 Y.C.Yong, Y.Y. Yu, X.H. Zhang, and H. Song, Angew. Chem. Int. Ed. 2014, 53, 1.

2 T.Zhang, H.R. Nie, T. S. Bain, Energy Environ. Sci., 2013, 6, 217.

3 Y.Z. Zhang, G.Q. Moa, X.W. Li, Journal of Power Sources 196 (2011) 5402.

4 Y. Yuan, S.G. Zhou, B. Zhao, Bioresource Technology 116 (2012) 453.

Track 4
Poster
Presentations

See schedule on
www.sustain.dtu.dk

In-situ Liquid Electron Microscopy Setups for Investigation of Nanoscale Electrochemistry

Eric Jensen[*1], *Rolf E. R. Møller-Nilsen*[1], *Silvia Canepa*[1], *Simone Laganá*[1], *Kristian Mølhave*[1]
[1]*DTU Nanotech, Ørsteds Plads, Building 345B, 2800 Kongens Lyngby*
**mailto: eric.jensen@nanotech.dtu.dk*

Recently there has been an explosion in the number of systems available for in-situ liquid-phase electron microscopy(1). These systems separate the liquid from the vacuum and allow for nanoscale imaging as well as electrical contact. Such systems are important for the further development of nanotoxicological studies, battery research and catalysis.
Here we present two unique systems for in-situ electron microscopy. The first system is a monolithic chip for Transmission Electron Microscopy(2)(Figure 1a). The proof-of-concept system verified the ability to separate the liquid from the vacuum while imaging. Current manufacturing will include lower liquid volume and electrical contact.
The second system is a peek holder with a microfabricated chip which allows for full electrochemical characterization in the Scanning Electron Microscope(3)(Figure 1b). The system has been used for in-situ electrochemistry and has achieved ~10 nm resolution.
Such systems are important tools for developing sustainable technology and for understanding nanoscale phenomena. However, both systems suffer from interacting with the electron beam, which is a high-voltage radiation source, and therefore initial experiments will necessarily have multiple reference experiments to ensure results can be made with negligible influence by the electron beam interaction.

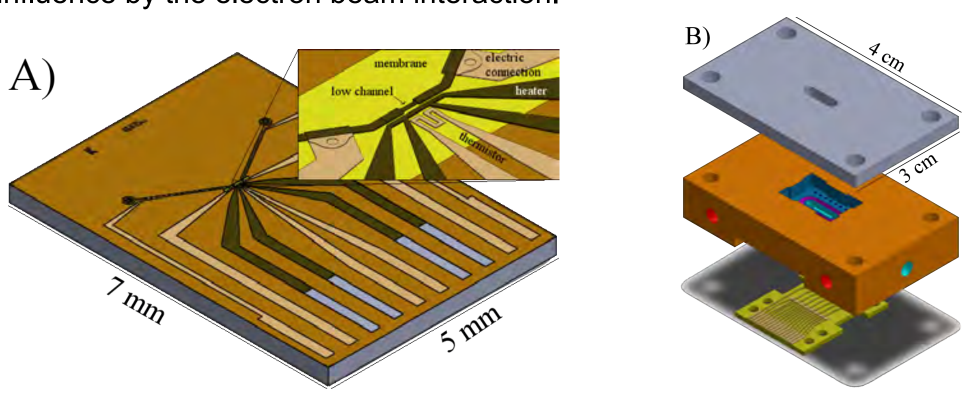


Figure 1: A shows the TEM chip with 10 leads. On the center of the chip is a 50 nm thick membrane with various components. B shows the EC-SEM setup with the lid at the top, holder in the middle and electrical connection from the below.

References

1. Ross, F. M. & de Jonge, N. Electron microscopy of specimens in liquid. *Nat. Nanotechnol.* **6,** 695–704 (2011).
2. Jensen, E., Burrows, A. & Mølhave, K. Monolithic chip system with a microfluidic channel for in situ electron microscopy of liquids. *Microsc. Microanal.* **20,** 445–451 (2014).
3. Jensen, E., Købler, C., Jensen, P. S. & Mølhave, K. In-situ SEM microchip setup for electrochemical experiments with water based solutions. *Ultramicroscopy* **129,** 63–69 (2013).

Towards Safer Nanomaterials

Rune Hjorth* and Anders Baun

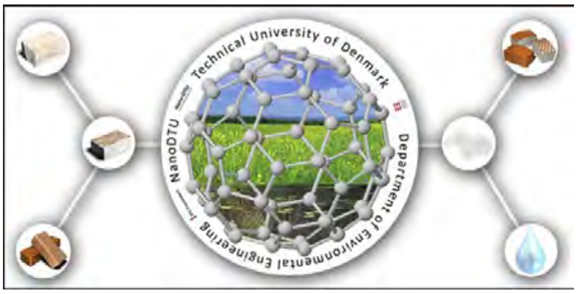
DTU Environment

*Corresponding author email: ruhj@env.dtu.dk

As nanomaterials become more widespread in everything from industrial processes to consumer products, concerns about human and environmental safety are being taken increasingly more seriously. In our research we are working with minimizing the impact and risks of engineered nanomaterials by looking into how the design of nanomaterials can be optimized to minimize their toxicity while still preserving their beneficial or wanted properties.

Current efforts in this field are focusing on identifying design rules or parameters that can be adjusted to obtain a risk reduction, either by reducing the hazard or the exposure and optimally both. Examples include the 5 SAFER principles (Morose, 2010) or screenings of early warning signs (Hansen et al., 2013). Taking the full life cycle of nanomaterials into account, the principles of Green chemistry and Green engineering could also prove useful to reduce the environmental impact of nanomaterials (Eckelman et al., 2008).

Our research interests include the feasibility of "safer-by-design" approaches, the production of greener nanomaterials and operationalization, adaption and creation of frameworks to facilitate safety engineering. Research and insight in these topics will provide technology developers, regulators and other stakeholders with relevant information needed to ensure the sustainable development of nanotechnologies.



References

Eckelman, M.J., Zimmerman, J.B. & Anastas, P.T. (2008). Toward Green Nano. *Journal of Industrial Ecology*. 12 (3). p.pp. 316–328.

Hansen, S.F., Nielsen, K.N., Knudsen, N., Grieger, K.D. & Baun, A. (2013). Operationalization and application of "early warning signs" to screen nanomaterials for harmful properties. *Environmental Science: Processes & Impacts*. 15 (1). p.p. 190.

Morose, G. (2010). The 5 principles of "Design for Safer Nanotechnology." *Journal of Cleaner Production*. 18 (3). p.pp. 285–289.

What Happened when a Superhydrophobic Surface was Immersed in Water? A Study by Optical Transmission Microscopy

Emil Søgaard[1], Nis K. Andersen[1], Kristian Smistrup[2], Simon T. Larsen[1], Ling Sun[1]*, and Rafael Taboryski[1]*

[1] Department of Micro- and Nanotechnology, Technical University of Denmark, 2800 Kongens Lyngby, Denmark

[2] NIL Technology, Diplomvej 381, 2800 Kongens Lyngby, Denmark

* to whom correspondence should be addressed, rata@nanotech.dtu.dk; lisu@nanotech.dtu.dk

Here we present a simple and fast optical transmission microscopy study on the wetting transitions on hierarchical polymer surfaces immersed in water. We analyze the influence of immersion time and the liquid pressure on wetting states of individual micro-cavities on these surfaces, as well as the lifespan of their superhydrophobicity. We show that transitions between the three wetting states (Cassie, Cassie-impregnating, and Wenzel) occur at a certain pressure threshold. Below this threshold, the transitions between the Cassie and the Cassie-impregnating states are reversible, while above the threshold, irreversible transitions to the Wenzel state start to occur. The transitions between the different wetting states can be explained by taking into account both the Young-Laplace equation for the water menisci in the cavities and the diffusion of dissolved gas molecules in the water. In addition, the wetting transitions had a stochastic nature, which may result from the diffusion of dissolved gas molecules in the water between neighboring cavities. Further, we compared the contact angle properties of two polymeric materials (COC and PP) with moderate hydrophobicity. We attributed the different water repellent properties of the two materials to a difference in the wetting of their nanostructures. The experimental observations indicate that both the diffusion of gas molecules in water, and the geometry of nanostructures influence the sustainability of superhydrophobicity of surfaces under water, understanding these factors can help improve the structural design of superhydrophobic surfaces.

ZeroWaste BYG: Redesigning construction materials towards zero waste society

Gunvor M. Kirkelund, Jakob W. Schmidt, Lisbeth M. Ottosen*, Pernille E. Jensen, Per Goltermann, Anja M. Bache, Carsten Rode, Pawel Wargocki, Jakub Kolarik, Ruut H. Peuhkuri , Annemette Kappel, Barbora Krejcirikova, Wan Chen: DTU BYG

*Corresponding author email: lo@byg.dtu.dk

The ZeroWaste research group (www.zerowaste.byg.dtu.dk) at the Department of Civil Engineering was established in 2012 and covers the broad range of expertise required for turning waste materials into attractive, new materials. Members of the group have developed methods for removal of heavy metals and phosphorous from waste incineration, sewage sludge and other bio ashes [1], providing the basis to make these ash types an attractive, new material for the building sector.

The amount of waste increases and it is both difficult and expensive to handle many waste types as e.g. different ashes. At the same time there are fewer natural resources and the general consumption increases. We wish to utilize alternative and new ash types as raw material in concrete, similarly to what was previously seen with fly ash from coal combustion and microsilica, which were both transformed from problematic waste to valuable raw material. The physical-chemical characteristics of fly ash, such as large uniformity coefficient, clay-sized particles and rich in some metal elements and salts, show the possibility of being a raw material also for bricks and lightweight aggregates. In the future we expect increasing political pressure to change the status of different ashes from waste to raw material and that export for disposal will be no longer be allowed. We wish to influence the consequences from this new situation. In principle some of the ashes can be used already, but the huge variation in ash characteristics and lack of knowledge in the construction industry on the qualities some of the ashes can give the concrete and clay materials means that they are not used today.

Link to ZeroWaste BYGs current Ph.D. projects:

http://orbit.dtu.dk/en/projects/alternative-asker-i-beton--ny-aestetisk-og-byggeteknisk-performance%28a891f626-2328-493d-9aca-e1dfd08da97a%29.html

http://orbit.dtu.dk/en/projects/electrochemical-upgrading-of-different-fly-ases-for-use-in-production-of-bricks-and-leightweight-aggregates%284ed33047-0ffc-4f85-8e18-07ed7793fcad%29.html

http://orbit.dtu.dk/en/projects/hygrothermal-conditions-and-pollutant-emissions-from-zero-waste-materials-and-their-effects-on-humans%288a448dcc-6b25-4af2-90fc-333366d219a3%29.html

[1] Ottosen L.M, Jensen P.E., Kirkelund G.M., Ebbers B.: Electrodialytic recovery and purification of phosphorous from sewage sludge ash, sewage sludge and wastewater, PCT/EP2014/068956

SYNTHETIC BIOLOGY TOOLS FOR THE MEMBRANE – TARGETED LOCALISATION AND ELUCIDATION OF PROTEIN INTERACTIONS

Wendel, Sofie[1]; Seppala, Susanna[1]; Nørholm, Morten*[1]

1: DTU Biosustain

*Corresponding author email: morno@biosustain.dtu.dk

To meet the need for new, green production scenarios, development of biological cell factories is becoming increasingly important. In order for cell factories to compete with traditional production means, it is essential to expand the available toolbox. We are developing tools for the E. coli cell factory, focusing on the membranes. Surface displaying enzymes may allow for development of whole-cell catalysts, but a recurring issue with the technique is to know that a protein is indeed surface displayed, and not detected due to lysis of cells or secretion. We are developing a fluorescence-based method for easy detection of surface display using GFP-nanobodies (1). We fused a GFP-nanobody to the E. coli outer membrane anchor LppOmpA, resulting in surface display of the nanobody. Addition of free GFP to the whole cells resulted in binding of GFP to the cells via the nanobody, as shown by fluorescence measurements, in-gel fluorescence and microscopy (fig. 1). We are now further expanding the toolbox for use in surface display applications. In addition, to expand our knowledge of protein interactions and protein complex formation in the membrane, we are exploring the use of styrene maleic acid (SMA) for isolation of membrane proteins. SMA is a polymer which spontaneously digs into a lipid membrane and carves out a disc containing protein and native lipids (2). By elucidating protein interactions we will be able to tune and optimise heterologous pathway expression in our E. coli cell factories.

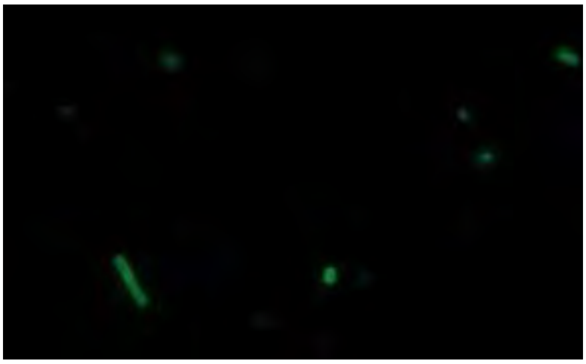


Fig. 1. Nanobody displaying cells biding GFP.

References:

1) Kirchhofer & al. Nat Struct Mol Biol, 2010, 17:133

2) Jamshad & al. Biochem Soc Trans. 2011 39:813

Efficient fabrication of micro- and nano-systems

Karen Birkelund, Jesper Hanberg, Anders M. Jorgensen*, Jörg Hübner

DTU Danchip

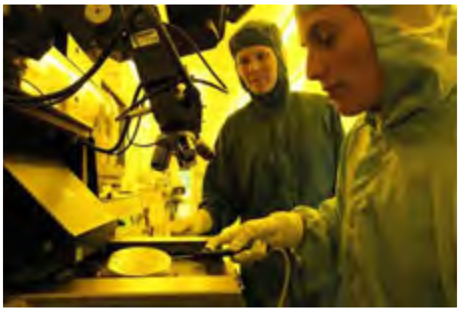
*Corresponding author email: ajoe@danchip.dtu.dk

There is an increasing demand for a more sustainable society where unnecessary use of the Worlds energy resources is avoided. Micro- and nano-fabricated sensors and actuators are in that sense desirable in many applications for power saving purposes, minimization of chemical consumption, rapid analyzing of e.g. waste water before it is lead out in our lakes and oceans or as sensors notifying when maintenance is required in due time before breakdown.

