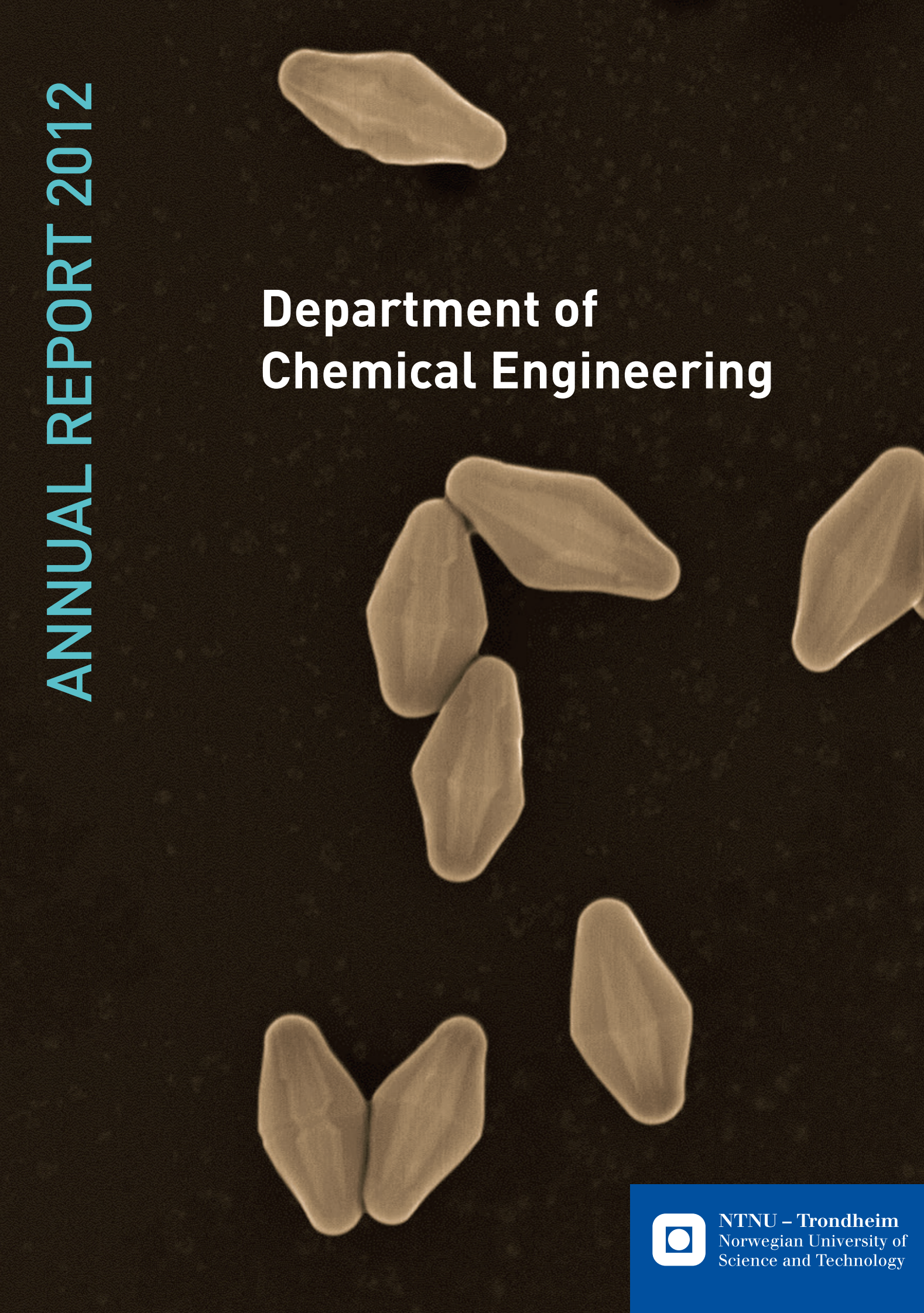
ANNUAL REPORT 2012

Department of Chemical Engineering



NTNU – Trondheim
Norwegian University of Science and Technology

DEPARTMENT OF CHEMICAL ENGINEERING, NTNU

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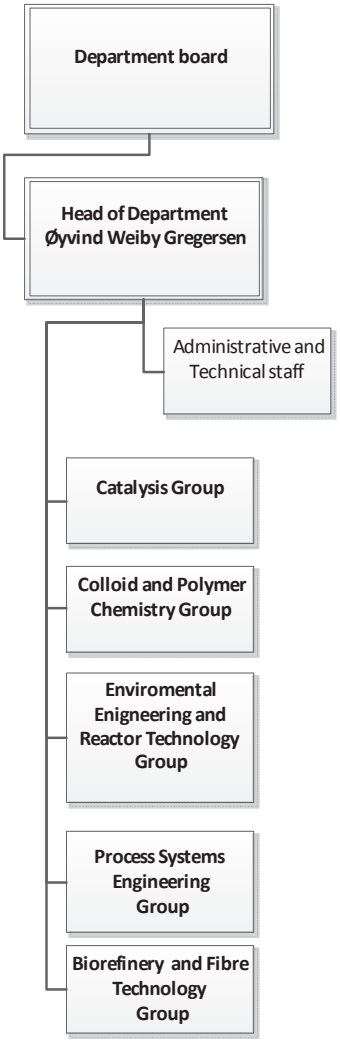
Head of Department:
Professor Øyvind Weiby Gregersen
Deputy Head of Department:
Associated Professor Jens-Petter Andreassen
Professor Sigurd Skogestad



Department board

External members:
Heidi Mediaas, Head of Energy and Environment, Statoil TNE R&D Research Centre Trondheim
Deputy member, Arne Grislingås, Chief Scientist Statoil TNE R&D Research Centre Trondheim
Philip Reme, Director PFI
Deputy member, Ole Wærnes, Research Director SINTEF Materials and Chemistry

Internal members:
Professor Hilde Venvik
Senior Executive Officer Torgrim Mathisen
PhD Solrunn Johanne Vevelstad (spring semester)
PhD Margrethe Nergaard (autumn semester)
Student Christina Carlsen (spring semester)
Student Roald Bræck Leer (spring semester)
Student Ebenezer Hayfron-Benjamin (autumn semester)
Student Peter J. Berg Lindersen (autumn semester)

Staff

Academic staff, see the individual research groups

Technical and administrative staff:
Head of Administration Tom Helmersen

Administrative staff:
Higher Executive Officer Martha Karin S. Bjerknes (from 01.07.2012)
Higher Executive Officer Hege Johannessen
Senior Executive Officer Torgrim Mathisen
Higher Executive Officer Lisbeth B. Roel
