Annual Report 2016
Key numbers of 2016

The vision of DTU Chemical Engineering is to be acknowledged as a world-leading chemical and biochemical engineering department. Below we have listed a selection of our key results of 2016 to show how they support our strategic objectives.

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<th>STRATEGIC AREA</th>
<th>VISION</th>
<th>RESULTS IN 2016</th>
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<tr>
<td>RESEARCH</td>
<td>Supports the development of sustainable solutions in the fields of chemistry, biotechnology, food, pharma, and energy through research and scientific advice.</td>
<td>239 SCIENTIFIC ARTICLES IN WOS-INDEXED JOURNALS, 3 BOOKS &amp; MONOGRAPHS, 12 CONTRIBUTIONS TO BOOKS, 35 PHD THESIS</td>
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<tr>
<td>INNOVATION</td>
<td>An attractive partner for university departments and research-based industry.</td>
<td>16 ACCEPTED PATENT IDEAS &amp; SPIN-OUTS, 8 INDUSTRIAL PHDS, 2 INDUSTRIAL POSTDOCS In cooperation with Haldor Topsøe, Hempel, Dupont, Novozymes, Valund, Rockwool International, Unibio, PHX Innovation, and Grundfos</td>
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<tr>
<td>EDUCATION</td>
<td>Helps to retain, develop, and attract knowledge-based national working places, including companies with affiliates abroad.</td>
<td>298 STUDENTS (STÅ**), 20 SINO-DANISH STUDENTS (STÅ**), 15 COMPLETED BENG PROJECTS, 32 COMPLETED BSC PROJECTS, 67 COMPLETED MSC PROJECTS</td>
</tr>
<tr>
<td>ORGANIZATION</td>
<td>Attractive place to work for ambitious and technology-passionate staff members.</td>
<td>47 TECHNICAL/ ADMINISTRATIVE EMPLOYEES, 98 PHD STUDENTS, 95 SCIENTIFIC EMPLOYEES—INCLUDING 33 FACULTY</td>
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240 EMPLOYEES IN TOTAL *

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<th>STAFF DISTRIBUTED BY AGE:</th>
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<td>35% 20-29</td>
<td>4% AFRICA</td>
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<tr>
<td>29% 30-39</td>
<td>34% ASIA</td>
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<tr>
<td>14% 40-49</td>
<td>53% EUROPE</td>
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<tr>
<td>13% 50-59</td>
<td>5% MIDDLE EAST</td>
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<tr>
<td>8% 60-69</td>
<td>1% NORTH AMERICA</td>
</tr>
<tr>
<td>1% 70-79</td>
<td>3% SOUTH AMERICA</td>
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* 1 JANUARY - 1 DECEMBER 2016
** ONE STÅ IS THE EQUIVALENT OF ONE STUDENT STUDYING FULL TIME FOR A YEAR
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### EDUCATION

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## USEFUL INFORMATION

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Front page photo: Rolf H. Ringborg and Mafalda Costa Artur Dias working on an experimental setup for the automated kinetic characterization of enzymes. Photo by Thorkild Christensen
Behind the process
Frederico Montes and Carlos Eduardo Castelan behind a large stirred tank which they are using for process intensification of gas-liquid bioreactors—a core research area at the CAPEC-PROCESS Research Centre where they work as PhD-students.

Photo: Thorkild Christensen
Welcome to this Annual Report 2016 where we proudly present a small selection of our great many activities during this year within education, research, and innovation.

DTU’s study programmes are becoming increasingly popular and in terms of student intake, 2016 was a year for the record books. One of the most popular branches of study was ‘Chemistry and Technology’, the qualifying main BSc for the MSc programmes which our department offers.

As a result, we are working hard to accommodate a reality where students not only have many different backgrounds, but also consume information in many different ways. This calls for innovative teaching methods, resulting this year in several e-learning videos that can be viewed on the digital platforms that our students use.

Innovation also goes hand in hand with research at our department. As the competition for research funds becomes fiercer, collaboration with our industrial partners accordingly becomes an important factor. Our research centres have extensive cooperation with both large global and small enterprises. It is from these relations that real innovation emerges. This year, we were proud to see that some of our innovative efforts were acknowledged with innovation awards from the Confederation of Danish Industry (DI) and at the international integrated water cycle show, iWater, in Barcelona.

Collaboration and through this, research, is further strengthened through the many conferences and annual discussion meetings that our researchers travel far to attend, as well as the ones we host ourselves. This year, we hosted ‘PetroPhase 2016’, the 17th International Conference on Petroleum Phase Behavior and Fouling, and we hosted the 6th international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles. Both conferences were well-attended by industry and academia from all over the world. These meetings and conferences are important because they provide the opportunity for interchange of knowledge and thereby ensures that the research we conduct here at our department is useful to society. Adding to this, we also this year launched a cross-departmental ‘KT Consortium’ which we will grow to include many more relevant partners in the future. Furthermore, long-term agreements with Novozymes and Lundbeck have been extended this year, and we received the first generous grant to establish The Hempel Foundation Coatings Science and Technology Centre. Accordingly, we look forward to welcoming even more PhD students in the coming years.

The increasing number of students and research activities means that our department is growing. Just as 2016 was coming to an end, we reached an important milestone: The blueprint for our building expansion which will provide a better working environment, an improved study environment, and further development of research facilities.

I would like to close this preface by expressing my deepest gratitude to our many dedicated employees for their hard work and to thank our many national and international partners in industry and academia for sharing their knowledge and views with us. I hope you will enjoy reading about some of the many exciting results we have achieved together.

Kim Dam-Johansen
Professor, Head of Department
The first graduates from the Sino-Danish programme

Graduation caps and dreams of the future were in the air when the very first graduates of the Sino-Danish programme in Chemical and Biochemical Engineering were celebrated at a festive ceremony in Beijing. Congratulations from DTU Chemical Engineering!

Photo: Yang Tian Peng
HIGHLIGHTS 2016

JANUARY

1 January
PROF. RAFIQUL GANI CONTINUES AS PRESIDENT OF EFCE
After two years as President of the European Federation of Chemical Engineering (EFCE), Professor Rafiqul Gani started his second term on 1 January 2016.

SELF-HEALING RUBBER GOES FOR COMMERCIALIZATION
The Danish Polymer Center (DPC) received a grant from the DTU Proof-of-Concept Fund which enables researchers to get new technology ready for the market and make it possible to test it in other products. DPC aims to expand the lifespan of many often expensive products by delivering the right recipe for self-healing silicone rubber.

FEBRUARY

10,000 FOR STUDENTS GOING TO CHINA
DTU’s Teknisk Kemisk Fond has established a new grant of up to DKK 10,000 to cover travel and start-up costs for Danish students who are accepted into the Chemical and Biochemical Master’s programme at the Sino-Danish Center in Beijing.

25 February
ELITEFORSK TRAVEL GRANT FOR PHD STUDENT
PhD Student Sofie Thage Morthensen from DTU Chemical Engineering was presented with the EliteForsk travel grant and honoured by HRH Crown Princess Mary and the (former) Danish Minister for Higher Education and Science, Esben Lunde Larsen. EliteForsk recognizes some of Denmark’s most talented researchers who set the bar high and strive to be the best in their individual fields.

MARCH

31 March
MULTICULTURAL INSIGHTS FOR INTERNATIONAL WORK
The administrative group got to walk a day in their international colleagues’ shoes in a course on ‘cultural intelligence’, providing insights that will strengthen the daily cooperation and understanding in the multicultural work environment that our department provides with more than 37 different nationalities.

APRIL

STUDENTS EXCEL AT PETROBOWL QUALIFIERS
Out of more than 20 teams from student chapters within the European region, Krystian Grzegorz Klepczyk, Adam Marczyński, Hadise Baghooe, Marton L. Szanyi, and Stefano Tafliaferri ranked among the top four elite teams in the Regional Petrobowl Contest—a great achievement and so far the best ranking in the history of DTU SPE Student Chapter.

26 April
DANISH SCIENCE FESTIVAL
DTU once again opened the doors to the public in order to showcase the best of science at the annual Danish Science Festival. Visitors were shown around the pilot plant, given a lecture on the history, future, and dynamics of volcanos and presented with laboratory examples of microfluidics.

26 April
HEMPEL-DTU AWARD FOR RYBNERS HIGHSCHOOL
The Hempel DTU award was given to Rybners high school for their dedication to and encouragement of science. The award was presented by DTU Dean, Martin Vigild as part of the ‘Young Scientists’ finals at the ‘Science in Forum’ event.
29 April
GOLD MEDAL, SAFETY PRIZE, AND SCIENTIFIC SPEECH

Representation was strong at this year’s DTU Commemoration Day. Professor Ole Hassager received the Julius Thomsen gold medal for excellent research throughout many years. Head of PILOT PLANT, Lars Kjærboe was honored with the Safety Prize for his long lasting dedication to help the students and employees get home safe. And, Professor Anne Meyer gave the evening’s scientific speech on ‘Biocatalysis for the future’.

MAY

1-7 May
PROF. KONTOGEORGIS APPOINTED ADJUNCT PROFESSOR
Head of AT CERE and professor Georgios Kontogeorgis visited Xi’an Jiaotong University in Xianyang, China, where he had the honour of being appointed adjunct professor to the university.

27 May
RESEARCH DAY

This year’s Research Day included poster presentations and a speech on innovation by DTU’s Senior Vice President for Innovation and Entrepreneurship, Marianne Thellersen. PhD student Sara Wingstrand took home the Best Research Award for her work on optimizing polymeric fibre, while the Best Innovation Award went to PhD student Arne Gladis who has developed a kinetic model to predict the mass transfer of CO₂ in carbon capture technology.