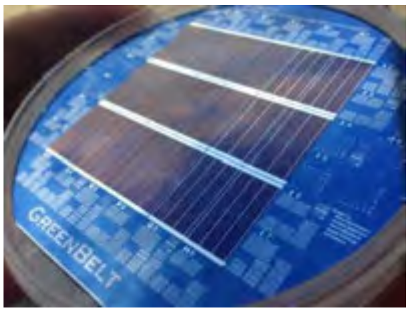
More and more of these sensors are also made self-sufficient of power by harvesting the energy from e.g. the sun, thermal excess energy, environmental vibrations or human motion, which means that they can be placed for monitoring on sites that are otherwise unreachable with no further powering and communicate with the outside world through wireless communications.

There is no doubt that the use of micro- and nano-devices for sustainability has come to stay and will further develop in the future. In Danchips clean room facilities realization of micro- and nano-devices are possible. It is of most importance that they are carefully designed and modelled before initiating the fabrication itself in order to keep the number of iterations at a low level as well as minimizing the consumption of materials, etchants and process time. Danchip excels in optimizing micro- and nanofabrication in order to simplify processes, minimize cost and at the same time maximize yield. Danchips team of process generalists is ready to guide you through your design and planning phase as well as to help you realizing your micro- and nano-devices in our clean room facilities.

Danchips team of process specialists will help you with developing and optimizing new fabrication processes so you can reach your goals most efficiently. Our dedicated technical staff supports the infrastructure and keeps the facilities up and running so you can focus on your research and not the equipment.



A training situation at Danchip



A processed Si wafer with solar cells.

Study of Grain Growth of CZTS Nanoparticles Annealed in Sulfur Atmosphere

Sara Engberg*[1], Andrea Crovetto[2], Ole Hansen[2], Jørgen Schou[1]

1: DTU Fotonik; 2: DTU Nanotech

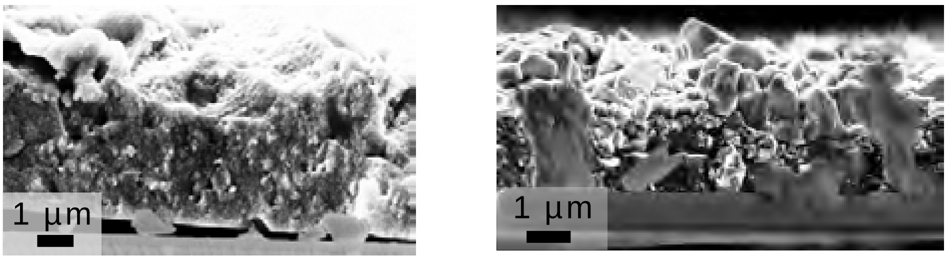
*Corresponding author email: sleen@fotonik.dtu.dk

The kesterite material, $Cu_2ZnSn(S_xSe_{1-x})_4$ (CZTS), is very promising as absorber material in future thin film solar cells. The elements are abundant, the material has a high absorption coefficient, and the pure sulfide CZTS is non-toxic. These properties make CZTS a potential candidate also for large-scale applications. Here, solution processing allows for comparatively fast and inexpensive fabrication and solution processing also holds the record efficiency in the kesterite family, however for the selenized compound. The current challenges are, (1) that the high carbon content in nanoparticle thin films is one of the main limitations for this approach, and (2) that grain boundaries and defects are believed to be a site for recombination that limits the efficiency. Annealing in vacuum and/or a nitrogen atmosphere facilitates grain growth and improves the electronic properties. Conventionally selenization (annealing in selenium) shows the best results, however sulfurization (annealing in sulfur) has the advantage of leading to a non-toxic material.

In this work, nanocrystals of CZTS with a targeted Cu-poor/Zn-rich composition are synthesized through a hot-injection method with oleylamine as the solvent. The nanocrystal inks are deposited through doctor blading in octanethiol, and annealed in a vacuum furnace using a graphite box with sulfur. The surface morphology and thus grain growth are studied for various annealing conditions in a 10-mbar nitrogen atmosphere with a varying amount of sulfur.

The films are characterized with scanning electron microscopy (SEM), and an example before and after annealing is displayed in Fig. 1 (a) and (b), respectively. Compositional changes are monitored by energy dispersive X-ray spectroscopy (EDX) and the crystallinity by X-ray diffraction (XRD).

A photovoltaic device of the structure soda lime glass (SLG)/Mo/CZTSSe/CdS/ZnO:Al/Ag has been built, and our preliminary results show a power conversion efficiency of 1.41% for the nanoparticles annealed in selenium.



(a) (b)

Fig. 1 (a) SEM image of cross-section of doctor bladed CZTS film after pre-annealing at 200˚C. (b) SEM image of cross-section of CZTS film after annealing at 500˚C, where grain growth is visible.

Microfabrication of Polymer Components

Claus H. Nielsen[*1], Anders M. Jørgensen[1],

1: DTU Danchip

*Corresponding author email: choi@danchip.dtu.dk

The integration of micro- and nanostructures into polymers is gaining interest to drive forward miniature-zation and tailoring of physical properties. Examples of applications are microfluidic systems, self-cleaning surfaces, cell sorting systems and structural colors. These applications bring along the potential to minimize use of chemicals, manipulate cells individually, and produce colored samples without dyes.

Polymer processing brings both integration of micro- and nanotechnology and sustainability to products. Micro- and nanostructures can be replicated using well established techniques such as injection moulding, resulting in very high throughputs, also with sustainable polymers such as PLA, poly(lactic acid).

DTU Danchip supports the development and production of micro- and nanostructured polymers from the initial design phase over master fabrication in our cleanroom facilities to pilot production of polymer components via injection moulding. Almost any structure ranging from nano- to centimeter scale can be realized. DTU Danchip also offers a wide range of characterization techniques relevant for characterization of micro- and nanostructured polymers, including AFM, SEM, DSC, XPS and hardness testing.

Figure 1 below illustrates a typical process flow in which structures are defined in silicon by either UV, DUV or e-beam lithography and dry etching techniques. An inverse replica is made in nickel by electroplating which can then be used for making multiple copies by e.g. injection moulding:

Figure 1: A typical process flow for making a micro-structured nickel master for injection moulding.

DTU Danchip offers three different standard formats for injection moulding: A standard microscope slide, a flat ø50mm disc and an ø50mm disc with Luer connectors. This enables customers at DTU Danchip to rapidly design and evaluate microsystems in liquid handling systems as well as many other applications.

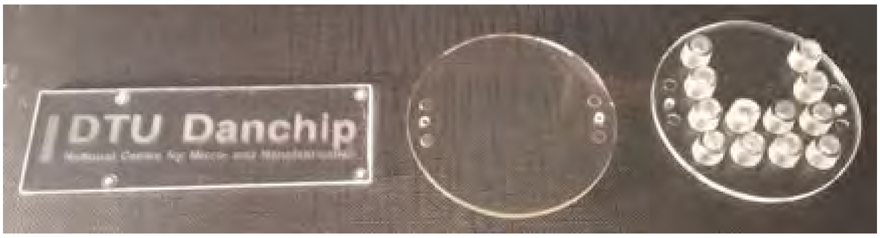


Figure 2: Sample formats available at DTU Danchip: The microscope slide (left), ø50mm flat disc (center) and ø50mm disc with Luer connectors (left).

Microbial electrosynthesis: understanding and strengthening microbe-electrode interactions

Pier-Luc Tremblay*[1], Daniel Höglund[1], Fariza Ammam[1] and Tian Zhang*[1]

1: DTU Biosustain

*Corresponding authors email: pitre@biosustain.dtu.dk, zhang@biosustain.dtu.dk

Powering microbes with electrical energy to produce valuable chemicals such as biofuels has recently gained traction as a biosustainable production strategy for the reduction of our dependence to oil. Microbial electrosynthesis (MES) is one of the few bioelectrochemical approaches developed in the last decade that could significantly change the current ways of synthesizing chemicals. MES is a process in which electroautotrophic microbes reduce CO_2 to multicarbon organics using electrical current as a source of electron. Electricity necessary for MES can be harvested from renewable resources such as solar energy, wind turbine or wastewater treatment processes. The net outcome is that renewable energy get store in the covalent bonds of valuable chemicals synthesized from greenhouse gas. However, low electron transfer rates from the electrode to microbes, poor adherence of cells on the electrode, and a general lack of knowledge about electron transfer mechanisms have been the main obstacles to MES commercialization to date. Developing genetic systems for known electroautotrophs, screening for better MES chassis organisms and superior electrochemical hardware, establishing alternative MES processes relying on co-cultures and investigating extracellular electron transfer from the cathode to the microbes are some of the strategies that we are implementing to transform MES into a commercially viable technology.

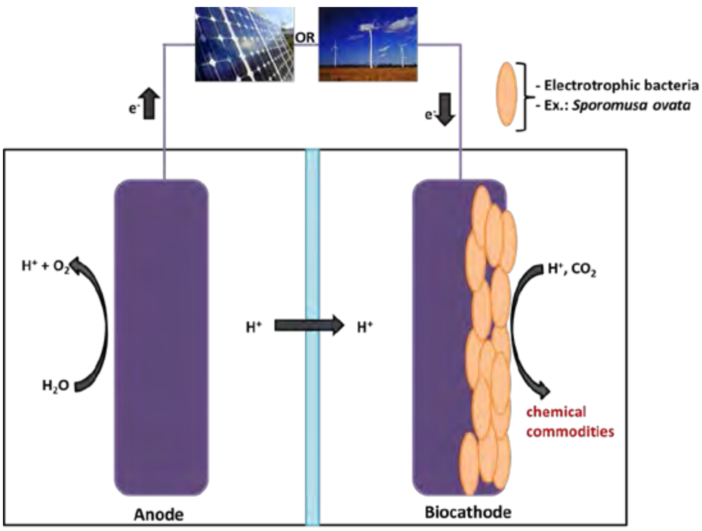


Figure 1: The principle of MES.

Depositing Materials on the Micro- and Nanoscale

Mikkel D. Mar*, Berit Herstrøm, Evgeniy Shkondin, Patama Pholprasit and Flemming Jensen
DTU Danchip
*Corresponding author email: mdyma@danchip.dtu.dk

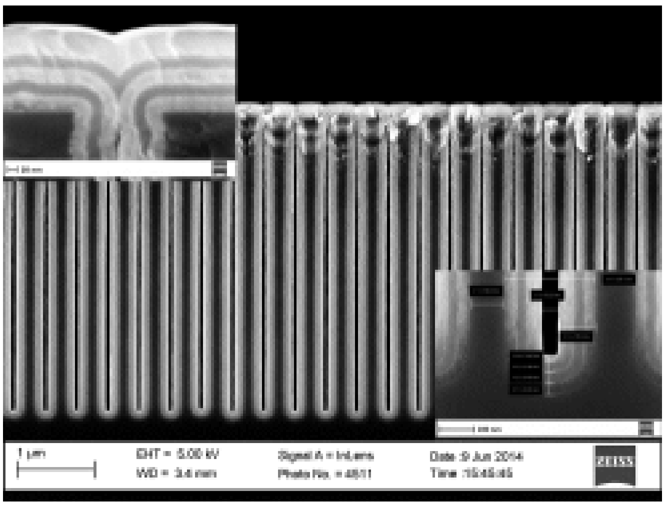
Micro- and nanotechnology systems are important in many sustainable products like solar cells and chemical, mechanical and optical sensors. Keeping the systems small will make a smaller demand for material and energy during production and also a smaller demand for energy during use. In these systems thin films of different kind are important parts of giving the system the properties needed. This can be properties like light absorbing layers, antireflection coatings or conductive layers in solar cells. It can be low stress layers in membranes, chemicals resistant layers in chemical sensors, layers with specific optical properties in optical sensors, piezoelectric thin films or insulating layers in many other applications. These different materials and properties impose a demand for different kind of deposition techniques. At DTU Danchip we have a large variety of these deposition techniques that can be used separately or in combination to give the micro/nano system the properties needed. These techniques and film properties are presented.

- **ALD (Atomic Layer Deposition)** is good for very thin films (down to monolayers) with extremely good step coverage and extremely good control of the layer thickness.
- **LPCVD** (Low Pressure Chemical Deposition) is good for dielectric layers for optical components, light absorbing layers, membranes and cantilevers. The processes take place at high temperature and create high quality films with high step coverage.
- **PECVD** (Plasma Enhanced Chemical Vapor Deposition) is good for fabricating dielectric layers for optical components and insulation layers. The layers are deposited at relative low temperature (300C).
- **Sputter deposition** deposits almost any material (metals and dielectrics including alloys) at low temperature with good step coverage.
- **E-beam evaporation** is good for high quality thin film metal deposition e.g. for electrical leads or surface plasmonic devices.
- **MVD** (Molecular Vapor Deposition) is used for making anti stiction coating.

Below is shown an example of Atomic Layer Deposition which is a self-terminating chemical vapor deposition technique based on sequential introduction of precursor pulses with intermediate purging steps. The process proceeds by specific surface ligand-exchange reactions and this leads to layer-by-layer growth control. No other thin film deposition technique can approach the conformity achieved by ALD on high aspect ratio structures.

The figure shows 4 μm deep Si-trenches with the period of 400 nm, coated with ALD TiO_2/Al_2O_3 multilayers. The insets show high resolution SEM images of top and bottom parts of coating.

This is an example of extremely high conformity deposition of multilayer thin films on high aspect ratio structure.



How does the choice of ILCD's recommended methods change the assessment of environmental impacts in LCA of products?