Controller Ling Lin (from 06.08.2012)
Executive Officer Tove Barø
HR Advisor Oddny Sagmo (from 01.07.2012)

Technical staff:
Senior Engineer Berit Borthen
Engineer Harry Brun
Senior Engineer Camilla I. Dagsgård
Staff Engineer Karin W. Dragsten
Head Engineer Gøril Flatberg (from 08.08.2012)
Head Engineer Geir Finnøy (until 30.06.2012)
Engineer Arne Fossum
Engineer Odd Ivar Hovin
Staff Engineer Signe Håkonsen (until 28.02.2012)
Staff Engineer Caterina Lesaint
Staff Engineer Jan Morten Roel
Engineer Frode Sundseth
Staff Engineer May Grete Sætran (from 08.10.2012)

COVER-PAGE: Photo by Gurvinder Singh: Scanning electron microscopy (SEM) image, which shows seed mediated growth of bipyramidal gold nanoparticles prepared by reduction of metal salts with a weak reducing agent (ascorbic acid) in the presence of cationic surfactants (cetyltrimethylammonium bromide and didodecyldimethylammonium bromide). The aspect ratio of bipyramidal nanostructures can be tuned by the ratio of cationic surfactants and pH of growth solution

DEPARTMENT OF CHEMICAL ENGINEERING, NTNU

www.ntnu.no/kjempros

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Prepared and edited by Lisbeth Blekkan Roel, Tom Helmersen, Øyvind Gregersen

CHAPTER 1: INTRODUCTION

Introduction to Annual Report 2012

By Øyvind Weiby Gregersen (Head of Department)

This report aims at summing up the activity in 2012 as well as providing more general information about the department. We hope you find it useful!