JUNE

14-15 June
EAP CONFERENCE

Danish Polymer Center hosted the 6th international conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles. 110 researchers from all over the world as well as several companies and research groups exhibited their knowledge about dielectric elastomer based products.

19-23 June
PETROPHASE 2016

PetroPhase 2016—The 17th International Conference on Petroleum Phase Behavior and Fouling was held in Elsinore, Denmark. The international conference was aimed at researchers in industry and academia dedicated to the study of the properties and chemistry of petroleum fluids and their effect on producing, processing, and refining in the upstream, mid-stream, and downstream industries. 180 people from all over the world attended this year’s conference.

29 June
FIRST GRADUATES FROM SINO-DANISH PROGRAMME

Graduation caps and dreams of the future were in the air when the very first graduates of the Sino-Danish programme in Chemical and Biochemical Engineering were celebrated at a festive ceremony in Beijing. Congratulations to the graduates!
While most DTU students were enjoying their holiday, the campus grounds were kept alive and kicking by Summer University participants from all around the world. 69 students came from the US universities Auburn, Case Western Reserve University, Virginia Tech, University of Alabama, Texas A&M University, and Johns Hopkins University. Another 5 students participated from Denmark and Portugal. 14 students from the Sino-Danish Center (SDC) also participated in the summer university course.

Solutions, socializing, and Segways. The scene for student-industry networking was set in Sorø at the annual BIOPRO World Talent Campus event, bringing together talents from all parts of the biochemical world. The Novo Nordisk Foundation was of course present as the sponsor of WTC, but also Chr. Hansen, CP Kelco, and Novozymes took part as well as the University of Copenhagen (KU-FOOD).

Marlène Vuillemin was granted a H.C. Ørsted COFUND postdoc fellowship enabled by the European Union’s Marie Skłodowska-Curie actions. She will spend the next two years researching a ‘Novel route to humanized glycoproteins by designed trans-sialidases (DESIGNGLYCO)’.

PhD student, Yashasvi Laxminarayan won the Richard W. Bryers award for the best student contribution at IFQ 2016 at the Czech Technical University in Prague.

Champagne corks were popping at DTU’s PhD reception for former students who submitted their PhD dissertation in 2016. At the celebration, Associate Professor and Head of the Danish Polymer Centre (DPC), Anne Ladegaard Skov, was presented with the honourable award PhD Supervisor of the year.

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NOVEMBER

9 November
HIGH SCHOOL INVASION
Passing on knowledge to the younger generations was at heart on 9 November. At the Danish Polymer Centre, Associate Professor Anders Egede Daugaard welcomed high school teachers into the Hempel Lab to play with polymers. In the other buildings, 63 students from Odense Tekniske Gymnasium were enjoying part of their Hempel-DTU prize: A visit to Lyngby Campus.

INNOVATION AWARD FOR WATINTECH PROJECT
An innovation award was given at the International Integrated Water Cycle Show in Barcelona to the inter-disciplinary project WATINTECH which covers the whole value chain around wastewater and urban run-off. Senior Researcher Xavier Flores-Alsina from CAPEC-PROCESS is in charge of WP5 (modelling and system-wide optimization).

30 November
AWARD AT DTU SUSTAIN CONFERENCE
PhD student Magnus Stummann (photo: in the back on the left) from CHEC research centre won a poster award for his work with the H2CAP project which this year succeeded in developing a new process for producing high-quality bio-fuel from beech tree.

DECEMBER

4 December
MOVIE AWARD FOR SCIENCE CARTOONS
At the ’2016 European Science TV and New Media Festival’ in Lisbon the animated Microfluidics trilogy explaining the science of the two EU projects BIOINTENSE and EUROMBR won. The trilogy also won ’Best Animation Cartoon 2016’ at the The Shortfest International in Malta and won silver in the Web/TV-Animation for Bleech.

4X25 YEARS IN SERVICE OF THE STATE
We wish to congratulate Associate Professor Flemming Jappe Frandsen (1 Feb), Professor Anker Degn Jensen (1 Aug), Associate Professor Peter Szabo (2 Oct), and Project Manager Michael Krogsgaard Nielsen (12 Nov) on their 25-year anniversaries this year.

CONTRIBUTIONS TO OUR BOOKSHELVES THIS YEAR
This year, the book ‘Fundamental Bio-Engineering’—edited by the prominent Professor Emeritus John Villadsen—finally found its way to our bookshelves. In addition, a new book on Applied Colloid and Surface Chemistry was written by Professor Georgios Kontogeorgis and Associate Professor Søren Kiil. The book is for use in our MSc course of the same name and is available on wiley.com. Professor Rafiqul Gani also co-authored the 4th Edition of the book ‘Product and Process Design Principles’ with professors Seider, Lewin, Widagdo and Ng. Several staff members have contributed to books which you can read about in page 47. For instance, Professor Krist Gernaey and Associate Professor Gürkan Sin contributed with a chapter on ’Data Handling and Parameter Estimation’ to the book ‘Experimental Methods in Wastewater Treatment’. The book has so far been downloaded more than 20,000 times—an amazing result for a technical book.

FIRST TWO INDUSTRIAL POSTDOCS
Innovation Fund Denmark has initiated an Industrial Postdoc programme—a collaboration between companies and research institutions about solving specific research and development tasks. This year, Seyednezamaddin Azizaddini was hired by PHX Innovation and Piotr Mazurek was hired by Grundfos.
“Scientific research at university level is a prerequisite for the development of Lundbeck’s chemical activities in Denmark. We have had a beneficial partnership with DTU Chemical Engineering for several years, collaborating on PhD projects and recruiting several of the department’s candidates. Furthermore, it has been a great advantage to be able to draw on the knowledge of DTU Chemical Engineering’s scientific staff as advisors/consultants.”

“Working closely with the best research groups within the fields of our core competences is of major importance to Haldor Topsoe A/S. Our cooperation with DTU Chemical Engineering enables us to resolve research challenges beyond our competences and resources and is an important source of inspiration and knowledge for employees at Haldor Topsoe, benefitting their own and the company’s development.”

“The close cooperation with DTU Chemical Engineering has ensured significant results in a lot of industries. Long-term focus on development and innovation is necessary to meet the ever-changing opportunities, rules, legislation, and profitability demands that all industries are faced with. DTU Chemical Engineering ensures a high level of education, motivated candidates, and industrial cooperation in important research projects that will lead to technologies of the future.”
RESEARCH CENTRES

DTU Chemical and Biochemical Engineering is home to six research centres—each focusing on their area of expertise. Below you can get a quick overview of the centres and their respective research areas. To learn more about our research in details, recent results, or current projects, please visit www.kt.dtu.dk/research.

▶ CAPEC-PROCESS

Process Systems Engineering (PSE), Process Intensification and Integration (PII), process design and control, industrial fermentation technology, biocatalysis, microfluidics

Contact: Professor
Krist Gernaey
kv@kt.dtu.dk
Phone: +45 4525 2970

▶ PILOT PLANT

Designing and building large-scale plants, Unit operations, Industrial chemical processes, Operational experience, Design of components, Plant safety, Good Manufacturing Practice

Contact: Lars G. Kjærboe
lgk@kt.dtu.dk
Phone: +45 4525 2857

▶ AT CERE


Contact: Professor
Georgios Kontogeorgis
gk@kt.dtu.dk
Phone: +45 4525 2859

▶ BIOENG

Enzyme engineering, Bioprocess enzyme technology, Biofuel production, Reactive separation technology, Biorefinery and sustainability

Contact: Professor
Anne S.Meyer
am@kt.dtu.dk
Phone: +45 4525 2800

▶ CHEC

Catalysis, Inorganic chemistry, Combustion and flue gas cleaning, Diagnostics, Gasification, Pretreatment of biomass, Coatings, Pharmaceuticals

Contact: Professor
Kim Dam-Johansen
kdj@kt.dtu.dk
Phone: +45 4525 2845

▶ DPC

Polymer technology, polymer chemistry, rheology, filament stretching rheology, surface modification, silicone polymers and elastomers

Contact: Associate Professor
Anne Ladegaard Skov
al@kt.dtu.dk
Phone: +45 4525 2825