Mikolaj Owsianiak*[1], Alexis Laurent[1], Anders Bjørn[1], Michael Z. Hauschild[1]

1: DTU Management

*Corresponding author email: miow@dtu.dk

The European Commission has launched a recommended set of characterization methods for application in life cycle impact assessment (LCIA). However, it is not known yet whether the choice of the recommended practice, referred to as the ILCD, over existing LCIA methodologies matter for interpretation of LCA results. Here, we compare the ILCD with two of the most frequently used LCIA methodologies, IMPACT 2002+ and ReCiPe 2008, focusing on characterization at midpoint, by applying them on a case study comparing four window design options. First, to see whether the choice of ILCD matters for identification of product with the lowest environmental burden, ranking of the four window options was done for each impact category within each of the three methodologies. Next, impact scores calculated using each of the three methodologies were converted into common metrics for each impact category to see whether the choice of ILCD matters for total impact scores. Results show that apart from toxic impacts on human health and ecosystems, all three methodologies consistently identify the same window option as having the lowest and the highest total environmental impact. This is mainly because production of heat dominates the total impacts and there is large difference in demand for heat between the compared options. Yet, there were significant differences in impact scores for some of the impact categories after conversion to common metrics: above 3 orders of magnitude for impacts from ionizing radiation on human health and impacts from land use on natural environment; between 1 and 3 orders of magnitude for metal depletion and for toxicity-related impact categories; and within 1 order of magnitude for the remaining impact categories. These differences are caused by the differences in underlying characterization models and/or substance coverage, depending on the impact category. In summary, we showed that different LCIA methods, including the ILCD, are likely to point to the same conclusion with respect to identifying the product with the lowest environmental burden, if one process is driving environmental impacts and there is large difference in demand for output from that process between the compared options. Nevertheless, the choice of ILCD' matters the most for assessment of impacts from ionizing radiation, land use, resource depletion (minerals), and all toxicity-related impact categories, where differences between ILCD and alternative methodologies are large.

Owsianiak, M., Laurent, A., Bjørn, A., Hauschild, M.Z., 2014. IMPACT 2002+, ReCiPe 2008 and ILCD's recommended practice for characterization modelling in life cycle impact assessment: a case study-based comparison. Int. J. Life Cycle Assess. 19, 1007–1021.

Plasmonic Structural Colors for Plastic Consumer Products

Højlund-Nielsen E.[1*], Mortensen N. A.[2], Kristensen A.[1]

1: DTU Nanotech; 2: DTU Fotonik;

*Corresponding author email: emiho@nanotech.dtu.dk

Today colorants, such as pigments or dyes, are used to color plastic-based consumer products, either as base for solid colored bulk polymer or in inks for surface decoration. After usage, the products must be mechanically sorted by color before recycling, limiting any large-scale efficient recycling effort. As an alternative to chemistry-based coloring, nano-scale structural coloring has been proposed to reduce the number of materials needed and to increase pattern resolution. Here colors are created by structural based light-matter interactions in the surface. Thereby, the sorting by color can be avoided in the recycling state. Plasmon color technology based on aluminum has recently been firmly established[1] as a route towards structural coloring of polymeric materials. We report on the fabrication of colors by localized surface plasmon resonances (LSPR) using roll-to-roll printing and demonstrate a route for scalable production and commercial uptake of plasmonic colors.

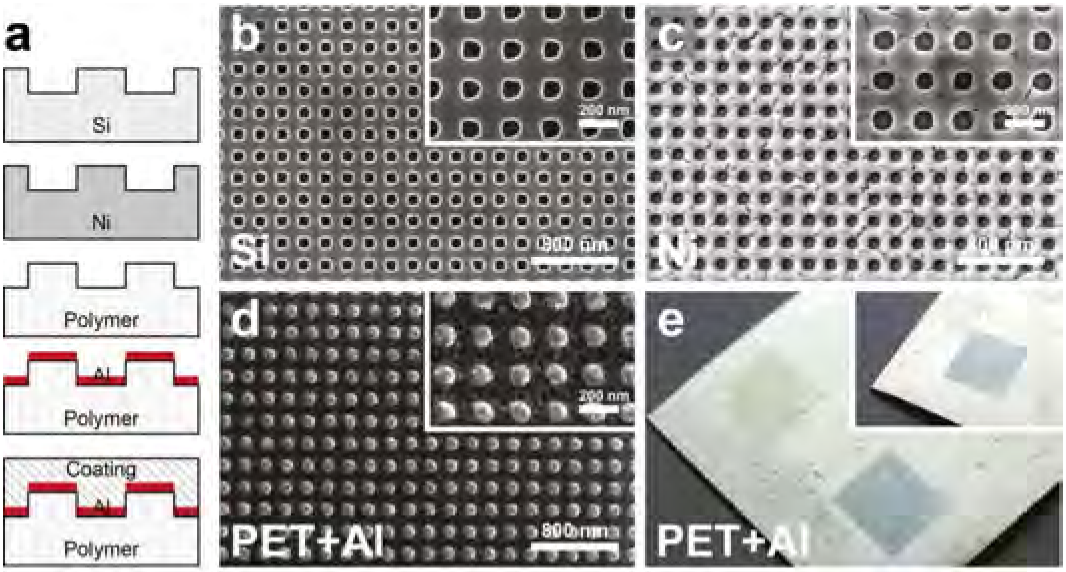


Figure 1: Fabrication process for 200 nm periodic structures from pattern definition to polymer metalized replica (blue area). a) Sketch. b) SEM images of Si master. c) SEM images of nickel master. d) SEM images of roll-to-roll polymer replication with aluminum on top. e) Photographs of the finished A-PET polymer surface without coating for 200 nm period (blue) and 300 nm period (green) areas of size 0.5 mm x 0.5 mm. From Højlund-Nielsen et al, Microelectron. Eng. (submitted).

1: Clausen, J. S., Højlund-Nielsen, E., Christiansen, A. B., Yazdi, S., Grajower, M., Taha, H., … Mortensen, N. A. (2014). Nano Letters, 14(8), 4499–4504. doi:10.1021/nl5014986

The Aesthetical quality of SSA-containing mortar and concrete

Annemette Kappel*, Gunvor M. Kirkelund, Lisbeth M. Ottosen, Anja M. Bache, Per Goltermann

DTU Byg

*Corresponding author email: anmk@byg.dtu.dk

SSA (sewage sludge ash) is resulting ash from the combustion of sewage sludge, and is a method employed at some water treatment plants in order to decrease volume and hygenize the sludge. Today, SSA is with a few exceptions landfilled. As cement production is responsible for app. 5 % of the total global CO_2 emission, the advantage of replacing cement with a secondary resource as SSA is obvious.

The focus of previous conducted research has mainly been on the chemical, mechanical properties and environmental consequences attached to the use of SSA in construction materials.(Cyr et al., 2007) Thus, this present study has focused on both the aesthetical and technical aspects of using SSA as a supplementary cementitious material. The SSA, which was tested, was taken from the wastewater treatment plant Avedøre Spildevandscenter, Biofos sited in the Copenhagen area. This ash had a high content of Fe that gives a characteristic red colour.

The process of grinding SSA has shown to improve the compressive strength of SSA- containing mortar(Donatello et al. 2010). Thus, in this study SSA was grinded in 6 different intervals ranging from 0 – 10 min, and then added to the mortar mix replacing 20% of cement. The experiment revealed that the colour of the SSA-containing mortar intensified as the time interval of the grinding process increased. Each of the 6 steps within the time interval provided an additional colour tone and generated a colour scale consisting of mortar samples ranging from greyish to a more saturated red brown colour.

SSA shows potential for colouring concrete, and if the aesthetical aspects such as colour are taken into account at an early stage, it could challenge a general idea that concrete is a grey, and in some views, a drab material.

Cyr, M., Coutand, M., Clastres, P., 2007. Technological and environmental behavior of sewage sludge ash (SSA) in cement-based materials. Cem. Concr. Res. 37, 1278–1289.

Donatello, S. et al., 2010. Effect of milling and acid washing on the pozzolanic activity of incinerator sewage sludge ash. *Cement and Concrete Composites*, 32(1), pp.54–61.

A compendium of genetic variant data

João G. R. Cardoso[1*], Lars Schöning[1], Markus Herrgård[1], and Nikolaus Sonnenschein[1]

1: The Novo Nordisk Foundation Center for Biosustainability, Technical University of Denmark

*Corresponding author email: joaca@biosustain.dtu.dk

Laboratory strains are genetically unstable if exposed to selective pressure as encountered, for example, during molecular cloning, fermentation, or adaptive laboratory evolution experiments. This genetic variation is the consequence of an adaptation process of the microorganism to stress conditions, e.g., high pressure or temperature, nutrient limitation, or toxic byproduct concentrations. The evolved strains display then new phenotypes: tolerance to a toxic byproduct or higher temperature, improved production rate of a byproduct, or higher uptake rates of nutrients. To understand the effects of those variations, it is necessary to collect and sort this genomic information in an organized fashion, including all relevant physiological data (e.g., growth rate, metabolomics, proteomics, transcriptomics, etc.). We propose a systematic way to collect heterogeneous datasets into a coherent database where the physiological characteristics of mutants can easily be queried. This database contains the experimental information sorted into normalized units. The aim of this repository is to become a golden-standard of genetic variation information for microorganisms, providing standardized data obtained from distinct experiments. This compendium of genetic variant is a critical step to develop approaches to automatically and systematically characterize mutated strains in the future.

Etching patterns on the micro- and nanoscale

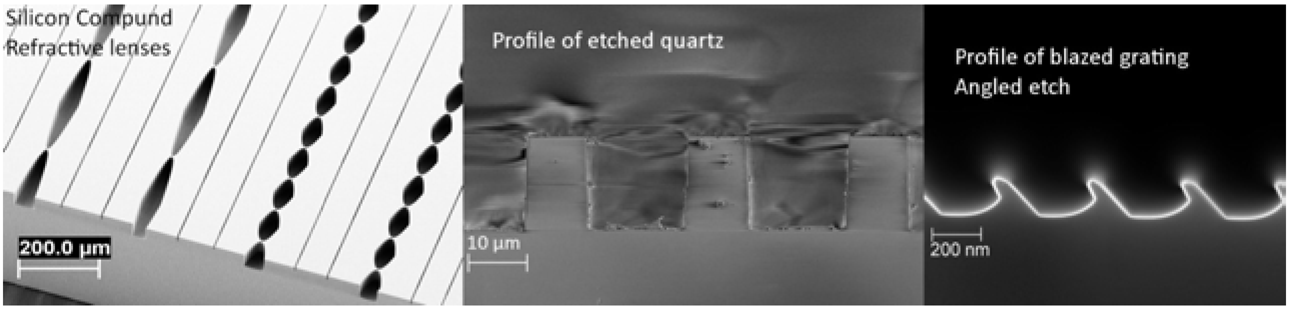
Jonas Michael-Lindhard, Berit Herstrøm, Frederik Stöhr, and Flemming Jensen*

DTU Danchip

*Corresponding author email: fj@danchip.dtu.dk

Dry etching is widely used for realizing micro- and nanostructured devices in various materials. Here, the available dry etching techniques and their capabilities at DTU-Danchip are presented. What sets the dry etching apart from the traditional wet etching in which a chemical agent dissolved in a liquid reacts with material from the substrate is the ability to fine-tune the etch process. In wet processing the removal of material generally occurs indiscriminately of direction in the substrate - hence in all directions. This puts a strong limitation on what may be achieved in terms of designs, materials and depths. With the dry etch tools available in the cleanroom at DTU-Danchip, the etching of a great variety of materials may be tuned very precisely from a purely chemical and isotropic etch to a purely physical and anisotropic etch.

The dry etching of silicon is the most flexible and well-established process that enables the users of our lab to realize devices on any scale in the sub 100 nm to the sub 1 mm range. The silicon compound refractive lenses (see left figure) for focusing hard X-rays from a synchrotron source are examples of etch processes with extreme specifications. In order to focus the X-ray beam down to a spot size of some 100 nm, the sidewalls of the cavities etched down to 300 µm into a silicon wafer must be perfectly straight and normal to the surface and have minimum roughness



The range of possible applications of the silicon etches is greatly extended if combined with electroplating and polymer injection molding. High precision patterns of, for instance microfluidic devices, are etched into silicon which is then electroplated with nickel that will serve as a stamp in the polymer injection molding tool where thousands of devices may be replicated.

In addition to silicon and its derived materials such as oxides, nitrides or quartz, a lot of materials may be dry etched. The list includes III-V materials that possess properties essential to photonic devices and polymers. A large number of metals and metal oxides may also be etched.

In the ion milling tool we can etch basically any material – although at a somewhat limited depth. The ion beam that sputters off material may be tilted and devices such as blazed gratings (see right figure) may be produced.

Pattern Definition with DUV-Lithography at DTU Danchip

Matthias Keil*[1], Elena Khomtchenko[1], Henrik Nyholt[1], Anders Gregersen[1], Leif Steen Johansen[1]

1: DTU Danchip, Ørsteds Plads, Building 347, 2800 Kgs. Lyngby

*Corresponding author email: makei@danchip.dtu.dk

Deep ultra violet (DUV) illumination generated with the help of a KrF laser can be utilized to produce components having sizes of some hundreds of nanometers. This light source with its 248nm wavelength is exploited in the DUV-lithography equipment at DTU Danchip in order to fill the resolution gap between traditional UV-lithography and e-beam lithography. With the help of a DUV stepper, devices with pattern sizes of 250 nm (see in fig. 1) can be produced on a high volume scale, with a throughput of 30 to 90 wafers per hour on 6" or 8" wafers. For R&D purposes also smaller line widths can be printed - as shown in fig. 2 - utilizing the possibility of beam shape variations that enables to adapt the resolution and the depth of focus of the stepper to the requirements of the fabricated device. However, generally the highest achievable resolution is dependent on the pattern type - as e.g. pillar, line or hole comprising patterns -, its symmetry and the separations between the different structures.