During 2012 the department has continued the trends from the last years delivering excellent research and being highly international. The last point is illustrated by our 26 students in the international master program and PhD candidates from more than 40 nations. Further 34 of our Norwegian students spent at least one semester abroad, and we had 34 visiting students. This is a desired development, which will serve a more international industry structure well and gives our students a wider perspective. However, an important challenge in the years to come will be to recruit sufficient numbers of Norwegian PhD candidates to cover our needs for teaching assistance in the three first years of the Chemical engineering program where all teaching is given in Norwegian.

In 2009 the Department received the evaluation report from the Research Council as part of an evaluation of all Chemistry Research in Norway. The evaluation was very positive for the Department. Since then we have continued to increase our research activity. In 2012, the research output, as expressed by the number of graduated PhD candidates and publications, was equally strong as in the last few outstanding years. The number of credited publications in international journals was 160 (2012) whereas it in the five previous years were 109 (2007), 84 (2008), 109 (2009), 126 (2010) and 161(2011). Furthermore, 14 PhD candidates graduated in 2012, this is around the average from the last few years except 2011 when we had an all-time high output of 25 PhD candidates. Since the average time to complete a PhD is about 4-5 years (including leaves of absence), we can infer from the table on page two, that the PhD production will be around 14 also in the years to come.

The Department has the last few years recruited some 40-50% of the students in the *Chemical Engineering and Biotechnology* program. This is a good development and a substantial improvement compared to the previous periods. In addition the number and quality of the applicants to our international master program is increasing and in 2012 we got 17 students into the national master program from the Norwegian university colleges. To attract as many good students as possible, we are working actively on recruiting and improving the quality of our study program. The student laboratories are upgraded, and in 2011 we have introduced a new subject in modeling of chemical processes. The teaching of basic subjects shall be rotated among the faculty and each subject has now a group of at least two faculty members who can step in at short notice. The use of PhD candidates for teaching has also recently been revised so that each candidate who are teaching shall have a 4 year plan for the teaching where he/she teach a few courses for several consecutive years.

In terms of strategy plans and for recruitment of faculty, we have made a new strategic plan for the 2012-2017 period. During 2012 we have employed Brian Grimes as Associate Professor within applied computational chemistry. Brian will work in the Ugelstad laboratory focusing on computational chemistry applied to colloidal stability and deposit formation in the oil and gas sector. During 2012 we have also appointed several new adjunct professors, thus strengthening our ties to industry and the research institutes. The new Adjunct Professors are: Krister Forsmann and Geert Versteeg, whereas Kristin Syverud and Jana P. Jakobsen will join the department as Adjunct Professors during 2013. To support teaching, research quality and our expanding laboratory and pilot scale research we are also working on increasing the number of engineers.

In May 2012 IKP Professor Jens Nørskov from MIT was created honorary doctor of NTNU based on a nomination from IKP. Jens is a leading international expert in computational chemistry applied within catalysis. In September 2012 our Ugelstad laboratory celebrated its 10 years anniversary. The 10 years have been highly successful in building up a strong lab, educating PhDs and MSc candidates and working on applied research within surface and colloid chemistry. Another important event in 2012 was that Professor Richard Spontak from North Carolina State University was appointed tas Onsager Professor. He spent three months at NTNU working with the Environmental Engineering and Reactor Technology Group of IKP.

The Department is located in chemistry buildings K4 and K5, experimental halls C and D and in the PFI-building. Our chemistry buildings date back to 1957/58 (K5/Exp. Halls) and 1965 (K4). A complete renovation of K4 (1st to 4th floor) was completed during 2010. The renovation of the K4 cellar pilot hall and hall D is finished during 2011. During 2011 and continuing in 2012 chemistry hall C was renovated. This hall contained and will contain our largest pilot experimental rigs including the rigs for amine based CO_2 capture. Plans are made to renovate chemistry building K5 and the rest of the chemistry halls to upgrade the standard, and create good research facilities for the European CO_2 Capture and Storage Laboratory (ECCSEL), however this renovation require additional funding.