COOPERATING COMPANIES

A.P. Møller-Mærsk
Addifab
Agro Korn
Akzo Nobel
Alfa Laval
Aminord
Aquaporin
ARKEMA FRANCE
Arla Foods
ART photonics
AstraZeneca
AT Sea Technologies
B&B Energy
Babcock & Wilcox Valund
BASF AG
BAWAT
Bayer Technology Services
BIC
Biofoss
BioProdict
BP
Calsep
Carlberg
Carigil
CelluComp
ChemStream
ChemProcessTechnologies
Chevron
Chr. Hansen
CLEA
c-LEcta
Coloplast
Conocophillips
CP Kelco
C-Tech
Dansk Gasteknisk Center
DDH
DONG Energy
DSM
DuPont
Esbjerg Farve- og Lakfabrik
eCoast Marine Research
Envidan
Evocatal
Evonik
ExxonMobil
FCC Aqualia
FiberVisions
Firmenich
Fermentationexperts
FLSmidth
Foss
FreeSense
GASSCO
GASSNOVA
GDF-SUEZ
GEA Process Engineering
Gelast
Genencor
Givaudan
GlucoSmithKline
Grundfos
H Lundbeck
Haldor Topsøe
Hempel
Hess
HOFOR
Hortimare
Hwam
Højmarks Group BHJ
IFP
Janssen Pharmaceutica
KBC
KMC
LEAP Technology
LEGO
Lentikats
Leo Pharma
LevOss
Lihne Protein
Solutions
Linde
Lloyd’s Register ODS
Lonza AG
Luxcel
Maersk Oil
MAN Diesel & Turbo
Melissa
Meneta
Microfluidic ChipShop
Micronit
Milliken
Mitsubishi
MOL
Morgenfrueerne
NamornyP
National Oilwell Varco
Neste Jacobs Oy
Nordic Bioenergy
Nordic Sugar
Nordisk Tang
Novo Nordisk
Novozymes
OMV
Ocean Rainforest
Petrobras
PHX Innovation
PPC Industries
Processium
ProSim
Prozomix
Radometer Medical
Rambøll
Rockwool
RWE
S&amp;M Offshore
Schlorberger
Schneider Electric
Shell
Sigma Aldrich
Sika
Sinopec
Sintef
Solvionic
S-PACT
SpinChem
SQM
Statoil
Supren
Syngenta
Teknologisk Institut
Tetra Pak Packaging Solutions
Total
Trioplast
Unibio
UNILEVER
Union Engineering
Umeda Krüger
Wacker
Welttec
Xella Pharmaceuticals

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A large part of the oil recovered in Denmark comes from underground chalk reservoirs in the Danish part of the North Sea. In the laboratories of DTU Chemical Engineering, researchers inject brines of different salinity into samples of chalk saturated with oil in order to push out the oil—a method known as 'smart water flooding'. The progress is then monitored using X-ray computer tomography scanning.

Photo: Thorkild Christensen
Age. Obesity. Diabetes. Threats to our health that are both widespread and rising. They are also the most common causes for chronic wounds—not only painful to the patients, but often complex and expensive to treat. At DTU Chemical Engineering, a PhD project could make a difference.

**Facts about the project**

The project by Piotr Mazurek is entitled ‘Glycerol-silicone elastomers as active membranes for wound dressings and beyond’.

Supervisors: Associate Professor Anne Ladegaard Skov (DTU) and Professor Michael A. Brook (McMaster University, Canada)

Objective: A list of features for an ideal chronic wound dressing has been proposed, which works as a guideline for our research. The list includes wound debridement, maintaining moist environment and gaseous exchange, absorption of blood and excess exudate, preventing infections, providing thermal insulation, low adherence, and cost-effectiveness. The aim was to create a material that would meet most (or all) these requirements and eventually create an attractive chronic wound care product.

A two-phase glycerol-silicone elastomer has been proposed as a novel membrane for wound dressings. It was discovered that this hybrid material is capable of releasing active substances when exposed to an aqueous medium. Various properties of the material (e.g. water permeability, water vapour transmission rate, water absorption, and ability to deliver active substances) were investigated and these were confronted with requirements of chronic wound treatment. Initial results are very optimistic and prove that it is possible to tune most of these properties.
Membrane can help patients with chronic wounds

Most of us take for granted the amazing ability of our skin to heal itself. Yet, the reality for the 6.5 million patients affected by chronic wounds in the US in 2008 was quite different. At that time, it was estimated that around USD 25 billion was spent annually on treating chronic wounds. And due to the ageing population and a sharp rise in widespread diseases such as diabetes and obesity, the numbers are growing rapidly.

By mixing silicone with glycerol, former PhD student, now postdoc at the Danish Polymer Centre (DPC) Piotr Mazurek, has developed a completely new material which may solve 7 out of 8 of the issues on a recent ‘wish list’ for the wound dressings of the future, providing a better and more cost-efficient solution.

Low price, high impact
Glycerol is abundant in the chemical industry and therefore very cheap. In addition to this, the methodology of mixing glycerol into silicone is quite simple and should be easy to upscale. This means that producing wound dressings in this way could be very cost-effective and therefore in high demand in a market where competition is intense.

Silicone and glycerol do not really mix; however, by spinning the ingredients at a certain rate and a certain temperature, Mazurek found that he could suspend glycerol as tiny droplets inside the silicone:

“The more droplets I supplied, the more soft and stretchable the material got. In the end, the large number of droplets assembled like raindrops on a window creating a new structure in the material. This turned out to be very interesting indeed,” says Piotr Mazurek.

Extended treatment
According to Mazurek, the medicating dressings available in the market today, release most of the medicine rather rapidly and then the release slows down, which means a part of the medicine goes to waste and the dressing needs to be changed more often. The new material provides a longer period of medication, which could mean more time for other care assignments for nurses and that wounds are allowed a little more time to rest. The extended release of medicine is provided by taking advantage of glycerol’s ability to absorb. When the wound secretes fluids, the fluids are absorbed into the droplets of glycerol, which at the same time pushes out the medicine, creating this constant treatment effect.

Great potential
According to Mazurek, the combination with silicone adds some more important features from the ‘wish list’. Silicone has low adhesion which most people recognize from, for instance, baking moulds. It also insulates very well and protects the wound from temperature changes. Furthermore, silicone allows for gaseous exchange so that the skin to breathe while keeping a moist environment around the wound which is key to the healing process.

“All of these properties combined in this new material gives it great potential. Not only as a wound dressing, but also for other applications. It seems like the sky’s the limit and I’m excited to see what the future will bring”, says Piotr Mazurek.
Straw is at the heart of a PhD project which earned Sofie Thage Morthensen a visit to Belgium and a rare opportunity to synthesize her own membranes.

Photo: Christian Ove Carlsson

Glucose from straw may play a big role in the future production of many everyday products such as pharmaceuticals and clothes. An EliteForsk travel grant winning PhD project from DTU Chemical Engineering aims to uncover how new processes can help increase the value of straw and make it an effective and profitable business.

Facts

Sofie Thage Morthensen’s PhD project is entitled ‘Integration between enzyme technology and membrane separation in biorefinery processes’, and is supervised by Associate Professor Manuel Pinelo.

The project is part of the BIOVALUE SPIR strategic platform for innovation and research on value-added products from biomass.

The objective of BIOVALUE SPIR is to ensure that Denmark is a world leader in sustainable biorefining technologies and solutions for tomorrow’s bio-based society.

The Department of Chemical Engineering’s Center for BioProcess Engineering leads the competences centre within Separation for BIOVALUE.
Getting the best out of straw

As the world population continues to grow and the search for alternative resources intensifies, researchers are looking at different and more efficient ways to use the materials at our disposal. Straw—a residual product from agriculture—can be used as raw material for production of, for instance, pharmaceutical products, cosmetics, and textiles. Yet, as is the case with many concepts, finances have great influence on whether or not it will become a success. Therefore, development of cost-effective processes with maximum yield and efficiency is needed. If a PhD project at DTU Chemical Engineering goes as planned, we may be one step closer to perfecting the process in the future.

Difficult to separate

Glucose and xylose are sugars that are used to make many everyday products such as medicine and clothes. When straw is processed these sugars can be obtained, however the challenge is that glucose and xylose have very similar chemical structures and are therefore notoriously difficult to separate. A PhD project by Sofie Thage Morthensen from the Centre for Bioprocess Engineering (BioEng) could change this.

She will develop a process based on the use of membranes and enzymes in order to separate the sugar molecules in bio-refineries.

“Membranes are super selective materials and have the potential to separate sugar molecules at a higher throughput and at milder process conditions compared to other separation processes,” says Sofie Thage Morthensen.

The performance of the membranes can be even further enhanced with the use of enzymes as biocatalysts to modify the process stream. In scientific terms, the concept of integrating conversion and purification is known as ‘reactive membrane separation’. However, there is yet another challenge to this: Enzymes are expensive.

“Designing processes that enable reusability and high biocatalytic productivity is a prerequisite for cost-effective enzyme use in biorefineries,” says the PhD student.

An EliteForsk-worthy idea

The idea has earned Sofie Thage Morthensen a travel grant from EliteForsk and she believes that travelling has given her some important experiences in working with membranes.

“When I received the travel grant, my first priority was to go to a university where I could learn something completely new within my field. In BioEng I have only worked with commercial membranes, but at KU Leuven in Belgium I had the opportunity to synthesize my own membranes and do some more advanced characterization of them”, says the EliteForsk grant winner.

Theory, however, is one thing. Practical application is another. Testing the reactive membrane separation on straw is the next phase of the project—and expectations are high.

“Taking into account that most of the cost of any biorefinery process corresponds to the separation steps, membrane technology by itself has a lot to say in the development of future green processes with a more feasible exploitation of biomass. But if membrane separation is integrated with enzyme technology, the viability and simplicity of the processes can be boosted to an even higher level,” says her supervisor Manuel Pinelo who has been researching the use of membranes for biomass conversion for around eight years at DTU Chemical Engineering.
Some things are highly important, but also highly complicated. Using micro technology, the ‘Mastering integration and intensification of bioprocesses’ project—also known as BIOINTENSE—has yielded new, greener, and more efficient methods for future chemical production. The complex science of this project has furthermore been made available through a series of animated films that invite everyone with an interest in this promising technology into the ‘World of Microfluidics’.

**Facts**

BIOINTENSE is a single-stage knowledge-based bio economy (KBBE) collaborative project which started in August 2012. In collaboration with the EUROMBR project (European network for innovative MicroBioReactor application in bioprocess development) three cartoons were produced by Golderner Westen in order to disseminate the two projects to a wide audience.