The projection lithography tool FPA-3000EX4 from Canon (max. NA=0,6; 1:5 reduction) produces patterns on the wafer within a maximum chip area of 22x22mm^2 that can be stitched together with an accuracy of 3σ=35 nm. Also alignment to already existing patterns on the wafer can be performed with an accuracy of 3σ=50 nm. These pre-made patterns might be defined in the resist with the help of different lithography methods or - alternatively - already be etched in the wafer.

a)

b)

Fig. 1: 250 nm pillars together with other pattern types printed in 1 μm thick resist with an exposure dose of a) 270J/m^2 and b) 290J/m^2.

Fig. 2: Lines and spaces printed in a 390 nm thick resist with an exposure dose of 220J/m^2.

Electron Beam Lithography for nano-patterning

Tine Greibe*[1], Thomas Aarøe Anhøj[1], Elena Khomtchenko[1], Jonas Michael-Lindhard[1], Leif Steen Johansen[1]

1: DTU Danchip

*tigre@danchip.dtu.dk

Electron beam lithography is a versatile tool for fabrication of nano-sized patterns. The patterns are generated by scanning a focused beam of high-energy electrons onto a substrate coated with a thin layer of electron-sensitive polymer (resist), i.e. by directly writing custom-made patterns in a polymer.

Electron beam lithography is a suitable method for nano-sized production, research, or development of semiconductor components on a low-volume level.

Here, we present electron beam lithography available at DTU Danchip. We expertize a JEOL 9500FZ with electrons accelerated to an energy of 100keV and focused to a beam spot size down to ~5nm. The electron beam can scan across the substrate with a speed of 100MHz and can write areas of 1mm x 1mm without stitching. In order to ensure high-precision patterning, the beam position on the substrate is controlled by a two-stage deflector system and substrates are mounted on a stage which is positionally controlled by laser-interferometry. This results in a resolution of 10 nm and stitching accuracy of 10 nm.

The electron beam writer is located in a class 10 (ISO 4) cleanroom which is vibrationally and electromagnetically screened from the surroundings. Furthermore, the room temperature is controlled to an accuracy of 0.1 degrees in order to minimize the thermally induced drift of the beam during pattern writing.

We present process results in a standard positive tone resist and pattern transfer through etch to a Silicon substrate.

Even though the electron beam is below 10 nm, the feature and pitch resolution in resist is limited by forward and backward scattering of the electrons. The scattering depends on the energy of the electrons, type and thickness of resist and type of substrate. Also, when patterning on a non-conductive substrate, the accumulation of electrons in the substrate will influence the patterning. We present solutions to overcome these obstacles.

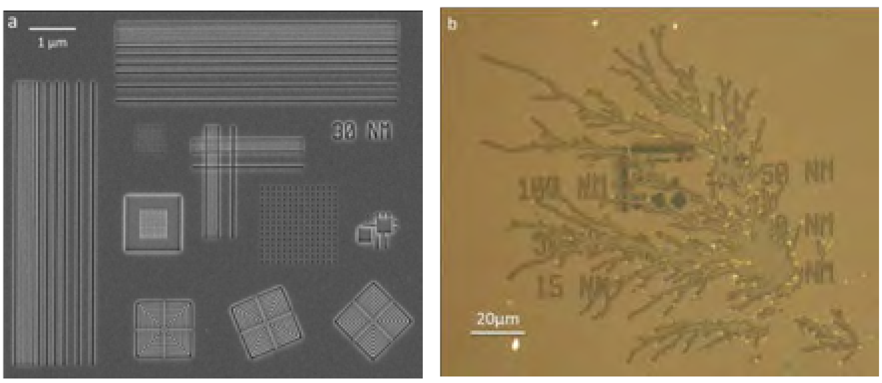


Figure a: 30 nm test pattern in a standard positive tone resist. The resist has been sputter coated with a thin layer of Pt before SEM imaging. **Figure b:** Discharging effects on a non-conductive substrate

How manufacturers can use their reverse supply chain: a typology of reverse supply chain roles

Samuel Brüning Larsen*[1], Peter Jacobsen[2]
1: DTU Management Engineering; 2: DTU Management Engineering,
*Corresponding author email: sbla@dtu.dk

Keywords: Reverse supply chain, reverse logistics, conceptual development, typology, roles

Abstract

While traditional forward supply chains end with customer markets, the reverse supply chain (RSC) both begins and ends with the firm's markets. The study applies the prevalent conceptual RSC-description in the theoretical field by Guide and Van Wassenhove (2009). In the description, the RSC begins with take back of used products and physical reverse distribution. Then, the RSC inspects and sorts products to determine the right disposition strategy. Finally, the RSC ends with product recovery and resale. Even though resale of unrecovered products, internal reuse, and disposal through waste streams is not explicitly part of the description, this study does include them as disposition strategies.

Although some RSC topics have been fairly well-addressed in extant literature (e.g. product acquisition, inventory models and product disassembly), the RSC-topic remains under-explored (Pohkarel and Mutha, 2009; Kocabasoglu et al., 2007; Huscroft et al., 2013). In supply chain and operations management (OM) literature a RSC is usually seen as a straightforward one-dimensional process, e.g. as the process described in the previous paragraph. However, a RSC can perform a variety of different functions for the firm. Among the many RSC-functions are remanufacturing complete end-products for resale in primary as well as secondary markets, refurbishing of components for reuse in servicing the firms installed product base, take back of items for disassembly and direct resale or for materials recycling, performing the reverse logistical processes required for supporting a liberal return policy, etc. Based on extant literature from the supply chain management and OM fields, this study develops a conceptual typology of what roles the RSC can play in the firm's efforts of achieving higher overall economic profits. Each role in the typology encompasses those RSC-functions that support the role.

The results of the study show four distinct RSC types: The logistician, the reuser, the servicer, and the reseller. Each role has its own distinguishable objective and set of functions. Further research is suggested for typology validation. A validated typology allows examination of the relations between specipfic RSC types and e.g. customer service, environmental responsibility, economic profit, material consumption, etc.

References

Guide Jr, V. Daniel R., and Luk N. Van Wassenhove. "OR FORUM-the evolution of closed-loop supply chain research." *Operations Research* 57.1 (2009): 10-18.
Huscroft, Joseph R., et al. "Reverse logistics: past research, current management issues, and future directions." *International Journal of Logistics Management, The* 24.3 (2013): 304-327.
Pokharel, Shaligram, and Akshay Mutha. "Perspectives in reverse logistics: a review." *Resources, Conservation and Recycling* 53.4 (2009): 175-182.
Kocabasoglu, Canan, Carol Prahinski, and Robert D. Klassen. "Linking forward and reverse supply chain investments: the role of business uncertainty." *Journal of Operations Management* 25.6 (2007): 1141-1160.

ZeroWaste BYG: Hygro-thermal conditions and pollutant emissions from ZeroWaste materials and their effects on humans

Barbora Krejcirikova*[1], Carsten Rode[1], Pawel Wargocki[1], Ruut Peuhkuri[1], Jakub Kolarik[1]

1: DTU Byg

*Corresponding author e-mail: bakr@byg.dtu.dk

The project is a part of the ZeroWaste project which deals with utilization of secondary resources in building materials. The focus is mainly on **hygrothermal characterization** of ZeroWaste materials, interactions between material and surrounding environment and its **impact on indoor environment quality**. The study includes laboratory testing of applicable material properties and their verification by computer modelling of combined heat, air, moisture and pollution transport.

The main motivation of the study is to map the effect of waste content on material properties, to develop or adapt the measurement methodologies to serve the purpose of the alternative materials and to study the influence on indoor environment quality.

Primarily, commonly used mortar panels are in focus. To make the mortar/concrete production sustainable, the cement content is widely replaced by fly ashes. In this case, by sewage sludge fly ash – a by-product from incineration process.

The hygro-thermal investigations concern the effect of various ash-cement ratios on mortar properties. Hygro-thermal properties dealt with comprise thermal conductivity, moisture sorption, water vapour permeability and water absorption. Also basic material parameters such as density and porosity are determined.

Due to the fact that ZeroWaste materials contain mixtures of different recycled items, it should be ensured that their emissions do not include odors and harmful chemicals, which are potential hazards to health or well-being of building occupants. Therefore, the effect of emissions from various building materials on perceived air quality is examined and gives an overview about emitted organic compounds.

BioREFINE-2G project – Engineering of industrial yeast strains for production of dicarboxylic acids from side and waste streams

Vratislav Stovicek[1], Xiao Chen[1], Irina Borodina[1], Jochen Förster*[1]

1: DTU Biosustain

*Corresponding author e-mail: jfor@biosustain.dtu.dk

For our future we need to assure that fuels as well as chemicals will be produced environmentally friendly from renewable resources. There must be a major move away from the use of food biomass towards the use of renewable non-food feed-stocks, such as wood, stover, straw etc. The existing 2nd generation biorefineries utilize less than 20% of the biomass feedstock for ethanol production. Major side-streams are produced such as pentose and lignin waste streams that are used for biogas and energy production. Converting the carbon from these waste streams into added-value products would improve the environmental benefits of the biorefineries. The BioREFINE-2G project aims at the development of genetically modified industrial *Saccharomyces cerevisiae* strains suitable for the production of the selected dicarboxylic acids from side and waste streams rich in C5 sugar and mixtures of C5/C6 sugars. The target compounds can be polymerised to biodegradable polymers that can find application as plastics, coatings or adhesives. To reach the goals, the identification of relevant metabolic routes, strain engineering and the development of a toolbox for manipulation of industrial *S. cerevisiae* strains are required. Here, we present advanced genetic engineering tools applicable for generally hardly amenable strains with industrial background. This involves tools for stable heterologous gene (over-)expression and a strategy for fast performance of gene disruption in multiple ploidy strains. The use of the developed toolbox in metabolic engineering of various industrial yeast strains will be demonstrated.

The identification and validation of novel small proteins in *Pseudomonas Putida* KT-2440

Xiaochen Yang, Katherine Long

Small proteins of less than 50 amino acids (s-proteins) have been understudied and largely overlooked in genome annotations and classical proteomic studies. As the s-proteins represent an untapped pool of bioactive molecules, their investigation will likely uncover novel cellular functions and activities and may lead to the discovery of novel antimicrobial agents.

Our project focuses on the identification, validation and characterization of novel s-proteins in the bacterium *Pseudomonas putida* KT-2440. As there is virtually no information on s-proteins in pseudomonads, the first step is to establish methods for the identification of short open reading frames (sORFs). A custom bioinformatics tool has been developed to predict sORFs from the genome and sRNA sequencing databases, where sequences containing a Shine-Dalgarno (SD) sequence and start/stop codon are identified. In a second approach, total protein samples are prepared, fractionated, and analyzed with mass spectrometry (MS/MS). The MS/MS data are compared to a custom database containing >80000 putative sORF sequences to identify candidates for validation.

A total of 56 and 22 putative sORFs were obtained from MS/MS data and bioinformatics prediction, respectively, where there is no overlap between the putative sORFs obtained from the two approaches. The sequences encoding the putative sORFs will be integrated onto the Tn7 site on the chromosome as well as on a plasmid expression vector for validation.

Life Cycle Costing model for Solid Waste Management

Veronica Martinez Sanchez[1]* and Thomas Fruergaard Astrup [1]

[1]DTU Environment

*Corresponding author email: vems@env.dtu.dk

To ensure sustainability of solid waste management, there is a need for cost assessment models which are consistent with environmental and social assessments. However, there is a current lack of standardized terminology and methodology to evaluate economic performances and this complicates the performance of new studies as well as the understanding of similarities and singularities between the different types of cost assessment applied in literature. This investigation develops a systematic framework for performing various types of cost assessments with different cost perspectives.

Most of the cost assessments in literature can be classified into: 1) Conventional Life Cycle Costing (LCC), 2) Environmental LCC and 3) Societal LCC. While the first two LCCs are financial assessments, the third one is a socio-economic assessment. The three LCCs included marketed goods, but they handle differently non-marketed goods (i.e. externalities). While non-marketed goods are beyond the scope of the Conventional LCC; the Environmental LCC included environmental externalities in a parallel LCA and the Societal LCC internalizes all the externalities into monetary terms. Different cost perspectives can be applied in each LCC, e.g. waste generator, waste operator and public finances and the perspective often defines the system boundaries of the study, e.g. waste operators often focus on her/his own cost, i.e. technology based, whereas waste generators and public finances often focus on the entire waste system, i.e. system based.

Figure 1 illustrates the proposed modeling framework that distinguishes between: a) budget cost, b) externality costs and 3) transfers and defines unit costs of each technology (per ton of input waste). Unit costs are afterwards combined with a mass balance to calculate the technology cost. Later, the costs of individual technologies can be combined to calculate the system or scenario costs. In the technology definition, each cost item is defined with a unit cost per item, which is calculated with two types of parameters: 1) economic (e.g. unit prices and depreciation periods) and 2) technical (e.g. usage rate and consumptions of commodities).

The investigation provides an overview of which cost items should be included in each pair of LCC-perspective and common calculations to estimate technical parameters for main waste technologies. The applicability of the cost assessment model is illustrated with a fictive case study focusing on source segregation of organic waste in Denmark.

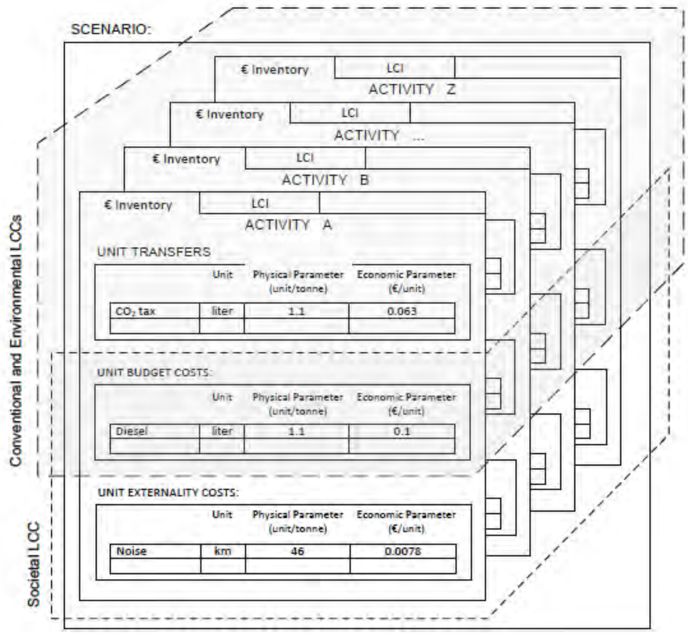


Figure 1: Overview of the cost model structure, illustrating a range of activities (A through Z) and the cost coverage of Conventional, Environmental and Societal LCCs. Figure taken from Martinez-Sanchez et al. (2014)

References:

Martinez-Sanchez, V., Kromann, M.A., Astrup, T.F., 2014. Life cycle costing of waste management systems and technologies: overview, calculation principles and case studies, accepted for publication in the Journal of Waste Management (DOI 10.1016/j.wasman.2014.10.033).