FACTS ABOUT THE DEPARTMENT OF CHEMICAL ENGINEERING

The Department of Chemical Engineering is located at the Gløshaugen campus of the Norwegian University of Science and Technology (NTNU) in Trondheim. NTNU is the only university in Norway that awards engineering degrees in all areas.

The Department offers a 5 year program leading to the degree of *sivilingeniør* (MSc) in Chemical Engineering. Most of the students start at NTNU in their first year, but about 10 to 20% enter in the fourth year based on a 3-year engineering Bachelor degree. On top of this we offer a 3 year doctoral program leading to a PhD degree in Chemical Engineering. In addition, we offer a 2 year International Master Program in Chemical Engineering.

The Department can trace its roots back to 1910 when the Norwegian Institute of Technology (NTH) started up in Trondheim with engineering chemistry as one of the seven majors. After the Second World War, three applied Departments were formed, Pulp and Paper Chemistry (*Treforedlingskjemi*, 1946), Chemical Engineering (*Kjemiteknikk*, 1949) and Industrial Chemistry (*Industriell kjemi,* 1949). These were merged to the present Department of Chemical Engineering (*Kjemisk prosessteknologi*) in 1999.

The objectives of the Department are:

1. *Education.* Offer a Master Degree in Chemical Engineering which is internationally recognized and makes the candidates attractive on the labour marked.
2. *Research*. Research shall be on an international level, and in some areas internationally leading.
3. The Department shall be attractive in order to recruit the best candidates, including academic faculty, PhD students and undergraduate students. The social environment shall be very good so that everyone feels welcome.

The permanent staff in 2012 included:

- 21 technical/administrative
- 21 academic, incl.13 Professors and 8 Associate Professors (*Førsteamanuensis*)

The non-permanent staff in 2012 included

- 4 technical
- 6 Adjunct Professors (*Professor II*) (20% *position)*
- 1 Associate Professor II *(Førsteamanuensis II)*
- 82 PhD students
- 28 Post docs. and researchers

The Department also houses 6 Professor emeritus, several visitors in addition to a large SINTEF group.

Student production

Year	MSc	PhD
1996	57	5
1997	67	9
1998	46	13
1999	81	8
2000	69	10
2001	18(*)	11
2002	75	12
2003	44	7
2004	30	10
2005	25	13
2006	19	15
2007	31	15
2008	31	13
2009	35	14
2010	31	16
2011	32	25
2012	46	14

(*) Transition from 4.5 to 5 year program.

MSc students 2012/13

5th year	46 (incl. 12 International Master and 6 exchange students)
4th year	71 (incl.14 International Master and 4 exchange students)
3rd year	23

New PhD students (exchange students not included)

2003	20
2004	10
2005	9
2006	18
2007	15
2008	38
2009	18
2010	17
2011	12
2012	12

New Post docs./Scientists

2006	10
2007	25
2008	28
2009	6
2010	6
2011	7
2012	6

CHAPTER 2: RESEARCH

CATALYSIS GROUP

Academic staff
Professor Edd A. Blekkan
Professor De Chen
Professor Magnus Rønning
Professor Hilde J. Venvik
Adjunct professor Kjell Moljord
Adjunct professor Erling Rytter
Professor Emeritus Anders Holmen

Post Docs./Researchers
Bjørn Christian Enger
Espen Standal Wangen (until 31.03.2012)
Ingeborg-Helene Svenum
Jia Yang
Jun Zhu
Navaneethan Mutuswamy
Nikolaos Tsakoumis (from 01.08.2012)
Sara Boullosa Eiras