The objectives of BIOINTENSE were to increase biocatalyst productivity and process intensity and thereby make way for more economically feasible processes by integration and intensification and also a shortening of the development times by developing optimized tools and protocols that can be widely applicable in industry. Furthermore, fundamental understanding on the interactions between reaction, biocatalyst and process characteristics achieved to minimize the uncertainties with respect to the cost of future biocatalytic processes. BIOINTENSE also increased understanding about the factors contributing to the total cost and environmental impact.

BIOINTENSE was EC-funded through the 7th Framework Cooperation Programme. The consortium was led by Professor John M. Woodley and manager of the project was Associate Professor Ulrich Krühne, both from the CAPEC-PROCESS research centre.

EUROMBR is a Marie Curie initial training network (ITN). The main objective of the EUROMBR project is to deliver a trans-European network of industrially oriented specialists fully trained in the development and application of microbioreactor (MBR) technology to support the progress of innovative bio-based manufacturing processes. This project is coordinated by Ulrich Krühne and managed by Nicky Ehrlich.
Welcome to the World of Microfluidics

Food, pharma, and materials for everyday products are, more often than not, the result of several chemical processes. As such, the chemical industry is on a constant search to improve these processes to ensure that they stay competitive, remain economically attractive all the while keeping a low impact on the environment.

Traditionally, chemical processes are run on large equipment and can as a result be expensive and even harmful due to considerable waste production or use of toxic substances. One solution to avoid using such processes could be to apply enzymatic bioprocesses. In enzymatic bioprocesses enzymes from nature are used as catalysts and could in this way potentially be more productive under mild reaction conditions and yielding less waste. According to Associate Professor Ulrich Krühne from the CAPEC-PROCESS research centre, it is these bioprocess methods that need to be rethought.

“It’s nearly impossible to reduce waste production without finding a way to distinguish the good enzymes from the bad. Here microfluidics can help us,” says the Associate Professor who is also the project manager of the BIOINTENSE project which was concluded this year. He continues;

“New enzymes must be designed and tested. This is the core of our project. We used a technology which first emerged in the 80’s called microfluidics. The technology enables us to control and test very small volumes of liquid and determine very precisely what works well and what does not. In this way, we can get quicker results and the small scale means we can do multiple tests at the time, making the process much more efficient”.

Multiple results in short time
Just like technology of microfluidics, the BIOINTENSE project has brought many results in very short period of time. New methods to increase biocatalyst productivity and process intensity through the development and application of novel microfluidic and modelling tools have been discovered. Furthermore, other points of progress include development of new microfluidic products, 24 mass fabrication compatible micro-reactors for further commercial application, standardization of device formats, making the systems applicable with standard laboratory equipment, new enzyme products and much more.

Animating the public
There is another important side to the BIOINTENSE project. The project aimed at communicating outside of academic circles. This was done by creating the ‘World of Microfluidics’ animation films; short explanatory cartoons that have received much recognition at several science film festivals around the world. At the Shortfest International in Malta they were awarded Best Animation Cartoon 2016. At the Annual Multimedia Award they won silver for Web/TV-Animation for Bleech, and most recently they won an award at the European Science TV and New Media Festival in Lisbon. According to Ulrich Krühne, there are three main motivations for promoting the project in this way:

“We are technical nerds here. We work in an environment where people understand our scientific lingo but of course most people are not used to this language. So communicating the project to non-technical spheres can help us with three things: Reaching young people who we will one day need to be interested in carrying on the research; making the public aware that we need to think about new and more sustainable ways to produce; and of course living up to our grant givers’ demand for communicating complex, but important science,” says Ulrich Krühne.
At DTU Chemical Engineering we have many years of experience teaching Good Manufacturing Practice or ‘GMP’ to students. This year, we added a continuing education course to our programme portfolio. The new GMP course has been adapted to companies in the pharma and food industry and combines theoretical aspects with practical experience using our pilot plant equipment.

Main activities of the PILOT PLANT—Centre for Experimental Process and Equipment Design:
Research and teaching focused on experimental work with large-scale equipment and processes. These activities are conducted with a strong focus on industrial practice. As a result the main activities include unit operations, reaction engineering, process control, process and plant design, instrumentation, automation, and industrial measuring technology, scale-up and scale-down as well as batch versus continuous processes. New focus areas are fermentation mainly from a process point of view and particle technology.

Current projects
The project portfolio of the PILOT PLANT research centre currently includes, for instance, microbial conversion of slaughterhouse waste, syngas fermentation, and downstream processing of the liquids products, ammonia enhanced biogas production, along with fermentation experiments for the new bio-tech cluster BIOPRO and research on flowability of bulk solids and coating of particles.

Technical competences:
- Designing and building large-scale plants (engineering, construction)
- Unit operations (theory and practice)
- Industrial chemical processes (designing the entire process)
- Operational experience, solving practical process problems
- Project management
- Plant safety
- GMP (Good Manufacturing Practice)
- Wide industry contact

Head of PILOT PLANT, Lars Kærboe, next to a vessel connected to the CIP (Cleaning In Place) facility where students can visually experience how the plant and the process behave in real life.
Photo: Thorkild Christensen.
Good Manufacturing Practice—In practice

In a corner of the large pilot plant of DTU Chemical Engineering, a student is scratching his head, looking at a mobile washing station connected to a model process plant made of transparent plastic which ensures that everything going on inside is visible. A moment ago his supervisor, Lars Kiørboe, Head of the centre PILOT PLANT, pointed to a large stain of mustard stuck in one of the valves.

"Pretend you’re standing in the big production hall of a pharmaceutical manufacturing factory. You have discovered that the CIP facility has not been able to clean the process plant entirely and every delayed second before the next batch of medicine can be produced count—what do you do?" the experienced teacher asks.

Practical GMP
Creating a realistic scenario tops the agenda in the Good Manufacturing Practice (GMP) courses which the centre offers to undergraduates and now also to small, medium, and large companies in Denmark. In addition to the large body of theory that goes hand in hand with the GMP world, these courses are especially focused on practical learning aspects.

According to Lars Kiørboe, the GMP philosophy states that you cannot base the product quality on chemical analysis of the finished drug alone—GMP activities have to completely permeate the entire production process. So GMP is very comprehensive.

"If your company is producing medicine, you cannot allow even the smallest mistake. Therefore, GMP is implemented into all steps of production from the raw material, to the design of the equipment and building, to the manufacturing processes, the education of employees further on to storage and transport of the finished products and the documentation. With our courses we want to ensure a workforce that can solve the practical challenges of GMP in the medical, food and biotech industry” says Lars Kiørboe.

The GMP courses cover general quality standards, hygienic design, cleaning technology, documentation practice in combination with work in the pilot plant and visit to industrial sites. Since GMP is so important to large Danish companies various aspects are also applied in other courses at the department. This includes the experimental courses in chemical unit operations where the students can work with the CIP unit and include CIP cleaning in the operation of, for instance, ultrafiltration and evaporation technologies. So the students are given a much more realistic study with experiences they can use directly in their future engineer jobs.

Companies can test their cleaning methods
Although there are standards prescribing the best design of production equipment, the equipment will often vary from company to company and many construction details may be considered. In the pilot plant it is possible for companies to come and use our facilities for testing and developing equipment and processes, where easy changing of design and process parameters can go hand in hand with modelling and test of various raw materials. In this way, the companies can get a better understanding of the challenges they may meet and how to better solve them in the future.
What if we could get more oil from the same reservoirs? The research centre AT CERE has taken up the challenge. The SmartWater project, which was concluded this year, is an attempt to extract more oil from the available reservoirs in the Danish part of the North Sea.

Industrial partners are Maersk Oil and DONG Energy. Funding is provided by the industry partners, by the Danish EUDP programme under the Danish Energy Agency and by the Danish research councils.

The SmartWater project was inspired by findings in the Middle East which suggested that by modifying salinity and water flooding is a standard method used by oil companies all over the world in order to extract extra oil from mature fields. The ‘Smartwater’ project aimed to improve the theoretical understanding of the detailed mechanisms involved in water flooding and it has suggested possible ways to improve recovery rates in the Danish part of the North Sea.

Water flooding is a standard method used by oil companies all over the world in order to extract extra oil from mature fields. The ‘Smartwater’ project aimed to improve the theoretical understanding of the detailed mechanisms involved in water flooding and it has suggested possible ways to improve recovery rates in the Danish part of the North Sea.

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The SmartWater project was inspired by findings in the Middle East which suggested that by modifying salinity and
Small revolution may have great consequences for oil recovery

This year, the SmartWater project came to an end. Since its birth in 2011, researchers have worked hard to make oil extraction more efficient. As Philip Loldrup Fosbøl, Associate Professor at AT CERE, explains, even a small improvement could mean a big difference:

“An oil reservoir basically consists of a big rock where the oil is embedded. Only about 30% of this oil is extracted with current conventional methods. If we could recover just 1% more oil out of the reservoirs, it would actually provide billions of DKK for the Danish State. SmartWater has been all about finding a way of doing this.”

Yet, oil recovery is by no means a simple discipline according to the Associate Professor.

“An oil reservoir is not a big ‘pool’ of oil somewhere under the sea floor, like many people intuitively think. It’s embedded in small holes and rooms in chalk like the kind you may remember from school. In the laboratory we use the exact same chalk combined with state-of-the-art technology to recreate the conditions under which oil is extracted—all of which happens under enormous pressure. This has enabled us to find out more about the effectiveness of oil extraction without having to actually go underwater and underground”.