Material recycling: Presence of chemicals and their influence on the circular economy concept

Kostyantyn Pivnenko*[1], Thomas F. Astrup[1]

1: DTU Environment

*Corresponding author email: kosp@env.dtu.dk

Linear production concept (extract-convert-use-discard) applied from the times of industrial revolution has created a lot of skepticism in the world of limited resources that we live in. As basis to tackle the issue of resource scarcity, circular economy concept has been proposed. The backbone of the concept is the pursuit of sustainability through re-use and recycling of products and materials once they have served their purpose. Once such materials (e.g. paper, plastics) are recycled, chemicals that they contain are re-introduced, spread or even accumulate in the newly manufactured products (Figure 1). As an example, paper and board products alone contain up to 10,000 different chemicals. While only small fraction is being regulated, most of them have not been identified in relevant materials or even lack hazard assessment.

The overall goal of the project is to provide a basis for systematically addressing the recyclability of waste materials with respect to the presence of substances. The outcomes of the work will provide crucial basis for future waste characterization activities, environmental and risk assessments of material recycling, as well as provide authorities, scientific community and society with a necessary basis for evaluating potential future limitations to recycling and address means of mitigating accumulation and spreading of chemicals in various materials.

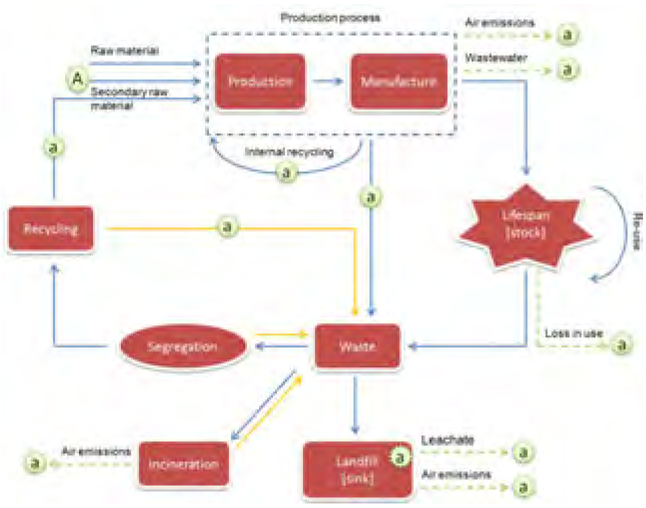


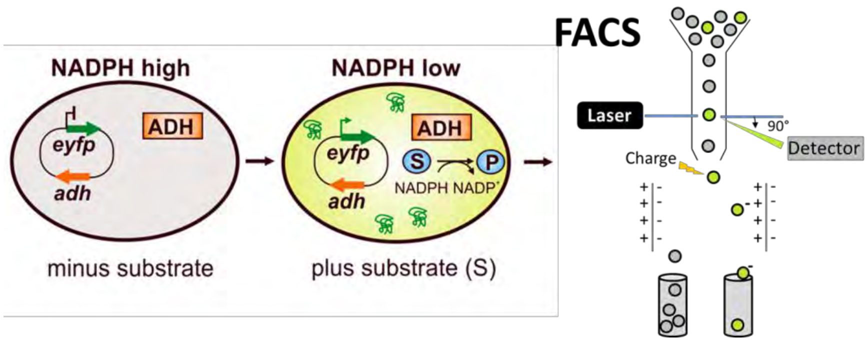
Figure 1. Schematic representation of a material life cycle (A/a: additives)

Design and application of transcription factor based metabolite sensors in *Escherichia coli*

Solvej Siedler[1]*, Steen G. Stahlhut[1], Stephanie Bringer[2], Michael Bott[2], Jerome Maury[1], Morten Sommer[1]

1: DTU Biosustain, 2: Research Center Jülich GmbH
*Corresponding author email: ssie@biosustain.dtu.dk

Identification of enzymes with the activity of interest is one of the major bottlenecks in enzyme and metabolic engineering. We have established a versatile ultra-high-throughput screening system for NADPH-dependent enzymes. It is based on the [2Fe-2S] cluster-containing transcriptional regulator SoxR that activates expression of *soxS* in the absence of NADPH in *Escherichia coli*. We coupled the response to the expression of an auto fluorescent protein and the specific fluorescence of sensor containing cells correlated with enzyme activity of an NADPH-dependent alcohol dehydrogenase from Lactobacillus brevis (*Lb*ADH). This property enabled sorting of single cells harboring wild-type *Lb*Adh from those with lowered or without *Lb*Adh activity by fluorescence-activated cell sorting (FACS). In a proof-of-principle application, the system was used successfully to screen a mutant *Lb*Adh library for variants showing improved activity with the substrate 4-methyl-2-pentanone.



To demonstrate the broad range of biosensors applications in E. coli we additionally describe the construction of two flavonoid responsive biosensors. The transcriptional activator FdeR from *Herbaspirilllum seropedicae* SmR1 responds to naringenin, while the repressor QdoR from *Bacillus subtilis* is inactivated by quercetin and kaempferol. The QdoR-biosensor was successfully applied for the detection of kaempferol production in vivo at the single cell level by FACS. Furthermore, the amount of produced kaempferol highly correlated with the specific fluorescence of *E. coli* cells containing flavonol synthase from *Arabidopsis thaliana* (fls1). These results show the potential of biosensors to minimize the construction time in bacterial cell engineering.

Siedler et al. (2014) ACS Synth Biol. 3 (1), pp 41-47; Siedler et al. (2014) Metab Eng. Jan;21:2-8.

Composition of municipal solid waste in Denmark

Vincent Maklawe Essonanawe Edjabou*[1], Claus Petersen[2], Charlotte Scheutz[1], Thomas Fruergaard Astrup[1]

1 : DTU Environment; 2 : ECONET

*Corresponding author email: vine@dtu.env.dk

Data for the composition of municipal solid waste is a critical basis for any assessment of waste technologies and waste management systems. The detailed quantification of waste fractions is absolutely needed for a better technological development of waste treatment.

The current waste composition data in Denmark are among the most detailed in the world. However, these data are more than 10 years old, and the following issues remain very important: (1) sampling approach, (2) representativeness of samples, (3) data uncertainties, (4) time and geographical variation. Moreover, in the absence of standardised and commonly accepted waste characterization methodologies, various approaches have been reported in literature. This limits both comparability and applicability of the results.

The purpose of this study was to introduce a consistent methodology that reduces uncertainties and ensures data comparability to characterize municipal solid waste. This methodology was applied to residual waste collected from 1,442 households in three municipalities in Denmark.

The main fractions contributing to the residual household waste were food waste and miscellaneous waste. Statistical analysis suggested that housing type is a critical stratification parameter for characterization of residual household waste.

Development of Industrial Yeast Platform Strains

Basti Bergdahl[1], Laura Dato[1], Jochen Förster*[1]

1: DTU Biosustain

*Corresponding author email: jfor@biosustain.dtu.dk

Most of the current metabolic engineering projects are carried out using laboratory strains as the starting host. Although such strains are easily manipulated genetically, their robustness does not always meet the requirements set by industrial fermentation conditions. In such conditions, the cells frequently encounter high substrate concentrations, low pH, high temperatures and various inhibitory compounds originating either from the raw material used or from cellular metabolism. The aim of this research project is to develop robust platform strains of *Saccharomyces cerevisiae* based on industrial and environmental isolates.

The project is expected to relate the genetic diversity among a group of 36 natural and domesticated isolates of *S. cerevisiae* strains to the observed phenotypes, with special focus on extreme phenotypes characterized by high robustness and specific metabolic traits. The genetic diversity will further be harnessed to generate completely new strains with selected, desirable traits. These new platform strains will be a preferable choice as starting hosts in which to implement existing and new metabolic engineering designs for the production of specific classes of compounds.

The project has four main tasks that are interconnected to reach the final goal (Fig. 1). It is highly multidisciplinary and involves several research fields. In this communication, we will present selected results from ongoing activities, such as the whole genome sequencing, intracellular metabolite profiling and tolerance screening of the 36 industrial and laboratory yeast strains. In addition, progress in the development of molecular biology methods for generating the new strains will be presented.

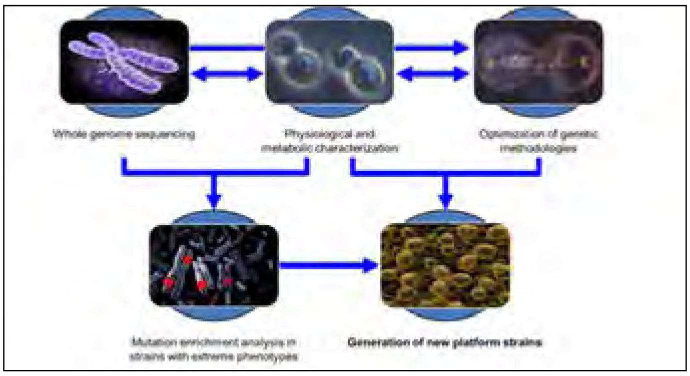


Figure 1. The project consists of four main tasks, each designed to provide a specific type of information. This information will be combined to reach the final goal of generating new platform strains.

Track 5

Competence development in sustainability

Scientific Committee

Coordinator: Stig Irving Olsen, DTU Management

Line Gry Knudsen, Climate-kic

Louise Hindenburg, Grøn Dyst coordinator

Tina Elisabeth Nielsen, Learninglab

Christian Thune Jacobsen, Adgangskursus

Track 5
Talk
Presentations

See schedule on
www.sustain.dtu.dk

Climate-KIC: the cradle for climate Entrepreneurs

Line Gry Knudsen, line@climate-kic-nordic.org

Climate KIC, DTU

Climate-KIC is Europe's largest public-private innovation partnership, working together to address the challenge of climate change. DTU is hosting the Nordic centre of Climate KIC and participates in various activities.

The aim of climate KIC is to drive innovation in climate change through creative partnerships large and small, local and global, between the private, public and academic sectors. All 230+ partners bring their industry experience to the community and are connected through a national or regional centre.

A core activity is educating the future climate innovators. We do that by offering added value to Master's and Ph.D. degree programmes at the best academic institutions across Europe. Additionally we host an annual summer school and a pre-incubation programme, the Greenhouse, which helps students to explore their business ideas.

Our teaching activities are based on the integration of the three sides of the knowledge triangle: education, research and business/innovation. Accordingly, we put a strong focus on creativity, innovation, and entrepreneurship and build on a set of specific quality criteria and overarching learning outcomes.

Besides presenting Climate-KIC and inviting you to collaborate, this presentation will aim to inspire the debate on how entrepreneurship is best taught at universities and how we can become not only the place-to-be for future climate scientists but also become the cradle for future climate entrepreneurs.

Energy research and teaching at CEE, DTU Elektro

Joachim Holbøll

DTU Elektro, jh@elektro.dtu.dk

The Center for Electric Power and Energy (CEE) at DTU Elektro focuses on research and teaching within the present and the future energy system, aiming at a reliable, cost-efficient and sustainable energy system based on renewable energy. In such way is addressed one of the major and most important challenges of our modern society.

The ongoing transformation of the energy system is triggered by technology development and specific energy strategies in Denmark. CEE is supporting the development of a range of new technologies and solutions as well as the underlying new knowledge, theory and methods.

Several keywords are characterizing the major trends, one of which is 'smart energy', mainly covering covers integrating multiple infrastructures (electricity, heat, gas, transport etc.) and the technologies to support this trend including automation, ICT and marked aspects.

Contrary to traditional operation of a power system, stability in the future system has now to be based on smaller, decentralized units. This covers not only generating units, but also includes the consumer side, where demand control contributes to support the power system. Here, technologies like energy storage, electric vehicles and smart buildings play an important role.

Another research area is within electric power networks, where renewable generation like large scale integration of wind power is a major challenge. Integration of the wind and solar power takes place at different voltage levels in the system and the solutions to be found need to take into consideration both technical and economic/environmental aspects.

Finally, the components at generation, transmission and distribution level must be suitable for this alternative powers system without any risk for reduced reliability or life time.

CEE is focusing on research and teaching in mentioned areas in order to support the considerable changes in the electrical grid towards much more dynamic operation of the power system in interaction with other energy infrastructures.

Sustainability at DTU from Campus Service point of view

-an invitation to use campus as *learning lab*

Lisbet Michaelsen

DTU Campus Service

Author email: limi@dtu.dk

Campus Service (CAS) at DTU has the mission of servicing our University with a high quality within all areas of Facility Management: planning, building, operation and maintenance. At the same time CAS supports the vision of DTU to be a sustainable university so we try to think sustainable in all aspects of our work.

DTU has set two targets in the contract with the ministry (FIVU). DTU wants to do 15% better on waste and energy in 2015. DTU will increase the recycling rate by 15% from 2010 – 2015 and DTU will use 15% less energy per man year staff and student in the same period. Both targets are ambitious and hard to reach.

First part of the presentation will give an introduction to DTU's sustainability policy, our targets and figures up until now as well as information about CAS initiatives on behavior campaigning.

CAS would like to get ideas and input on how to reach the two targets.