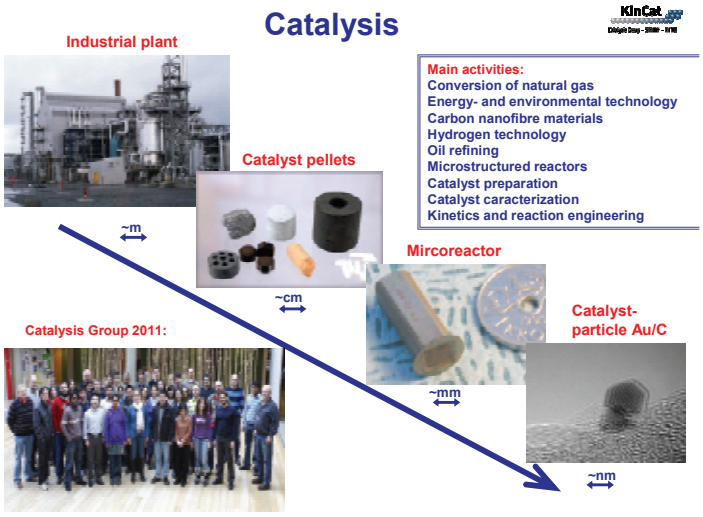
PhD candidates
Alexey Voronov
Andreas H. Lillebø
Andrey Volynkin
Charitha Udani
Daham Sanjaya Gunawardana
Eleni Patanou (until 12.09.2012)
Farbod Dadgar
Fengliu Lou
Georg Voß
Hassan Jamil Dar (until 24.08.2012)
Ida Hjorth (from 01.09.2012)
Ilya Gorelkin
Ingvild Tronstad
Marie Døvre Strømsheim (from 15.06.2012)
Marthe Emelie Melandsø Buan (from 06.08.2012)
Michael Wycisk (from 15.10.2012)
Nicla Vicinanza
Paul Radstake (until 17.12.2012)
Tayyaba Noor
Yanying Qi (from 27.08.2012)

Technical staff
Karin Wiggen Dragsten
Inger Marie Bjørnevik (until 26.04.2012)
Stefan Kjærnli (until 30.06.2012)

Guests
Henrik Romar, Karleby Universitetscenter Chydenius, Finland
Javier Fermoso Dominguez, Spanish Council for Scientific Research (CSIC)
Maria Victoria Gil Matellanes,
Juan Du, Zhengzhou Research Institute of Chalco, China
Seyedali Hosseini, University of Tabriz, Iran

KinCat
Catalyst Group – SINTEF – NTNU

The Organization
The research and teaching in catalysis, petrochemistry and related subjects (including surface science, adsorption and physical studies of porous materials, reaction kinetics and process engineering) is organised in the Catalysis Group, a joint effort where NTNU, and the research company SINTEF share laboratories and equipment.

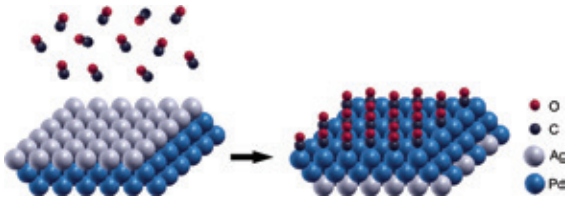


Personnel from the two organisations work together and participate in teaching and research. About 10 -15 MSc students graduate each year. The group participates extensively in international networks, research programs etc., and cooperates closely with a number of universities and research groups inside and outside the EU.

The group and the laboratories
At present the group comprises about 50 people: 4 Professors, 2 Adjunct professors, 1 professor emeritus, about 10 fulltime research scientists holding Ph.D's, 5-10 Post.doc's and approximately 20 PhD students. The laboratories and equipment include a large number of microreactors for catalyst studies, several small pilot plants, all the necessary equipment for catalyst and material characterization (chemisorption, physical adsorption, Temperature Programmed techniques (TPR, TPD, thermal analysis), XPS, Auger spectroscopy, STM, FTIR and others). Recently, *in situ* IR/Raman and the TEOM-technique (Tapered Element Oscillating Microbalance) have been introduced in the laboratory, and we were the first group in Europe to utilize the TEOM technique in catalyst studies. Cooperation with the Departments of Physics (TEM and surface science), and Materials Science and Engineering, the other groups at the department of Chemical Engineering (all aspects of chemical and process engineering, particularly reactor engineering and colloid and polymer chemistry) and other departments ensures a wide scope and a high quality of the work. The

research is funded by the Norwegian Research Council, EU, Norwegian and international industry and other sources, and spans from fundamental studies of ideal surfaces to studies of real catalysts and process development work in small pilot plants.