A small revolution in oil recovery

And the prospects are looking good. The project has challenged one of the basic understandings of how to best utilize the SmartWater concept. As Philip Loldrup Fosbøl says:

“I like to think that, in the course of the project, we have revolutionized the way we think about SmartWater technology. When injecting Smartwater into the oil reservoir, small particles are formed as it mixes with the other fluids in the reservoir. Until now, scientists have believed this to be a problem, which it still is if there is too much of it and it clogs the reservoir, of course. But, what our research has also shown is that the particles are actually part of the solution: The oil ‘sticks’ to the particles and carry it to the production site. This way, we can get even more oil out,” says the Associate Professor who has been researching oil recovery at AT CERE for years, and believes we are now closer than ever to achieving the desired increase in oil production.

Industry is catching on

The project has not been confined to DTU Chemical Engineering alone. DTU Civil Engineering has coordinated the project which was funded by Maersk Oil, Dong Energy and EUDP. According to Associate Professor at AT CERE, Kaj Thomsen who has been a main actor in the project, the collaboration has been of great importance and is expected to have influence on oil production in Denmark and beyond.

The new methods for oil extraction that are presented as a result of the SmartWater project have not yet been applied on a larger, industrial scale. However, this may be about to change:

“We have a lot of ideas from the project and the industry is very interested in them—this has a lot of potential. As it looks now, one of the funders of the project will most likely try to apply the methods in the future,” says Associate Professor, Kaj Thomsen.
It is a very promising, but so far not entirely cost-effective process to convert CO₂ into useful fuels and chemicals. Developing a cost-effective process will require the right catalyst and reaction. At the CHEC research centre, researchers are developing new and more effective catalysts.

Catalysis research in the CHEC research centre

The research within catalysis in CHEC focuses mainly on providing solutions to energy and environmentally related challenges, but also covers parts of green chemistry. The objectives of the research are:

To synthesize new catalytic materials

To characterize the materials using spectroscopic methods and other techniques, and by theoretical means—such as density functional theory calculations—to understand and predict the properties of the materials

To test the activity and selectivity of the materials in relevant reactions and under industrially relevant conditions, and derive kinetic models including models describing diffusion limitations applicable for real reactor design

To investigate and minimize deactivation of the catalysts under relevant conditions; To model catalytic reactors and thereby obtain an improved understanding of the interplay between the process and the catalyst

The VILLUM Center for the Science of Sustainable Fuels and Chemicals is a constellation headed by Technical University of Denmark (DTU) and with the participation of Stanford University, University of Copenhagen (KU), and the University of Southern Denmark (SDU). It is an anniversary grant on account of the 75 year of the VKR group and is the biggest grant from VILLUM FONDEN to a scientific project.

‘Low-temperature processes for CO₂ reduction to fuels and chemical building blocks’ is a project in the centre which aims to find catalysts that will work at low pressure and temperature in distributed units compatible with solar hydrogen production.
CO₂ should be a sustainable business

Our planet is in need of alternative energy sources to replace fossil fuels. However, we are still far from being independent of oil, coal, and natural gases, the use of which every year leads to tons of CO₂ being emitted into the Earth’s atmosphere. But what if you could use this otherwise harmful greenhouse gas for storing green energy or producing useful chemicals for everyday products? Around the world, researchers are racing to find an effective and affordable way to achieve exactly this. And, according to Anker Degn Jensen, Professor at DTU Chemical Engineering, CO₂ could very well become an important resource in the future.

“Almost all fuels and chemicals contain carbon which today is obtained from fossil fuels. However, CO₂ is also a possible source of carbon. So, when we no longer wish to use or do not have any more fossil fuels, the ability to effectively convert CO₂ into chemicals could prove to hold great potential in the long run. And in the meantime, large point sources – such as power plants and cement factories – are attractive sources of CO₂,” says the professor and catalysis expert.

Methods to convert CO₂ into, for instance, ethanol – one of the promising alternatives to fossil fuels – already exist. However, there is a significant bump on the road: The process remains too ineffective and the yield of ethanol too low in the end. Therefore, Professor Anker Degn Jensen together with his colleague from the CHEC research centre, Assistant Professor Jakob Munkholt, are working with colleagues from DTU and Stanford University to find a solution that is both environmentally and economically attractive. Their research project is called ‘Thermally driven processes for CO₂ reduction to fuels and chemical building blocks’. The aim of the project is to develop a catalyst which can convert CO₂ into ethanol at a low pressure and temperature. Conversion of CO₂ traditionally requires a great amount of energy. However, if it can be done at lower pressures and temperatures, it will be feasible to use, for instance, solar or wind power for the process. The ethanol can, as such, become a way to store the electricity produced from these sustainable energy sources.

Too much is wasted

Ethanol can be produced by a reaction between CO₂ and hydrogen using a catalyst. However, the challenge with this process is that the currently best catalysts used for this reaction cannot prevent that a significant part of the CO₂ ends up as unwanted light hydrocarbons, particularly methane. Furthermore, too much of the hydrogen is wasted as it is converted into water.

“The waste of hydrogen is problematic, as there are significant costs associated with producing hydrogen and that means we are still relatively far from having anything of commercial interest. That’s why we are trying to develop new catalysts with the ability to effectively convert CO₂ into ethanol as well as other valuable alcohols to replace fossil fuels,” says Assistant Professor Jakob Munkholt Christensen.

Difficult, but with great potential

Although converting CO₂ is a challenging process, the team of researchers are optimistic about finding the right materials with the right abilities to make effective catalysts.

“Rhodium-based catalysts have shown great potential, but are expensive. We will research how and why it functions so well and with this knowledge we hope to imitate the properties to make a cheaper synthetic catalyst,” says Jakob Munkholt Christensen.

The project is part of the new V-Sustain research centre at DTU focusing on sustainable chemicals and fuels. The work was kicked off in the summer of 2016 and will continue for the next eight years with four new PhD students expected to be hired at DTU Chemical Engineering.
The former CAPEC consortium has been reorganized into a united cross-departmental consortium called KT Consortium. Masterminds behind the consortium are Head of Department Professor Kim Dam-Johansen and Professor Rafiqul Gani who with this strategic move will strive to take the department’s collaboration with industry partners to the next level—a networking platform in full scale.

Facts about the KT Consortium

The consortium was established in 1997 by Professors Rafiqul Gani and Sten Bay Jørgensen under the name CAPEC consortium.

Currently, the KT Consortium offers:

Computational tools
Property estimation methods, mathematical models, numerical solvers, process simulators, process-product synthesis/design toolbox, process control toolbox, and many more.

Technology
Methodologies for process-product synthesis, design, analysis and control/operation, simulation strategies, solvent selection/design, pollution prevention, sustainable process-product alternatives and many more.

Application
Industrial case studies, tutorial case studies, technology transfer studies, and consulting.
KT Consortium is an industry-academia collaboration that offers networking opportunities, state-of-the-art methods, and tools to its members in the chemical, petrochemical, pharmaceutical, agrochemical, food and biochemical industries.

“KT is short for KemiTeknik, the Danish version of our name,” Kim Dam-Johansen explained at the opening of the very first KT Consortium Annual Meeting at DTU on 28 October 2016.

The consortium will continue to develop generic methods and tools using computer aided systems approach to solve and analyse problems related to product-process modelling, simulation, synthesis, design, analysis, control, and operation in collaboration with the member companies. Yet, these services are going to be broadened in the future according to Kim Dam-Johansen.

“The name is new, so are the future perspectives. Although the consortium originally was established in 1997, this is not a case of old wine in a new bottle,” says Kim Dam-Johansen about the recent developments.

“In the future, research from all our six research centres will be included and more industrial partners from both small, medium and large enterprises from all over the world will be invited to join. My hope is that this broader mix of knowledge and experience will strengthen our ability to deliver directly applicable research that solve the future challenges of our global society,” he explains.

Going far for innovation
Present at the KT Consortium Annual Meeting was Graduate Programme Lead, Manufacturing at GlaxoSmithKline, Dr Conchita Jimenez-Gonzalez. Coming all the way from the US, there must be some good reasons to join the annual meetings according to Dr Jimenez-Gonzalez, who has been a frequent visitor since 2003 when Glaxo-SmithKline became a member.

“Always before I come here, I do a good amount of research and I always find good things on the agenda,” says Dr Jimenez-Gonzalez and continues, “I like that I get updated on developments in the research arena. I like the opportunity to be in some projects. And now that I’m leading the graduate programme in my company, I’ve brought six of my UK graduates to this meeting. I’m really interested in hopefully providing them with a view of the world of research besides what we do at the company, because I do believe that the more people are exposed to different research, the better their work is and the more innovative their thoughts become”.

As Programme Lead, Conchita Jimenez-Gonzalez believes a good chemical engineer is a problem solving professional that is really good at thinking in networks, because nothing happens in isolation.

“It might be that there is a tool that we can’t use right away in the company, but it might spark another idea of something else that we can use. That’s always, I think, how innovation works, it’s not just somebody sitting alone in a room. It’s the cross-pollination of ideas,” says Conchita Jimenez-Gonzalez.

Open for new members
The KT Consortium is open for new company members. Read about the new consortium, services and how to apply for membership on the website www.kt.dtu.dk/research/kt-consortium.
Polymers and particles

Synthesis of polymers (flask) and surface modification of particles (small vials) can be used to control agglomeration of particles (petri dish).