Second part of the presentation is about using our Campus as a living lab. CAS will try to support sustainability initiatives or projects from researchers and students. We are willing to share our data and if possible to try out - or test new products or solutions. CAS is also keen on getting input on doing things in another and more sustainable way. It can be hard to know which solution is the most sustainable but working together with i.e. DTU Management CAS has received valuable input for our new buildings and our daily operation and maintenance. Some examples will be given.

The quest for sustainability in existing buildings

Susanne Balslev Nielsen[1] ; Lisbet Michaelsen[2] Per Anker Jensen[1]

1: Centre for Facilities Management; DTU Management Engineering

2: DTU Campus Service

*Corresponding author email: sbni@dtu.dk

Centre for Facilities Management (CFM) at DTU has the mission of developing the management discipline Facilities Management (FM). FM deals with design, operation and development of buildings and infrastructure so that this constantly is adjusted to user needs; while also contributing to sustainability at societal level.

Due to lack of professional skills, decisions about operation and renovation of buildings are made every day in Denmark and beyond, without adequate knowledge about e.g. energy management and the potential ways of integrating sustainability (social, environmental and economic). The consequence is energy-ineffective building stock and an extremely slow transmission into more sustainable buildings and cities.

The professionals in facilities management has so far been overlooked as a key to ensure energy effective buildings. Through research, education and practice collaboration CFM intend to change this by upgrading the skills of especially Danish but also European facilities managers.

The workshop includes an introduction to sustainability in FM (SFM) and CFM; but also participant reflections on the collective quest for sustainability in the existing buildings at DTU.

Teaching sustainability in engineering solutions with Campus Service as case

Stig Irving Olsen[*1], Tim McAloone[2], Susanne Balslev Nielsen[1]

1: DTU Management Engineering; 2: DTU Mechanical Engineering

*Corresponding author email: siol@dtu.dk

Engineers potentially influence the sustainability of technological solutions significantly. At DTU Management Engineering we aim to address sustainability to all engineering students at DTU. One of the means to address students throughout DTU is the establishment of a course aimed at bachelor students on all study lines. The objectives of the course is for the participants to acquire an understanding of the basic concept of sustainability and its three dimensions as well as getting an overview of a number of tools for analysis and synthesis of solutions that are sustainable throughout their life cycle and acquire the skills to use the most central of the tools. Furthermore, they should understand the engineer's role and responsibility in the development of sustainable solutions. Examples of learning outcomes are:

- Explain that each sustainability dimension is multifactorial and that trade-offs exist within and between them
- Illustrate how companies can work towards the development of sustainable solutions
- Know and use various simplified tools for use in sustainability assessment
- Be able to relate critically to the results of various tools
- Master the analysis of solutions using life cycle check
- Master the synthesis of solutions using ideal concepts in product development

The course runs over the June three week period. It employs project based problem oriented learning and is organized around a theme within which there are several subprojects/-problems that the students work on in groups of 4-5 persons. Different themes have been used but especially “The Sustainable Campus” in cooperation with CAS has been successful. CAS frequently has to choose between different solutions for DTU Campus - but how to choose the most sustainable? The students get engaged since DTU Campus is part of their everyday life and they get a real opportunity to influence how CAS operate.

The general outline of the course is that theory lectures and exercises are given in the morning whereas the afternoons are fully devoted to project work applying the theory learned in the morning. However, app. half of the days are fully devoted to project work with supervision. Several milestones for the project are defined at which the student presented their work. The students were evaluated on their presentations, their final report and a multiple choice questionnaire.

Integration of ethics and sustainability in Diploma education

Mickey Gjerris
M.Th., PhD in bioethics, Associate Professor
Consultant to Learning Lab, DTU
Member of the Danish Ethical Council

LearningLab DTU have initiated a project to integrate ethics into the bachelor of engineering programs at DTU by focusing on the concept of "sustainability" and the values that different understandings of it entail. The talk will discuss why ethics is of relevance in engineering education and describe how the underlying goals are aligned with the specific learning goals set out and the methods chosen.

Track 5
Poster
Presentations

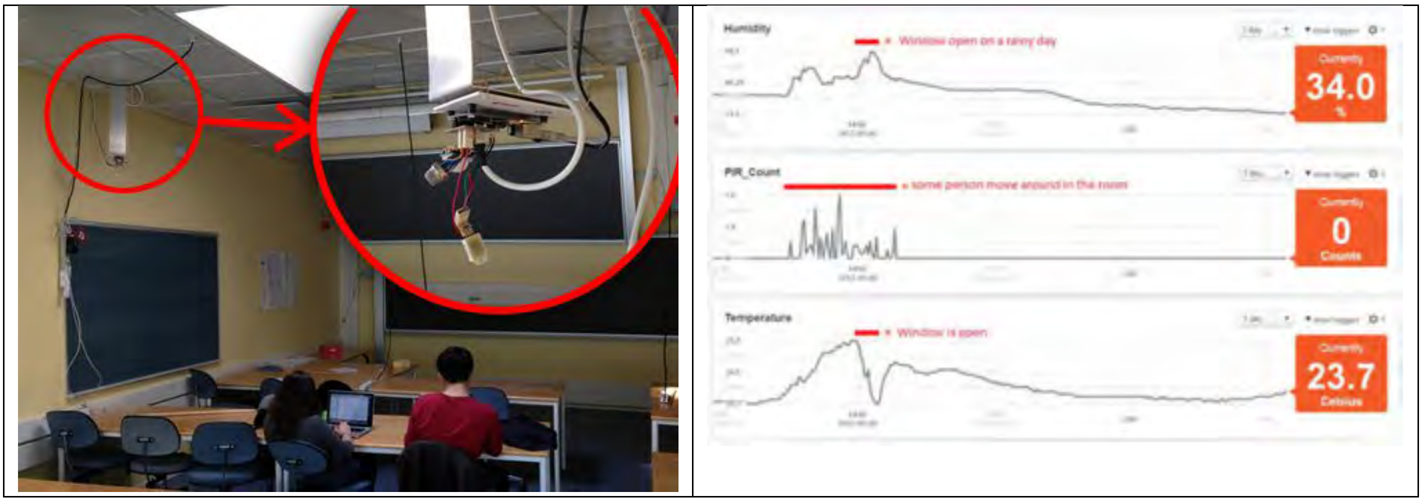
See schedule on
www.sustain.dtu.dk

Sustainable DTU, Electronics and It

Ole Schultz (osch@dtu.dk), Jesper Molin(jemol@dtu.dk), Peder Hundesbøl (pehu@dtu.dk); Gitte Mellemgaard(gime@dtu.dk) - DTU Center for Diplom Engineering Education, Ballerup

Diplom engineering students from basically all education can take the elective course SDTU where they learn about sustainability within product development – products which make DTU-Diplom Campus greener. In this course all participant learn about energy screening. They create an energy plan and suggest what should be done at the Campus to make it green and as the last part of it the prototype and suggest in detail what could be done. Over time there have been participating students from another elective course, Sustainable Electronics and IT as well students from Process and Innovation, Export Engineering and Civil Engineering students. The courses teach students that sustainability is a cross disciplinary topic – where engineering's from different education has to cooperate for getting a proper solution.

Electronic and IT Diplom engineering students are motivated learning about sustainability within their field when sustainability and environmental impact is seen in a context. That is done in an elective course: Sustainable Electronics and IT (SUSIE). We have integrated sustainability in the context of embedded wireless systems for building monitoring and control using the Internet of Things concept. The students work on projects in the last 3 – 4 weeks of the course mainly prototypes related to building monitoring and control



Class room monitoring and data sampling to the cloud (1)

The these elective classes has 3 dimensions – general knowledge behind low power design and life cycle/energy screening, energy plan and learning about building control/automation leads to less energy consumption and developing prototype of an internet of things system used for building monitoring and control.

The poster will present and discuss some parts of the courses curriculums, some pedagogical methods used in the course and case exercises used as well as few examples on projects

2014-11-09 Ole Schultz

(1) Rapport BIHK-course by Morten T. Egholm., 2013

Unsustainability, eMergy and LCA

Andreas Kamp, Fabiana Morandi, Sune Tjalfe Thomsen, Hanne Østergård*

DTU Chemical Engineering

*Corresponding author email: haqs@dtu.dk

Unsustainability is the distance from an ideal of sustainability. Sustainability is determined by the degree to which a system depends on renewable resources for its operation. Emergy Assessment (EmA) identifies the total demand on the ecosphere and sociosphere, and evaluates the ability of a subsystem to sustain itself within a larger system (the planetary ecosystem). Life Cycle Assessment (LCA) identifies inputs from the sociosphere and emissions to the ecosphere, and evaluates a product's impact in a set of subsystem analyses. The two unsustainability analysis methods are fundamentally different but can be used complementary to provide insight on different levels.

We will present how eMergy is particularly suited for systems analysis and for evaluation of 'renewability'. We welcome discussions that can develop our understanding of why and what we are measuring and how diverse tools provide us with different types of answers and conclusions.

Creating an information quantum leap in early design phases.

Lotte Bjerregaard Jensen[1], Alfred Heller, Brian Hurup-Feldby.

1: DTU Civil Engineering.

*lbj@byg.dtu.dk

The poster will outline the dynamic simulations tools developed in the building industry during the last two decades for integrating knowledge of indoor climate and energy in early phases of a building design and give a brief up date of the present quest to include and integrate information from urban environment climatic conditions, broad multi-criteria sustainability certification in early design phases aiming a.o. at meeting the obligations defined by smart cities challenges.

Civil and Environmental Engineering has special challenges concerning design processes. These design projects are always influenced by their location and the topography (be it natural or manmade), climate, etc. This means that each project is unique and must be viewed in its own right. This reduces the benefits of mass production and standardization that are so heavily emphasized in mechanical design and manufacturing. This also means that design theories, tools, and techniques cannot be adopted directly from other design disciplines such as product design where different solutions can be developed for each individual or group.

The natural environment has dynamic, unpredictable, and sometimes chaotic properties and behavior. This is more true than ever when considering the challenge of climate change. The requirements and behavior of the human users also vary in time. To meet these challenges, Civil and Environmental Engineering projects must be designed to be flexible so they can adjust for temporary changes in natural or human conditions. They must also be adaptable so they can evolve with technology, society, and the environment. The recent years, increasing application of renewable energy sources put extreme pressure onto the energy grids and need for demands side management, where buildings play a decisive role in stabilizing the energy demand through e.g. thermal storage in building components.

Design in Civil and Environmental Engineering also defines the reality in which we live, work, and play. Thus, it borders other fields such as architecture, landscape design, and urban planning - influencing them and being influenced in exchange.

The design of sustainable and climate adaptive systems and structures requires a very high level of information in all of the design phases. Addressing the challenges will require even more information with a better level of integration than is currently available today in either industry or education. Interdisciplinary design methods building on the know-how created during the past 2 decades is at the fore. How can we better integrate the knowledge at hand in Civil and Environmental Engineering in interdisciplinary design processes?

Open Access and ORCID poster presentation

Mikael K. Elbæk (http://orcid.org/0000-0001-8037-7577)[1], Jeannette Ekstrøm (http://orcid.org/0000-0003-2791-4219)[2]*

1: DTU Bibliometrics and Data Management; 2: DTU Library

*jeek@dtu.dk

Open Access

Open Access is high on the agenda in Denmark and internationally. Denmark has announced a national strategy for Open Access that aims to achieve Open Access to 80% in 2017 and 100% in 2022 to peer review research articles. All public Danish funders as well as H2020 requires that all peer review articles that is an outcome of their funding will be Open Access. Uploading your full texts (your final author manuscript after review) to DTU Orbit is a fundamental part of providing Open Access to your research. We are here to answer all your questions with regards to Open Access and related topics such as copyright, DTU Orbit, Open Access journals, APCs, Vouchers etc.

ORCID

ORCID – Open Research & Contributor ID – is an internationally recognized and widely used researcher-ID. ORCID makes it easy to reuse your data across disciplines, publishers and databases – all you need to do is to refer to your ORCID instead of entering your data again. But most importantly is maybe that ORCID ensures, that you will get cited correctly – no matter if your name is spelled with special characters or if you change your name for one reason or another. Increasingly publishers and funders are asking you to submit your ORCID when you submit articles or apply for funding. DTU is a member of the international ORCID organization and you can register your ORCID through DTUBasen. We are here to help you answer all questions related to ORCID. Visit our poster and get your ORCID and learn about

Dynamic Energy Budget theory: a means to develop competences in sustainable use of biological systems

Starrlight Augustine[1]*

1: DTU Aqua

*Corresponding author email: staug@aqua.dtu.dk

Dynamic Energy Budget (DEB) theory is a quantitative theory which specifies uptake of substrate and its use to cover all metabolic costs (i.e. maintenance, growth, reproduction, etc.). The theory applies to all living organisms using the idea that the metabolic organization of all life is subject to the same physical and thermo-dynamic constraints. The objective of this poster is to create a platform to discuss how such a theory contributes to developing competences in the sustainable use of biological systems.

First I will present the DEB theory as a theoretical construct which enables users to specify mass balances of 'biological systems' such as: bacterial cultures in a batch reactor (e.g. biomass, biofuel production), particular fish or bivalve species (e.g. aquaculture, fisheries) etc. Using the concepts and tools of the theory, taxon-specific DEB models of the biological system are built. Parameters of the model are estimated from data. This allows the user to make quantitative predictions for how the system will respond to variable input (food/substrate) and temperature.

These taxon-specific models, once tested against data (via the process of parameterization), already allow for a range of simulation studies which allows users to detect problems in an experimental set-ups (e.g. there is a problem with the data), decide on experimental priorities (e.g. what information is missing), improve experimental design (optimize costs/ time investment/ information content), make simulation scenarios (e.g. what happens under different types of pulsed food regimes, how does that effect yields), or contribute to fundamental knowledge on the organisms eco-physiology.

DEB models can also be coupled to other models. Users can build cost functions taking into account different components like (i) the physical environment, (ii) costs of equipment and (iii) relevant aspects of the eco-physiological performance of the 'biological system' (generation times, biomass production, yields). Component (iii) is quantified by particular parameter values obtained from the DEB theory and estimated from actual data.