Highlights in 2012
A large effort has gone into moving a number of experimental setups into the newly renowated laboratories. In connection with the annual promotion of new PhDs, Professor Jens Nørskov from Stanford University, a long standing collaborator with the group, was awarded an honorary doctorate (Doctor Honoris Causa), by NTNU. In connection with this a very successful scientific seminar was arranged, with contributions from professor Nørskov as well as from young scientists in the group.



Adsorption of CO on a Pd_3Ag (111) model surface, studied using density functional theory (DFT) calculations. From: I.-H. Svenum, J.A. Herron, M. Mavrikakis, H.J. Venvik, Catalysis Today 193 (2012) 111– 119.

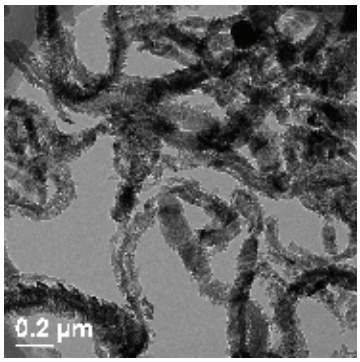
The projects
A description of the Group as well as further details of all the projects, are given in our Annual Report (KinCat).

Natural Gas Conversion
Natural gas is an abundant hydrocarbon fuel and chemical feedstock, and utilizing this resource with minimum environmental impact is a major challenge to catalysis. It is the main goal of the present programme to study catalytic processes for conversion of natural gas to chemicals and fuels including hydrogen. The programme includes production of synthesis gas, Fischer-Tropsch synthesis, and dehydrogenation of C_2-C_4 alkanes. The work is carried out in close collaboration with Norwegian industry and SINTEF. The group also participates in a Centre for Research-based Innovation (SFI-inGAP) focusing on the use of natural gas, and was awarded several new projects 2012.

Hydrogen Technology
Particular attention is directed towards hydrogen technology: Catalysis is important in the production of hydrogen from hydrocarbons. Natural gas is an important source of hydrogen, and research is thus linked to syngas issues. In addition, the conversion of "transportable" hydrogen carriers such as propane, methanol and (bio) ethanol is studied. Of particular relevance is the integration of CO_2 separation technologies in hydrogen production processes, and this is targeted through sorption enhanced reactions and membrane reactors (see below). The group is also involved in development of improved fuel cell catalysts based on carbon nanofibers (also below). Collaborations include SINTEF as well as Norwegian industry. Hydrogen technology is also part of the MIT-NTNU cooperation.

Design and Preparation of New Catalysts and Supports
The catalytically active material is the key to any catalytic process, and the preparation of these, highly specialized functional materials is an important industry. Understanding the processes involved in the preparation, and developing improved methods are therefore central research areas. We work with new methods for the preparation of supports and catalysts such as flame spray pyrolysis and spray drying, as well as the preparation and use of structured, mesoporous supports. Other areas include core-shell particles and size and shape-control of metal particles.

Carbon Nanofibres
Carbon nanofibres (CNF) have several interesting properties such as high resistance to strong acids and bases, high electric conductivity (similar to graphite), relatively high surface area and high mechanical strength. These unique properties lead to a large number of applications, such as catalyst supports, selective sorption agents, energy storage, composite materials, nano-electric and nano-mechanical devices, as well as field emission devices. The programme includes synthesis of carbon nanofibres and nanotubes of different morphology and the use of CNF/CNT in applications such as heterogeneous catalysis, fuel cells and conversion and storage of energy. This is done in collaboration with other groups at NTNU, SINTEF and Norwegian Industry



Carbon Nanofibres (TEM image)

New reactor concepts and structured supports
Emerging reactor technologies such as microstructured reactors and (catalytic) membrane reactors are being developed and tested. The use of structured supports such as monoliths and foams is being studied, particularly for short contact time reaction systems like partial oxidation and oxidative dehydrogenation.