Photo: Thorkild Christensen
Programmes at DTU Chemical and Biochemical Engineering

The department participates in two 3½-year Bachelor of Engineering (BEng) programmes, one in Chemical and Biochemical Engineering and one in Chemical Engineering & International Business, a three-year Bachelor of Science (BSc) programme in Chemistry and Technology, three two-year Master of Science (MSc) programmes in Applied Chemistry, Chemical and Biochemical Engineering, which includes an Honours programme, and Petroleum Engineering, and finally a Sino-Danish Master of Science programme in Chemical and Biochemical Engineering.

Our students work both theoretically and experimentally with the core disciplines in chemical engineering such as unit operations, transport phenomena, reaction engineering, mathematical modelling, and thermodynamics. They are taught by faculty specializing in these areas with applications in energy conversion, enzyme technology and biotechnology, polymers, computer modelling, process and product design.

COURSES 1 SEPTEMBER 2015 – 31 AUGUST 2016

PHD COURSES

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<tr>
<th>Code</th>
<th>Title</th>
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<tbody>
<tr>
<td>28901</td>
<td>Advanced Computer Aided Modelling</td>
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<td>28902</td>
<td>Process &amp; Tools Integration</td>
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<td>28904</td>
<td>Soft Matter Physics</td>
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<td>28905</td>
<td>Advanced Topics in Process Systems Engineering</td>
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<td>28908</td>
<td>Rheology of complex fluids</td>
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<td>28909</td>
<td>Thermodynamics Models, Fundamentals and Computational Aspects</td>
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<td>Statistical Thermodynamics for Chemical Engineering</td>
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<td>28923</td>
<td>Uncertainty and Sensitivity Analysis of Numerical Models</td>
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<td>Process Engineering Laboratory</td>
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<td>Advanced Topics in Process Technology</td>
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<td>Electrolyte Solution Thermodynamics</td>
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<td>28930</td>
<td>Advances in Chemical and Biochemical Engineering</td>
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<td>28931</td>
<td>Biorefinery and Sustainability</td>
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SINO-DANISH CENTER (SDC) COURSES

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<td>88700</td>
<td>Industrial Reaction Engineering</td>
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<td>88701</td>
<td>Transport Processes</td>
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<td>Laboratory Experiments</td>
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<td>Progress in Research</td>
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<td>Process Design—Principles &amp; Methods</td>
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<td>Energy and Sustainability</td>
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<td>Industrial BioReaction Engineering</td>
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<td>SDC Green Challenge</td>
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<td>88714</td>
<td>SDC Summer School in Unit Operations</td>
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<td>88715</td>
<td>Biorefinery</td>
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MSC, BSC, AND BENG COURSES

Below, course numbers and names are shown for 2016, with the number of students attending shown in brackets. Courses for Bachelor of Engineering are marked with a (B). The other courses are Bachelor of Science courses, Master of Science courses or common courses.

SPRING SEMESTER

28012 Chemical and Biochemical Process Engineering (55) (B)
28016 Mathematical models for chemical and biochemical systems (72) (B)
28017 Chemical and Biochemical Process Engineering (21) (B)
28020 Introduction to Chemical and Biochemical Engineering (63)
28022 Unit Operations of Chemical Engineering and Biotechnology (87) (B)
28025 Bio Process Technology (83)
28121 Chemical Unit Operations Laboratory (10)
28122 Chemical Unit Operations Laboratory—3 weeks Summer University Laboratory (7)
28124 Summer course in chemical process and plant design (14)
28157 Process Design (40) (B)
28160 Mathematical models for chemical systems (45)
28212 Polymer Chemistry (15)
28214 Polymer Synthesis and Characterization (7)
28221 Chemical Engineering Thermodynamics (31)
28231 Laboratory in Chemical and Biochemical Engineering (18)
28322 Chemical Engineering Thermodynamics (61) (B)
28342 Chemical Reaction Engineering (53) (B)
28344 Biotechnology and process design (64) (B)
28345 Chemical Reaction Engineering (34)
28350 Process Design: Principles and Methods (47)
28352 Chemical Process Control (40) (B)
28361 Chemical Engineering Model Analysis (20)
28415 Oil and Gas Production (45)
28423 Phase Equilibria for Separation Processes (20)
28434 Membrane Technology (40)
28443 Industrial Reaction Engineering (33)
28451 Optimizing Plantwide Control (17)
28811 Polymers in Processes and Products (5)
28850 Quality by Design (QbD): Integration of product and process development (64)
28855 Good Manufacturing Practice (60)
28864 Introduction to Matlab Programming (26)
28871 Production of Biofuels (15)
28885 Technology and Economy of Oil and Gas Production (49) (B)

Courses offered together with other departments:

26317 Instrumental Chemical Analysis (33)
27944 Biotechnology and process design (11) (B)
41683 Materials Science (70) (B)

FALL SEMESTER

228001 Introduction to Chemistry and Chemical Engineering (67)
28012 Chemical and Biochemical Process Engineering (72) (B)
28016 Mathematical models for chemical and biochemical systems (89) (B)
28022 Unit Operations of Chemical Engineering and Biotechnology (86) (B)
28121 Chemical Unit Operations Laboratory (18)
28125 Chemical Unit Operations Laboratory (24)
28140 Introduction to Chemical Reaction Engineering (39)
28150 Introduction to Process Control (66)
28157 Process and product design (37) (B)
28213 Polymer Technology (55)
28233 Recovery and Purification of Biological Products (55)
28242 Chemical Kinetics and Catalysis (51)
28244 Combustion and High Temperature Process (55)
28246 Applied Enzyme Technology and Kinetics (55)
28247 Advanced Enzyme Technology (15)
28310 Chemical and Biochemical Product Design (51)
28315 Colloid and Surface Chemistry (63)
28316 Laboratory Course in Colloid and Surface Chemistry (19)
28322 Chemical Engineering Thermodynamics (78) (B)
28342 Chemical Reaction Engineering (34) (B)
28352 Chemical Process Control (32) (B)
28361 Chemical Engineering Model Analysis (56)
28420 Separation Processes (39)
28515 Enhanced Oil Recovery (42)
28530 Transport Processes (60)
28831 Computational fluid dynamics in chemical engineering (23)
28845 Chemical Reaction Engineering Laboratory (22)
28852 Risk Assessment in Chemical Industry (26)
28864 Introduction to Matlab Programming (31)
28870 Energy and Sustainability (127)
28872 Biorefinery (49)

Courses offered together with other departments:

23522 Rheology of food and biological materials (10)
26010 Introductory Project in Chemistry (49)
27004 Health, Diseases and Technology (68)
27944 Biotechnology and process design (30) (B)
41683 Materials Science (35) (B)
BACHELOR OF ENGINEERING DEGREES

15 students finished their research projects for the BEng degree. The project titles and names of the students are listed below:

- Agertoft, Frederik Cornali: Sustainable CO2 Capture and Conversion Process Design
- Ali, Nabilah Nasrudin Abdulqadir: Preparation of bio-based polymers by enzymatic polymerization
- Alwan, Zaman Mothana: Reduction of Metal Contaminants in Coal Tars
- Al-Afrozi, Ali Omar: Identification of antioxidants in polymers by HPLC
- Appelt, Julius Lai & Struve, Rasmus: Separation of trace components from aqueous solution
- Azizi, Haroon-Ur-Rashid: Modelling of thermodynamics of hydrate inhibitor systems
- Cakir, Meral: Development and use of sensor particles
- Carlsen, Niels Frahm Vilhjelm: Speciation of Chemistry in Biomass Ashes
- Jepsen, Ulf: Enzyme immobilization on ceramic membranes
- Kjeldbjerg, Camilla Maria: Conversion of Lignosulfonate to Value-Added Chemicals
- Kreutzfeldt, Mads Gram: Catalyst oxidation of methane
- Olsen, Martin Due: Experimentation Determination of the Solubility of Exotic Scales at High Pressures and High Temperatures
- Pallesen, Jeppe Væver: Modelling Gas Hydrates with Improved Langmuir Adsorption constants
- Susataine, Cornali: Technical and economical evaluation of using a radial flow methanol converter as part of the reactor capacity in a methanol synthesis loop
- Yildiz, Omer: Separation of trace components from aqueous solution
- Zilstorff, Frederikke Byrial: Modelling of Phase Equilibria for Salt-Acetone-Water Mixtures

BACHELOR OF SCIENCE DEGREES

32 students finished their research programme for the BSc degree. The project titles and names of the students are listed below:

- Andersen, Bastian Borum: Model Development for Cyclic Distillation
- Andersen, Jakob Afzali: Removal of particulates and NOx from automotive exhaust gas by combined diesel particulate filter and SCR
- Anderssen, Mads Gade: Dynamic Simulation Study of Failing Film Evaporation
- Biel-Nielsen, Tessa Lund: Measurement and Modeling of Gas Diffusion in Coated Enzyme Particles
- Bokhari, Syed Muhammad Qasim: Reaction Equilibria in Liquids
- Boje, August: Mechanism for Fouling of Waste Heat Boiler Tubes in Regeneration of Spent Sulfuric Acid
- Brogaard, Mads Schack: The influence of the Operating Conditions and Influent Composition on the Reactor Performance in a Full-Scale *Anaerobic* Solvent Exchange in Continuous Processing
- Bugge, Anders: Recycling of Phosphorus From Biomass Ashes
- Fayyaz, Umar: Commissioning of Fluidized Bed Coating Equipment
- Freiesleben, Louise la Cour: Modelling the Aqueous Acetate Acid-Sodium Acetate-Potassium Acetate System
- Hoang, Michael Kolling: Proactive Well Workover Maintenance Model
- Jacobsen, Bjartur: Rate-Based Model for Enzyme Upgrading of Biogas
- Jensen, Martin Pilgaard: Combustion Behavior of Bio Slurry Oils and Their Use in Boilers
- Johansen, Matthias: Advanced Control Strategies for NOx Control From WWTPs
- Jørgensen, Søren Ege: Studies of the Active Site and Reaction Mechanism for the Industrial Methanol Synthesis Catalyst
- Kjeldbjerg, Camilla Maria: Heat Transfer in Dielectric Elastomers and its Influence on Dielectric Breakdown
- Kreutzfeldt, Mads Gram: Techno-Economic Study of Carbon Dioxide Capture and Conversion
- Li, Jiangui: Measurement and Correlation of Kinetic Rate Constants in Enzymatic Promoted CO2 Removal Solvents
- Lomboldt, Niels Frithjof: Pilot scale Development, Measurements and Modelling of Enzyme Catalysed CO2 Removal Processes
- Nguyen, Thanh Thien: Synthesis and Quantification of Various New Poly(acrylate)/PDMS Interpenetrating Networks
- Nielsen, Rasmus Fjordbak: Design of Cyclic Distillation Units
- Olsen, Martin Due: Modeling and Measurement of Carboxylic Acid Extraction from Fermentation Broth
- Pol, Isabel: Conversion of Lignosulfonate to Value-Added Chemicals
- Rasmussen, Jess Bjørn: Development and use of sensor particles
- Rehman, Mujeeb Ur: HCl Absorption by Raw Meal
- Schmidt, Morten Saaby: Recycling of Phosphorus From Biomass Ashes
- Sieverts, Michael Gram: Degradation of Keratin by Bacteria
- Sode, Michael: Methods of permeability measurements
- Tomás, Elena: Catalytic oxidation of methane
- Zilstorff, Frederikke Byrial: Experimental Determination of the Solubility of Exotic Scales at High Pressures and High Temperatures

MASTER OF SCIENCE DEGREES

67 students completed their research projects for the MSc degree. The project titles and names of the students are listed below:

- Abdullahi, Abdirahman: Modelling of thermodynamics of hydrate inhibitor systems
- Aloupis, Georgios: Preparation of bio-based polymers by enzymatic polymerization
- Andersen, Christian: Reduction of Metal Contaminants in Coal Tars
- Andreasen, David Richterhausen: Identification of antioxidants in polymers by HPLC
- Assaf, Rima Adnan: Separation of trace components from aqueous solution
- Baghoee, Hadise: Modelling of thermodynamics of hydrate inhibitor systems
- Berendt, Kasper Leonhard: Development and use of sensor particles
- Bisgaard, Jonas: Speciation of Chemistry in Biomass Ashes
- Bonde, Christian: Optimal catalyst composition for a propane dehydrogenation catalyst
- Bloch, Gabriele Sejer: Susustainable CO2-Capture and Conversion Process Design
- Calvera, Cristina Plaza: Modelling Gas Hydrates with Improved Langmuir Adsorption constants
- Camacho Vergara, Edgar Luis: Separation of trace components from aqueous solution
- Carlsen, Niels Frahm Vilhjelm: Speciation of Chemistry in Biomass Ashes
- Jepsen, Ulf: Optimal catalyst composition for a propane dehydrogenation catalyst
- Nielsen, Rasmus Fjordbak: Modelling Gas Hydrates with Improved Langmuir Adsorption constants
- Pallesen, Jeppe Væver: Separation of trace components from aqueous solution
- Zilstorff, Frederikke Byrial: Separation of trace components from aqueous solution
Chatterjee, Rishika

Studies of the Interaction between Cu and ZnO in the Industrial type Methanol Catalyst

Kurz, Dorothee Luise

Modeling and experiments for recycling of phosphorus

Kikas, Erki

Simulation and Analysis of a Deodorization Process

Khusainov, Ilsur

Diffusion in Protective Organic Thermoset Coatings

Kepa, Katarzyna

Thermodynamic modeling of scale formation in brines from HP/HT reservoirs

Marke, Henrik Sander

Design and process for the removal of SO2 from diesel exhaust

Malek-Shah, Masoud Mohamed

Influence of additives on soot formation in diffusion flames

Madsen, Line Riis

Further development of the electrolyte equation of state for electrolyte systems

Lymperis, Konstantinos

Centralization of liquid from pre-treated sugar beets by using membrane technology

Bischof, Caroline

Substrate selectivity of endo-beta 1.4-mannanases

Lydom, Simon Ingvardt

Continuous production of solvent-based coatings

Madsen, Martin Møller

Generation of reactive extraction for impregnation of facial implants

Lundquist, Casper Wolf

Simulation tool development and control study of heat integrated distillation

Lydersen, Søren

Validation of a general acid-base equilibria model plug-in for bio-based processes

Masik, Joseop

Linear transition of enzyme-based biogas upgrading

Meester, Michel

Further development of the electrolyte equation of state for electrolyte systems

Meyer, Kristian

Genom-based enzyme discovery

Milla Diaz, Kevin Julio

Biogas production in fixed filter fixed film reactor systems

Mortensen, Søren

Accessory enzymes for improved removal of carbohydrates from biofouling lignin

Mosbech, Caroline

Validation of Oxygen Mass Transfer in a Static Mixer Section of a U-Loop Reactor

Møller, Lars Bo

Influence of additives on soot formation in diffusion flames

Mueller, Casper Stryhn

Solvent Swap Method for Separation Tasks

Muse, Mohamud Abdi

Modeling and experiments for recycling of phosphorus

Niemling, Louise Kjer

Modeling of a microfiltration recovery process

Nikolaev, Maksim

Characterization of PEO-based copolymers' behaviour and stability in fouling-release coatings

Nienborg, Ludwina

Improved dissolved oxygen control in fermentations with filamentous fungi

Nielsen, Mette Joan

Substrate selectivity of endo-beta 1.4-mannanases

Nielsen, Nans Liv

Continuous production of solvent-based coatings

Nielsen, Nans Liv

Modeling Oxygen Mass Transfer in a Static Mixer Section of a U-Loop Reactor

Palazon, Lorena Blanco

Modeling of a microfiltration recovery process

Paraskeva, Ioulietta

Diffusion in Protective Organic Thermoset Coatings

Pedersen, Patrick Nicklas

Validation of a general acid-base equilibria model plug-in for bio-based processes

Pran, Robin Christiaan

Operative well workover & maintenance model

Rajendram, Rajatheepan

Solubility modeling of active species

Rasmussen, Morten Lund

Thermal conversion of CH3Cl

Rodriguez Pupo, Alejandro

Thermodynamic modeling of scale formation in brines from HP/HT reservoirs

Rosenas, Ana-Franci Sanchez Arcilla

Design and process for the removal of SO2 from diesel exhaust

Schmidt, Ricky Daniel

Polymeric materials for medical applications

Schouw, Mathias

Development of gasoline isomerization kinetics and study of carbon compounds deposited on the catalysts used in the upgrading of TIGAS gasoline

Seab, Brian Graham

Value added biochemical production from complex substrates

Sigurdardottir, Sigyn Bjork

A membrane biolektor for high performance production of fluoric acid and lactic acid

Sivth, Casper Stryhn

Single particle modeling of RDF combustion

Toderascu, Andreea Genoveva

Kinetics for gasification of biomass char

Torbenes, Kasper

Proactive well workover & maintenance model

The preparation and application of a multifunctional membrane based on polypamine (PDA) coatings

Co-production of activated carbon, bio-oil and combustible gases from pyrolysis of penicillin mycelial dreg

Stability of bioreactors responding to environmental disturbance associated with microbial diversity

In-situ hydrodeoxygenation upgrading of bio-oil

System Evaluation of Power To Gas

Synthesis of terephthalic acid from cellulose derivatives

Recycle of TIO2 carrier from Waste SCR catalyst and property evaluation of fresh SCR catalyst made by this recycled carrier

Cellulose-based hybrid aerogels

Promotion of methane hydrate formation by adding other trace of gases

Validation study on the continuum modeling of dense granular flow

Synthesis of diphynyl carbonate from phenol and carbon dioxide catalyzed by multi-functionalized ionic liquid

Removal of nitrogen-containing compounds from fuel oil through reactive extraction

CFD simulation of an industrial MTO fluidized bed reactor

Computational study of dissolution of lignin in ionic liquids

14 students completed their research projects for the MSc degree/dual degree. The project titles and names of the students are listed below:
Our student organization, KTStudents, represents all students in the courses at the department. Its goal is to improve the study environment for students through social and professional activities.

Company presentations
Companies within the chemical and biochemical areas are invited to present their daily work and challenges. The company presentations give the students a better understanding of their potential future jobs, an opportunity to network and thereby a way for the students to attain projects, internships, or student jobs.

Company visits
The students are given the opportunity to visit companies within the chemical and biochemical fields. The tours around the production plants give the students insight into large-scale industry and the surrounding working environment.

Social events
Through social events, students get to socialize and network with other students. These activities especially strengthen the network between international and Danish students.

Liaison between the department and the students
In addition to providing knowledge about what a career in the chemical engineering industry entails, KTStudents also aims to help the academic development of chemical engineering students by acting as a liaison between the department and the students. We aim to expose students to research undertaken at DTU Chemical and Biochemical Engineering to generate awareness about the research centres and to facilitate a direction for BSc, MSc or PhD thesis topics.