In short, I think that DEB theory is concretely applicable for quantifying and predicting the performance of biological systems in a way that can be integrated into cross-disciplinary sustainability projects. I would be very interested in exploring this further through discussions at this conference.

The internationalisation of sub-suppliers' innovation processes in the wind power industry

Anne Nygaard Tanner

DTU Management

*Corresponding author email: anny@dtu.dk

The wind power industry has undergone significant change during the last couple of decades which has resulted in an internationalisation of the industry. The key factor behind this development is a continuously increasing demand for renewable energy sources such as wind power caused by the strong focus on mitigating the environmental impact of energy production as well as increasing energy security. This has caused a steep increase in installed MW capacity across the world and has attracted a diverse range of OEMs from different world regions and today the industry is no longer dominated by Danish wind turbine manufacturers. This has caused internationalisation on activities related to manufacturing, sales and more recently research and development. This study focuses on the first and second tier suppliers located in Denmark and asks whether these companies are able to adapt to the new international agenda and take advantage of both local and international knowledge sources in the development of new innovations. This paper applies a biographical approach, which enables to focus on the innovation process as it unfolds over time from idea generation trough problem solving phases to the phase of implementation. By following three innovation processes this study provides detailed information about the innovation process and not least about its varying geographical configurations. The study indicates that 1) in the offshore wind power sector innovative activities at the sub-supplier level are driven by strong customer needs, if the need of the customer fades the development project is given up until a new customer has been identified 2) For all three innovation processes it is evident that the core activities around the innovative event change physical site during the development. This requires intense processes of knowledge transferring either by stationing employees at the new site. 3) It seems that the earlier in the innovation process the more local the knowledge sourcing and similarly the later in the innovation process the more international the innovative activities become. The findings indicate that the Danish sub-suppliers have adapted to the new international agenda and today operate internationally when it comes to knowledge sourcing for innovation.

Workshops

See schedule on
www.sustain.dtu.dk

Workshop 1

What is the sustainability of your project?

This workshop will introduce you to the different aspects and methods of assessing the overall impact of a technology and documenting 'how green it is'. This will help guiding and optimizing your research towards documented sustainable solutions.

After a brief introduction to the fundamental principles of life cycle assessment (LCA) as a tool to assess environmental sustainability we will look more into the details of concrete projects and help identify the environmental hot spots and the main environmental improvement possibilities for your technology or project, looking across its whole life cycle from the cradle (raw material extraction) to the grave (end of life and potential new life in other products), and addressing all the relevant environmental impacts.

We have a limited number of LCA experts available so register quickly to have a discussion of your case during the workshop.

Workshop registration on www.sustain.dtu.dk

Organized by Michael Zwicky Hauschild, DTU Management

DTU

Workshop 2

Kick-start Your next Post Doc Funding Application

In this two-hour workshop, you will: Get an overview of where to apply for post doc funding

- Be introduced to the different sections of a typical post doc application, such as state-of-the-art, research plan and budget
- Benefit from talking to other early stage researchers
- Do a one-page-proposal of your best research idea
- Get some sound writing principals and some tips for the successful application
- Learn where to get more help when applying for external research funding
- It is our ambition that you leave the workshop with a better possibility of writing a successful application

Aimed at Post docs, but others are very welcome too. Later you can follow a one-day course in the spring 2015.
Workshop Program

- Welcome and introduction
- Where to apply for post doc funding
- The 1-page proposal
- Your research idea! - interview exercise
- Going through and application - section by section
- Writing principles and tips for the successful application
- Your research idea - writing exercise
- Q&A and wrap up

Workshop registration on www.sustain.dtu.dk
Organized by Fundraisers from DTU Nanotech

Workshop 3
Water DTU Workshop
- an introduction to the new Center for Water Activities at DTU

Introduction the new Water DTU center. Come to this workshop to learn what Water DTU is about, or to get the latest updates since the kick-off seminar in October 14:15 Presentation: Introduction to Water DTU by center leader professor Peter Steen Mikkelsen, DTU Environment.

Program
- Interactive session: identification of collaboration possibilities across DTU
- Interactive session: generation of wish list for future Water DTU hosted activities

Poster with examples of water related research at DTU and a presentation of Water DTU will be placed outside the room, so everyone is welcome to cruise by and be inspired

Organised by Water DTU (www.water.dtu.dk)

Workshop registration on www.sustain.dtu.dk

Workshop 4
Fundraisers Lounge
- Get help for you fundraising!

DTU fundraisers will be available for questions and discussions in the Fundraisers Lounge. Just come by to hear more about the possibilities you have and what help you can get.

Registration is *not* needed for this event

Organizers & Host

The conference was organized by

- Kristian Mølhave Kristian.Molhave@nanotech.dtu.dk
- Michael Zwicky Hauschild mzha@dtu.dk
- Anders Baun abau@env.dtu.dk
- Stig Irving Olsen siol@dtu.dk
- Jane Hvolbæk Nielsen jane@fysik.dtu.dk
- Steffen Foss Hansen sfha@env.dtu.dk

The conference is hosted by The Office for Research and Relations:

- Claus Henrik Andersen cha@adm.dtu.dk
- Anne Line Mikkelsen amik@adm.dtu.dk
- Vibeke Tine Aagaard Pedersen vtap@adm.dtu.dk
- Lene Reeh lenre@adm.dtu.dk

First name	Last name	Academic title	Email	Affiliation
Alexis	Laurent	Assistant Professor	alau@dtu.dk	DTU Management Engineering
Anders	Baun	Professor	abau@env.dtu.dk	DTU Environment
Anders	Damgaard	Senior Researcher	adam@env.dtu.dk	DTU Environment
Anders	Riisager	Assoc. Prof.	ar@kemi.dtu.dk	DTU Chemistry
Anders	Jorgensen	Dr.	ajoe@danchip.dtu.dk	DTU Danchip
Andrea	Cazzaniga	PhD student	andcan@fotonik.dtu.dk	DTU Photonics
Andreas	Kamp	PhD Student	ankam@kt.dtu.dk	DTU Chemical Engineering
Anja	Boisen	Professor	aboi@nanotech.dtu.dk	DTU Nanotech
Anke	Hagen	Prof.	anke@dtu.dk	DTU Energy conversion
Anna	Sitarz	PhD	aks@kt.dtu.dk	DTU Chemical Engineering
Anne	Nielsen	MSc	avfn@kt.dtu.dk	DTU Chemical Engineering
Anne Line	Mikkelsen	Senior Research Officer	amik@adm.dtu.dk	AFR
Anne Marie	Vinggaard	professor	annv@food.dtu.dk	DTU Food
Anne Nygaard	Tanner	Postdoc	anny@dtu.dk	DTU Management Engineering
Anne S.	Meyer	Professor, PhD	am@kt.dtu.dk	DTU Chemical Engineering
Annemette	Kappel	PhD	anmk@byg.dtu.dk	DTU Civil Engineering
Athanasios	Papakonstantinou	Postdoc	athpapa@elektro.dtu.dk	DTU Electrical Engineering
Axel Wright	Larsen	PhD	axla@fysik.dtu.dk	DTU Physics
Bahar	Bingol	Dr.	dkbbi@coloplast.com	Coloplast A/S
Barbora	Krejcirikova	Ph.D. student	bakr@byg.dtu.dk	DTU Civil Engineering
Basti	Bergdahl	PhD	baber@biosustain.dtu.dk	DTU Biosustain
Berit	Herstrøm	Cand.scient.	bge@danchip.dtu.dk	DTU Danchip
Birgitte	Zeuner	Postdoc	biz@kt.dtu.dk	DTU Chemical Engineering
Birte Holst	Jørgensen	Deputy head of deaprtment	bhjq@dtu.dk	DTU Management Engineering
Bo	Jørgensen	Lektor	bojo@food.dtu.dk	DTU Food
Brian	Elmegaard	Assc. Prof.	be@mek.dtu.dk	DTU Mechanical Engineering
Brian	Seger	Assistant Professor	brse@fysik.dtu.dk	DTU Physics
Carl Esben	Poulsen	PhD-Student	cepo@nanotech.dtu.dk	DTU Nanotech
Carsten	Jers	PhD	cj@kt.dtu.dk	DTU Chemical Engineering
Cathrine	Frandsen	Associate Professor	fraca@fysik.dtu.dk	DTU Physics
Charlotte	Jacobsen	Professor mso	chja@food.dtu.dk	DTU Food
Charlotte	Corfitzen	Project coordinator	cbco@env.dtu.dk	DTU Environment
Charlotte	Algreen	Architect maa DGNB consultant	ca@algreenarkitekter.dk	DTU Civil Engineering
Christian	Thune Jacobsen	Head of Department	ctj@adk.dtu.dk	DTU
Christian Danvad	Damsgaard	Associate Professor	cdda@cen.dtu.dk	CEN and DTU Fysik
Christine	Ipsen	Associate Professor	chip@dtu.dk	DTU Management Engineering
Christos	Ordoudis	Research Assistant	chror@elektro.dtu.dk	DTU Electrical Engineering
Claus Højgård	Nielsen	M.Sc.	choi@danchip.dtu.dk	DTU Danchip
Dennis Ringkjøbing	Elema	Head of Division	derj@dtu.dk	DTU Nutech
Duc-The	Ngo	Dr	dngo@nanotech.dtu.dk	DTU Nanotech
Duy Michael	Le	Industrial PhD-student	dumi@kt.dtu.dk	DTU Chemical Engineering
Elena	Khomtchenko	M.Sc.	elk@danchip.dtu.dk	DTU Danchip
Emil	Højlund-Nielsen	PhD-student	emiho@nanotech.dtu.dk	DTU Nanotech
Eric	Jensen	Dr.	eric.jensen@nanotech.dtu.dk	DTU Nanotech
Erik Huusfeldt	Larsen	senior researcher	ehlar@food.dtu.dk	DTU Food
Eva Bay	Wedebye	Chief advisor	ebawe@food.dtu.dk	DTU Food
Evgeniy	Shkondin	PhD student	eves@fotonik.dtu.dk	DTU Danchip
Ewa Maria	Musiol-Kroll	Dr.	emmu@biosustain.dtu.dk	DTU Biosustain
Fabiana	Morandi	PhD	fmor@kt.dtu.dk	DTU Chemical Engineering
Fariza	Ammam	Ph.d	faram@biosustain.dtu.dk	DTU biosustain
Flemming	Jensen	Ph.D., Associate Professor	fj@danchip.dtu.dk	DTU-Danchip
Francesco	Rosati	Postdoc	frro@dtu.dk	DTU Management Engineering
Frederik	Stöhr	Ph.D. Student	frsto@danchip.dtu.dk	DTU-Danchip
Fredrik	Haglind	Associate Professor	frh@mek.dtu.dk	DTU Mechanical Engineering
Getinet	Woyessa	PhD Student	gewoy@fotonik.dtu.dk	DTU Photonics
Graham	Town	Prof	gtown@fotonik.dtu.dk	DTU Photonics
Gunvor Marie	Kirkelund	Researcher	gunki@byg.dtu.dk	DTU Civil Engineering
Hafeez Ul	Hassan	Industrial PhD	hafeez.ul.hassan@medtronic.com	DTU Photonics
Hamed	Safafar	Mr.	hasaf@food.dtu.dk	DTU Food
Hamid	Chivaee	Postdoc researcher	hsar@dtu.dk	DTU Wind Energy
Hannah	Swee	PhD Fellow	hannah.swee@anthro.ku.dk	University College London and CPHU
Hanne	Østergård	Professor	haqs@kt.dtu.dk	DTU Chemical Engineering
Hanne	Thomasen	Ph.D.	hthom@space.dtu.dk	Polar DTU
Hans Hvidtfeldt	Larsen	Dr.	hala@dtu.dk	DTU Natlab
Harilaos	Psaraftis	Professor	hnpsar@transport.dtu.dk	DTU Transport
Helena	Rasmussen	Industrial PhD Student	heras@dongenergy.dk	DTU Chemical Engineering
Helene Lunde	Robertsen	Ph.D. student	helur@bio.dtu.dk	DTU Biosustain
Henrik	Saxe	Dr. Agro.	Henrsa@dtu.dk	DTU Management Engineering
Henrik	Engell-Hedager	Research Coordinator	hene@vet.dtu.dk	DTU Vet
Henrik	Gudmundsson	Senior Researcher	hgu@transport.dtu.dk	DTU Transport
Hjalte J. Danielsen	Sørup	Assistant Professor	hjds@env.dtu.dk	DTU Environment
Hyun Uk	Kim	Guest Research Assistant Prof.	hukkim@biosustain.dtu.dk	DTU Biosustain
Ida	Heebøll	EU adviser	ida.heeboell@regionh.dk	creoDK
Ioanna	Karagali	Researcher	ioka@dtu.dk	DTU Wind Energy
Ioannis S.	Chronakis	Associate Professor	ioach@food.dtu.dk	DTU Food
Irina	Borodina	Dr.	irbo@biosustain.dtu.dk	DTU Biosustain
Jacob	Larsen	Post doc	jacb@fysik.dtu.dk	DTU Physics
Jakob Berg	Johansen	Research assistant	jajoh@byg.dtu.dk	DTU Civil Engineering
Jane H.	Nielsen	Institutdirektør	jane@fysik.dtu.dk	DTU Physics
Jeannette	Ekstrøm	Information Consultant	jeek@dtic.dtu.dk	DTU Library
Jennifer	Fiebig	Master of Arts in Architecture	jenfi@byg.dtu.dk	DTU Civil Engineering
Jens	Mølgaard Pedersen	PhD Student	jkmpe@fotonik.dtu.dk	DTU Photonics