The work on microstructured reactors, where channels with micrometer dimensions (1-1000μm) and up-scaling by parallelization is applied to enable new properties and possibilities, is performed in collaboration with Karlsruhe Institute of Technology (KIT) in Germany. Membrane reaction concepts based on novel Pd thin film technology are being developed together with SINTEF, and a partnership with MIT and Statoil is directed towards the use of high-temperature proton-conducting membranes in hydrogen production with CO_2 capture.

Oil Refining
Upgrading of crude oil and oil fractions is an important subject of research, especially due to new environmental legislation demanding more efficient processes. The programme includes catalytic reforming, isomerization, hydrotreating/ hydrocracking and heavy oil upgrading. The work is carried out in close cooperation with SINTEF and the industry.

Photocatalysis
Accelerated environmental pollution on a global scale has drawn attention to the need for totally new environmentally friendly and clean chemical technologies. The application of photocatalysis to reduce toxic agents in air and water by developing catalysts that can utilise clean and abundant solar energy and convert it into useful chemical energy is a promising challenge. Photocatalysts that can operate at ambient temperature without producing harmful by-products are ideal as environmentally sound catalysts. For such systems to be considered in large-scale applications, photocatalytic systems that are able to operate effectively and efficiently using sunlight must be established. Hydrogen can be produced by photoinduced reforming of organic compounds, including methane and alcohols. Furthermore, the photoreduction of carbon dioxide into useful chemicals is a desirable prospect. It is essential to convert CO_2 into useful substances that are common feedstocks for the production of other chemicals (C_2-C_{3+}, alcohols, etc.). The photocatalysis work is carried out in close collaboration with other European universities and the Department of Materials Technology.

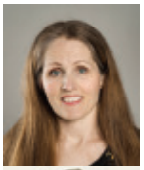
Biofuels
The research is focused on catalytic aspects of thermochemical conversion, such as bio-oil upgrading, syngas cleaning and composition adjustment, residual hydrocarbon reforming and Fischer-Tropsch synthesis.

The Güssing 10 MW biomass gasification reactor, a hub for biofuel research in Europe

Some of our facilities have now been opened to visitors from all over Europe through our participation in the EU-project BRISK.

Fundamental Studies in Heterogeneous Catalysis
Several experimental techniques are used to study the details of solid catalysts. We are working together with Department of Physics on the use of Transmission Electron Microscopy and Scanning Tunneling Microscopy. We focus on characterisation of catalysts at working conditions and for this purpose we are using the European Synchrotron Radiation Facility in Grenoble and together with the Ugelstad Laboratory we have recently purchased new facilities for IR and Raman spectroscopy. The TEOM (Tapered Element Oscillating Microbalance) is also a powerful technique for studying important phenomena like catalyst deactivation, diffusion in porous materials and adsorption, absorption and desorption.

Catalysis Group



First row from left:	*Camilla Otterlei, Andreas H. Lillebø, Ida Hjorth, Farbod Dadgar, Jun Zhu, Charitha Udani, Nicla Vicinanza, Micael Wycisk, Nikolaos Tsakoumis*
Second row from left:	*Rune Lødeng, Torbjørn Gjervan, Haitao Zhou, Håkon Bergem, Marie Døvre Strømsheim, Tayyaba Noor, Karin W. Dragsten, Hilde Bjørkan, Georg Voss*
Third row from left:	*Svatopluk Chytil, Marianne Aune, Fengliu Lou, Rune Myrstad, Xuehang Wang, Marthe Emelie M. Buan, Eleni Patanou, Yanying Qi, Sara Boullosa Eiras, Ingeborg-Helene Svenum*
Fourth row from left:	*Jesus Manuel Garcia Vargas, Ilya Gorelkin, Edd A. Blekkan, Anders Holmen, Magnus Rønning, Navaneethan Muthuswamy*
Not present:	*Hilde Venvik, Trung Dung Tran, Jia Yang, Bjørn Christian Enger,*
(right column)	*Daham Sanjaya Gunawardana,, De Chen,.*