GUESTS

VISITING PHD STUDENTS
Yang Wang from North China Electric Power University, China
Miguel Angel-Vazquez Dominguez from Dept. de Ingenieria Quimica y Ambiental, Spain
He Liu from Chinese Academy of Sciences, China
Xiaolong Li from University of Petroleum, China
Isabel Maria Gonzalez Delgado from URJC, Spain
Seongwoong Bae from KAIST, South Korea
Shuai Yang from University of Chinese Academy of Sciences, China
Shiwen Sun from TU Graz, Austria
Maximilliam Kuhnhenn from TU Darmstadt, Germany
Anna Panteli from Imperial College London, UK
Salvatore Constanzo from University of Kreta, Greece
Xianling Zheng from Institute of Bioenergy & bioprocess Technology, China
Shi Huang from Qingdao Institute of BioEnergy & Bioprocess Technology, China
Aurora Srishti from University Montpellier, France
Alessandro Rosengart from Politecnico de Milano, Italy
Boeun Kim from KAIST, South Korea
Dasom Lm from KAIST, South Korea
Klaus Pellicer Alborn from TU Berlin, Germany
Matej Danko Slovak from University of Technology, Bratslavia, Slovakia
Stefano Lillia from Politecnico de Milano, Italy
Teng Ma from Chinese Academy of Sciences, Beijing, China
Xinsheng Hu from China University of Mining & Technology, China
Huang Shi from QIBEBT, Chinese Academy of Science, China

OTHER VISITORS
Postdoc Xiaoguang Yang from Harbin Eng. University, China
Professor Luke E.K. Achenie from Virginia Tech, USA
Professor Victor M. Ugaz from Texas A&M University, USA
Professor Karim Muhammad Nazmul from Texas A&M University, USA
Professor John Kim from University of Alabama, USA
Professor Paul Marshall from University of North Texas, USA
Professor Bernhard Hauer from University of Stuttgart, Germany
Professor Heath Turner from University of Alabama, USA
Professor Michael A. Brook from McMaster University, Canada
Professor Dimitrios Vlassopoulos from University of Crete, Greece
Professor Yujun Wang from Tsinghua University, China
Professor Zhimin Lu from South China University of Technology, China
Assistant Engineer Megane Richez from Polytech Grenoble, France
Engineer Julian Le from INSA Lyon, France
Senior researcher Dou Kejun from CNREC, China
Researcher Jisong Bai from Chongqing University of Science & Technology, China
Distillation column

The distillation column is at the heart of many of the chemical processes going on inside the pilot plant of DTU Chemical Engineering. The column can be used to separate liquids with different boiling points, e.g., water and concentration of ethanol.

Photo: Thorkild Christensen
WoS publications

Aili, David; Jawahishvili, Irakli; Han, Junyoung; Jankova Atanasova, Katja; Pan, Chao; Hvilsted, Søren; Jensen, Jens Oluf; Bjerrum, Niels; Li, Qingfeng / Amino-Functional Polymethylimidazole Blends with Enhanced Phosphoric Acid Mediated Proton Conductivity as Fuel Cell Electrolytes. Macromolecular Chemistry and Physics, Vol. 217, No. 10, 2016, pp. 1161-1168.

Ale, Marcel Tutor; Barrett, Kristian; Addico, Gloria; Rhein-Knudsen, Nanna; de Graft-Johnson, Amoako; Meyer, Anne S. / DNA-Based Identification and Chemical Characteristics of Hymena musciformis from Coastal Sites in Ghana. Diversity and Distributions, Vol. 8, No. 2, 2016.

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Awan, Javeed A.; Coquelet, Christophe; Tsivintzis, Ioannis; Kontogeorgis, Georgios / Phase Equilibrium Measurements and Modelling of 1-Propanethiol+1-Butanethiol+ CH 3 in Methane Ternary System at 303, 336, and 368 K and Pressure Up to 9 MPa. Journal of Chemical and Engineering Data, Vol. 61, No. 1, 2016, pp. 41-44.


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Bisgard, Thomas; Skogestad, Sigurd; Abildskov, Jens; Huusom, Jakob Kjebsted / Optimal operation and stabilising control of the concentric heatintegrated distillation column (HIDIC). Computers & Chemical Engineering, Vol. 96, 2016, pp. 196-211.

Bjønner, Martin; Sin, Gürkan; Kontogeorgis, Georgios / A flexible well-mixed milliliterscale reactor with high oxygen transfer rate for microbial cultivations. Chemical Engineering Journal, Vol. 303, 2016, pp. 655-666.

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Christensen, Jakob M.; Gruvwaldt, Jan-Dierk; Jensen, Anker D. / Importance of the oxygen bond strength for catalytic activity in soot oxidation. Applied Catalysis B: Environmental, Vol. 188, 2016, pp. 235-244.

Christiansen, Caspar; Stolberg-Rohm, Thomine; Fateev, Alexander; Clausen, Sannik / High temperature and high pressure gas cell for quantitative spectroscopic measurements. Journal of Quantitative Spectroscopy & Radiative Transfer, Vol. 119, 2016, pp. 96-103.


Colom, Juan M.; Alzueta, Maria U.; Christiansen, Jakob Munkholt; Glarborg, Peter; Cordtz, Rasmus Faurk; Schramm, Jesper / Importance of Vanadium-Catalyzed Oxidation of SO 2 to SO 3 in Two-Stroke Marine Diesel Engines. Energy & Fuels, Vol. 30, No. 7, 2016, pp. 6098-6102.

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Valverde Perez, Borja; Fuentes-Martinez, Jose Manuel; Flores Alsina, Xavier; Gernaey, Krist; Huusom, Jakob Kjabsted; Ploz, Benedek G. / Control structure design for resource recovery using the enhanced biological phosphorus removal and recovery (EBP2R) activated sludge process. Chemical Engineering Journal. Vol. 296, 2016, pp. 447-457.


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PhD theses

Alexeev, Artem /Modeling of Salinity Effects on Waterflooding of Petroleum Reservoirs.
Anantpnijwatna, Amata/Generic Model-Based Tailor-Made Design and Analysis of Biphasic Reaction Systems.
Azizaddini, Seyednezamaddin/A New Type of Non-Mechanical Valves for Recirculation of Fine Particles.
Bisgaard, Thomas/Operation and Design of Diabatic Distillation Processes.
Bjørner, Martin Gamel/Thermodynamic modeling of CO2 mixtures.
Boiocchi, Riccardo/Plant-wide modelling and control of nitrous oxide emissions from wastewater treatment plants.
Chakravarty, Krishna Har/Modeling of Salt Solubilities for Smart Water flooding in Carbonate Reservoirs using Extended UNIQUAC Model.
Gaspar, Jozsef/CO2 Capture Dynamic and Steady-State Model Development, Benchmarking, Optimization and Control: Applied to Piperazine and Enzyme Promoted MEA/HDEA.
Guzman, Jon Trifo/Hybrid nanocellulose/nanoclay composites for food packaging applications.
Hansen, Stine Broholm/Model for Deposition Build-up in Biomass Boilers.
Hengeller, Ludovica/Entangled Polymer Melts in Extensional Flow.
Johansen, Joakim Myung/Power Plant Burners for Bio-Dust Combustion.
Kalakul, Sawitree/Property Model-based Tailor-made Design of Chemical-based Products.
Kamp, Andreas/Environmental Sustainability Assessment of Integrated Food and Bioenergy Production with Case Studies from Ghana.
Khusainova, Alsu/Enhanced Oil Recovery with Application of Enzymes.
Larsson, Hilde Kristina/Modelling of Mass Transfer Phenomena in Chemical and Biochemical Reactor Systems using Computational Fluid Dynamics.
Liu, Ming/Pretreatment of hemp fibers for utilization in strong biocomposite materials.
Manns, Dirk Martin/Sourcing and bioprocessing of brown seaweed for maximizing glucose release.
Mazurek, Piotr Stanislaw/Mechanically invisible encapsulations.
Mears, Lisa/New strategies for control of fermentation processes.
Narayan, Vikas/Ash behavior and de-fluidization in low temperature circulation fluidized bed biomass gasifier.
Nguyen, Hiep Dinh/Bio-based alkyds by direct enzymatic bulk polymerization.
Nielsen, Joachim Bachmann/Valorization of Lignin from Biorefineries for Fuels and Chemicals.
Nordvang, Rune Thorbjørn/Production of prebiotic oligosaccharides by novel enzymatic catalysis.
Papadakis, Emmanouil/Modelling and synthesis of pharmaceutical processes: moving from batch to continuous.
Petersen, Thomas/Model Stickiness in Spray Drying.
Rasmussen, Helena/Carbohydrate degradation mechanisms and compounds from pretreated biomass.
Seita, Catarina Sanches/Benchmarking of Processes for the Biosynthesis of Natural Products.
Shabbir, Aamir/Supramolecular Polymeric Rheology.
Trubetskaya, Anna/Fast pyrolysis of biomass at high temperatures.
Zakaria, Shamsul Bin/Electrical Breakdown and Mechanical Ageing in Dielectric Elastomers.
Zhou, Guofeng/Simultaneous fast pyrolysis and in situ hydrogenation of lignin to obtain a marine diesel fuel.

For an updated overview of our publications, go to our website www.kt.dtu.dk/publications
Automation
An automated liquid handling workstation gives a high throughput evaluation of engineered enzymes in the laboratory of the BioEng research centre.

Photo: Thorkild Christensen
Overview

The Thermometry Lab at DTU Chemical Engineering
DTU Chemical Engineering Risø Campus
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