Jens E.	Wilhjelm	Professor	jw@elektro.dtu.dk	DTU Electrical Engineering
Jens Juul	Rasmussen	professor	jjra@fysik.dtu.dk	DTU Physics
Jesper	Rasmussen	Dr	jeras@fysik.dtu.dk	DTU Physics
Jesper	Holck	Researcher	jeh@kt.dtu.dk	DTU Chemical Engineering
Jesper	Hanberg	PhD.	jehan@danchip.dtu.dk	DTU Danchip
Jesper Graa	Andreasen	PhD Student	jgan@mek.dtu.dk	DTU Mechanical Engineering
Joachim	Holbøll	Vicecenterleder	jh@elektro.dtu.dk	DTU Electrical Engineering
João	Cardoso	PhD Student	joaca@biosustain.dtu.dk	DTU Biosustain
Jochen	Förster	Professor MSA	jfor@biosustain.dtu.dk	DTU Biosustain
Jonas	Michael-Lindhard	Cand. Scient.	jml@danchip.dtu.dk	DTU-Danchip
Ju	Feng	Post-Doc	jufen@dtu.dk	DTU Wind Energy
Julie	Kirkegaard	Phd student	julki@nanotech.dtu.dk	DTU Nanotech
Jun	Chen	PostDoc	junch@food.dtu.dk	DTU Food
Jørgen	Schlundt	Professor	jors@dtu.dk	DTU Management Engineering
Jørgen Juncher	Jensen	Professor	jjje@mek.dtu.dk	DTU Mechanical Engineering
Jørn	Smedsgaard	Forskningschef	smeds@food.dtu.dk	DTU Food
Kai	Zhuang	Research Scientist	kazh@biosustain.dtu.dk	DTU Biosustain
Karen	Birkelund	Dr.	kabi@danchip.dtu.dk	DTU Danchip
Karen	Stephansen	PhD student	kaste@food.dtu.dk	DTU Food
Kasper	Kistrup	PhD-Student	kkis@nanotech.dtu.dk	DTU Nanotech
Katrine	Landbo	Project coordinator	kal@kt.dtu.dk	DTU Chemical Engineering
Kim	Pilegaard	Professor	kipi@kt.dtu.dk	DTU Chemical Engineering
Klaus	Mogensen	Assoc. Prof.	klaus.mogensen@nanotech.dtu.dk	DTU Nanotech
Kostyantyn	Pivnenko	MSc	kosp@env.dtu.dk	DTU Environment
Kristian	Mølhave	Lektor	kristian.molhave@nanotech.dtu.dk	DTU Nanotech
Kristina	Enders	Cand. MSc.	kren@aqua.dtu.dk	DTU Aqua
Lasse Bo	Nielsen	Ph.D student	lbni@kemi.dtu.dk	DTU Chemistry
Laura	Dato	PhD	ldat@biosustain.dtu.dk	DTU Biosustain
Leif Sønderberg	Petersen	MSc	lepe@dtu.dk	DTU Natlab
Leifeng	Chen	Dr.	leich@biosustain.dtu.dk	DTU Systems Biology
Lene	Reeh	Administrative Officer	lenre@adm.dtu.dk	AFR
Leon	Mishnaevsky Jr.	Senior Researcher, Dr. habil.	lemi@dtu.dk	DTU Wind Energy
Line	Munk	Phd	lmun@kt.dtu.dk	DTU Chemical Engineering
Line	Hagner Nielsen	Postdoc	lihan@nanotech.dtu.dk	DTU Nanotech
Line Gry	Knudsen	Education Lead	line@climate-kic-nordic.org	DTU Climate KIC
Ling	Sun	Dr.rer.nat	lisu@nanotech.dtu.dk	DTU Nanotech
Lisbet	Michaelsen	Sustainability Coordinator	limi@dtu.dk	Campus Service
Lone	Gram	Professor	gram@bio.dtu.dk	DTU Systems Biology
Lone Falsig	Hansen	Senior Executive Research Offic	lfal@adm.dtu.dk	Research and Relations
Lotte Bjerregaard	Jensen	Associate Professor	lbj@byg.dtu.dk	DTU Civil Engineering
Louise	Belmonte	Assistant professor	lojon@byg.dtu.dk	DTU Civil Engineering
Louise	Hindenburg	Academic Officer	lohi@adm.dtu.dk	Student Affairs
Maj Munch	Andersen	Senior Reearcher	mmua@dtu.dk	DTU Management Engineering
Maria	Grishkova	PhD student	mgri@food.dtu.dk	DTU Food
Maria Helbo	Ekgreen	phd student	mheek@food.dtu.dk	DTU Food
Marianne	Dybdahl	PhD	mdyb@food.dtu.dk	DTU Food
Marie Inger	Dam	Research Assistant	madam@biosustain.dtu.dk	DTU Biosustain
Mark	Olsen	Post doc.	maol@nanotech.dtu.dk	DTU Nanotech
Marta	Matos	PhD student	mrama@biosustain.dtu.dk	DTU Biosustain
Martin	Dufva	Associate Professor	martin.dufva@nanotech.dtu.dk	DTU Nanotech
Matthias	Keil	Dr.	makei@danchip.dtu.dk	DTU Danchip
Mhairi	Workman	Associate Professor	mwo@bio.dtu.dk	DTU Systems Biology
Michael	Andersson	phd	mica@fysik.dtu.dk	DTU Physics
Michael	Løiten	Phd Student	mmag@fysik.dtu.dk	DTU Physics
Michael	Hauschild	Professor	mzha@dtu.dk	DTU Management Engineering
Michael Engelbrecht	Nielsen	Associate Professor	mice@food.dtu.dk	DTU Food
Michael Havbro	Faber	Professor, Head of department	mihf@byg.dtu.dk	DTU Civil Engineering
Mickey	Gjerris	Associate Professor, Ph.D	mickeygjerris@gmail.com	Learning Lab
Mikael	Elbæk	Senior Project Officer	miel@dtu.dk	Office for Bibliometrics and Data Man.
Mikkel	Mar	M. Sc.	mdyma@danchip.dtu.dk	DTU-Danchip
Mikolaj	Owsianiak	PhD	miow@dtu.dk	DTU Management Engineering
Mingaudas	Kalvaitis	Master student	s142426@student.dtu.dk	DTU Transport
Miriam	Varón Izquierdo	Postdoc	mirva@fysik.dtu.dk	DTU Physics
Mogens Bjerg	Mogensen	Prof., Ph.D.	momo@dtu.dk	DTU Energy conversion
Mogens Rysholt	Poulsen	Head of Department	mogens.poulsen@nanotech.dtu.dk	DTU Nanotech
Mohammad (nafi)	Al-Sabi	RESEARCHER	MOALS@VET.DTU.DK	DTU Vet
Monia	Niero	Postdoc	monni@dtu.dk	DTU Management Engineering
Morten	Birkved	Associate professor	birk@dtu.dk	DTU Management Engineering
Morten	Ryberg	MSc	moryb@dtu.dk	DTU Management Engineering
Morten	Willatzen	Professor, PhD	morwi@fotonik.dtu.dk	DTU Photonics
Nabin	Aryal	PhD student	naba@biosustain.dtu.dk	DTU Biosustain
Niels B.	Larsen	Professor	niels.b.larsen@nanotech.dtu.dk	DTU Nanotech
Niki	Bey	Associate Professor	niki@dtu.dk	DTU Management Engineering
Nis Korsgaard	Andersen	PhD-Student	nikoa@nanotech.dtu.dk	DTU Nanotech
Nuno	Cosme	PhD student	nmdc@dtu.dk	DTU Management Engineering
Ole	Sigmund	Professor	sigmund@mek.dtu.dk	DTU Mechanical Engineering
Ole	Bang	Professor	oban@fotonik.dtu.dk	DTU Photonics
Ole	Schultz	Associate Professor	osch@dtu.dk	DTU Ballerup Campus
Ole	Høyberg	Special consultant	ohoy@adm.dtu.dk	Div. for Innovation and sector devel.
Oleg	Lysenko	Mr.	ollyse@fotonik.dtu.dk	DTU Photonics
Patama	Pholprasit	M. Sc.	paphol@dtu.dk	DTU Danchip
Paul Michael	Petersen	Professor	pape@fotonik.dtu.dk	DTU Photonics
Per Anker	Jensen	Professor	pank@dtu.dk	DTU Management Engineering

Peter	Fantke	Assistant Professor	pefan@dtu.dk	DTU Management Engineering
Peter	Fristrup	Associate Professor	pf@kemi.dtu.dk	DTU Chemistry
Peter	Kjeldsen	Professor	pekj@env.dtu.dk	DTU Environment
Peter	Holtappels	Professor MSO	peho@dtu.dk	DTU Energy conversion
Peter	Vesborg	Ass. Professor	peter.vesborg@fysik.dtu.dk	DTU Physics
Peter Andreas	Sattrup	Associate Professor	pans@byg.dtu.dk	DTU Civil Engineering
Peter Ruhdal	Jensen	Professor	perj@food.dtu.dk	DTU Food
Peter Steen	Mikkelsen	Professor	psmi@env.dtu.dk	DTU Environment
Pier-Luc	Tremblay	Researcher	pitre@biosustain.dtu.dk	DTU Biosustain
Pil	Møntegaard Fredericia	PhD-student	pilf@dtu.dk	DTU Nutech
Poul	Norby	Dr.	pnor@dtu.dk	DTU Energy conversion
Ramneek	Gupta	Associate Professor	ramneek@cbs.dtu.dk	DTU Systems Biology
Rasmus	Halvgaard	Industrial Postdoc	rhal@dtu.dk	DTU Compute
Rasmus	Fehrmann	Professor	rf@kemi.dtu.dk	DTU Chemistry
Roberto	Turconi	PhD	robt@env.dtu.dk	DTU Environment
Robin	Lenz	stud. MSc.	roble@aqua.dtu.dk	DTU Aqua
Rokon	Uddin	MSc	rokud@nanotech.dtu.dk	DTU Nanotech
Rune	Hjorth	Ph.D Student	ruhj@env.dtu.dk	DTU Environment
Samuel Brüning	Larsen	Ph.D. student	sbla@dtu.dk	DTU Management Engineering
Sara	Engberg	PhD student	sleen@fotonik.dtu.dk	DTU Photonics
Seunghwan	Lee	Dr.	seele@mek.dtu.dk	DTU Mechanical Engineering
Shruti Harnal	Dantoft	Postdoctoral Researcher	shrh@food.dtu.dk	DTU Food
Sofie	Wendel	PhD student	sowen@biosustain.dtu.dk	DTU Biosustain
Solvej	Siedler	Dr.	ssie@biosustain.dtu.dk	DTU Biosustain
Soren	Hansen	Chemical Engineer	smh@adm.dtu.dk	Innovation and Sector Services
Starrlight	Augustine	PhD	staug@aqua.dtu.dk	DTU Aqua
Steen	Nordentoft	Senior researcher	snni@food.dtu.dk	DTU Food
Stefan	Neuenfeldt	Ph.D.	stn@aqua.dtu.dk	DTU Aqua
Steffen	Foss Hansen	Ph.d.	sfh@env.dtu.dk	DTU Environment
Stig Irving	Olsen	Associate Professor, PhD	siol@dtu.dk	DTU Management Engineering
Stina	Frosch	Associate professor	sfro@food.dtu.dk	DTU Food
Sune	Ebbesen	Dr.Ir	sueb@dtu.dk	DTU Energy conversion
Susan Løvstad	Holdt	-	suho@food.dtu.dk	DTU Aqua
Susanne Balslev	Nielsen	Associate professor	sbni@dtu.dk	DTU Management Engineering
Søren	Molin	Prof. PhD	sm@bio.dtu.dk	DTU Systems Biology
Søren	Aabo	Senior Researcher	sabo@food.dtu.dk	DTU Food
Tais	Pinheiro	MEM	tais.smp@gmail.com	
Tao	Li	PhD	taoli@nanotech.dtu.dk	DTU Nanotech
Thomas	Astrup	Associate Professor	thas@env.dtu.dk	DTU Environment
Thomas	Aarup Larsen	Project Coordinator	thlar@transport.dtu.dk	DTU Transport
Thomas Aarøe	Anhøj	PhD	taran@danchip.dtu.dk	DTU Danchip
Tian	Zhang	Senior Researcher	zhang@biosustain.dtu.dk	DTU Biosustain
Tilmann	Weber	Senior Scientist	tiwe@biosustain.dtu.dk	DTU Biosustain
Tina E	Nielsen	Educational consultant	tien@llab.dtu.dk	LearningLab DTU
Tine	Greibe	PhD	tigre@danchip.dtu.dk	DTU Danchip
Trine	Arndal	M.Sc. Chemical Engineering	trina@kt.dtu.dk	DTU Chemical Engineering
Uffe	Møller	Researcher	ufmo@fotonik.dtu.dk	DTU Photonics
Ulla Høeberg	Jørgensen	Specialkonsulent	uhoej@adm.dtu.dk	AFR/Forskningskontoret
Vahab	Akbari	candidate student	s112156@student.dtu.dk	DTU Civil Engineering
Veronica	Martinez Sanchez	PhD Student	vems@env.dtu.dk	DTU Environment
Veronika	Hansen	PhD student	veha@kt.dtu.dk	DTU Chemical Engineering
Vibeke Tine	Aagaard Pedersen	Administrative Officer	vtap@adm.dtu.dk	AFR
Vida	Krikstolaityte	PhD	vkri@nanotech.dtu.dk	DTU Nanotech
Vincent M. E.	Edjabou	Ph.D	vine@env.dtu.dk	DTU Environment
Volker	Naulin	Professor	vona@fysik.dtu.dk	DTU Physics
Vratislav	Stovicek	Ph.D.	vrast@biosustain.dtu.dk	DTU Biosustain
Xiaochen	Yang	Ph.D student	xiaya@biosustain.dtu.dk	DTU Systems Biology
Xinglin	Jiang	postdoc	xinji@biosustain.dtu.dk	DTU Biosustain
Yaojun	Tong	Dr.	yato@dtu.dk	DTU Biosustain
Yi	Sun	Assistant Professor	sun.yi@nanotech.dtu.dk	DTU Nanotech
Zhihao	Wang	-	zhiwan@food.dtu.dk	DTU Aqua
Zsófia	Kádár	Researcher	zska@kt.dtu.dk	DTU Chemical Engineering