COLLOID- AND POLYMER CHEMISTRY GROUP

(UGELSTAD LABORATORY)

Academic staff
Professor Johan Sjöblom
Professor Gisle Øye
Associate Professor Wilhelm R. Glomm
Associate Professor Brian A. Grimes
Adjunct Professor emeritus Per Stenius
Professor II Hans Oschmann
Associate Professor II Martin S. Foss
Professor Emeritus Arvid Berge
Professor Emeritus Preben C. Mørk

Reseachers
Bartolomiej Gawel
Kristofer Paso
Sébastien Simon

Post docs
Galina Rodionova (from 01.02.2012)
Gurvinder Singh
Meysam Nourani (from 17.10.2012)
Serkan Keleşoğlu

PhD candidates
Albert Barrabino Ponce
Andreas Lyng Nenningsland
Birgitte Hjelmeland McDonagh (from 13.08.2012)
Karina Kovalchuk
Lalit Kumar
Mehdi Benmekhbi
Mona Eftekhardadkhah
Sina Maria Lystvet
Sulalit Bandyopadhyay (from 20.08.2012)
Thomas Tichelkamp (from 01.08.2012)
Yansong Zhao

Laboratory Manager
Camilla I. Dagsgård

Technical staff
Bicheng Gao
Caterina Lesaint
May Grete Sætran (from 08.10.2012)
Runar Sandnes (04.09. – 31.12.2012)
Signe Håkonsen (until 28.02.2012)
Murside Kes Keleşoğlu (from 01.04.2012)

Guests
Jamilia Safieva, Post Doc, Russian Academy of Science, Moscow
Jens Norrman, Lund University, Sweden

Overview:

The Ugelstad Laboratory was founded in honour of Professor John Ugelstad at the Norwegian University of Science and Technology in January 2002 (Department of Chemical Engineering). The laboratory specializes in surfactant chemistry and its technical applications, emulsions and emulsion technology, preparation of polymers and polymer particles and their technical applications, plasma chemical modification of surfaces and silica-based chemistry.

Applications include crude oil production and processing, pulp and paper, biomedicine, catalysis and materials science.

The main purpose is to raise the national level of colloidal science by establishing a modern educational, research and development laboratory within the field of colloid, polymer and surface chemistry.

Diploma and PhD studies are offered within these topics, often in close collaboration with industrial companies. The aim is to educate highly qualified candidates for industrial positions. In order to attract the best and most motivated students and researchers, the laboratory has invested in new and modern instrumentation. The laboratory also participates in international exchange programmes, and hosts internationally renowned guest researchers and lecturers.

The Ugelstad Laboratory is sponsored by industrial companies, the Research Council of Norway (NFR), research institutes and NTNU. All the members are annually invited to a presentation of the recent research activities at the laboratory. This is combined with the Ugelstad Lecture, where invited scientists lecture within the field of colloid, polymer and surface chemistry.

Research Activities:
In the following paragraphs, selected ongoing research programs for 2011 are briefly described. For a complete description of the research activities at the Ugelstad Laboratory, please visit our web page: www.chemeng.ntnu.no/research/polymer/ugelstadlab

JIP-1: Increased Energy Savings in Water-Oil Separation through Advanced Fundamental Emulsion Paradigms (NFR PETROMAKS) 2011 – 2013

The goal of the project is to advance fundamental knowledge of the water-oil separation process in order to make it more energy efficient. The focus will be on accelerating the processing of high volumes of water and viscous oil by speeding-up the sub-processes of creaming and sedimentation of existing emulsions in the first stage. The second stage involves the treatment of concentrated w/o or o/w emulsions. This program is a continuation of two previous JIP projects run in the past 6 years which were focused on an improvement of understanding of the stabilizing and destabilizing mechanisms of water-in crude oil emulsions based on heavy and particle-rich crude oils and also on the modeling (start-up, rheology and separation).

This project is a collaborative effort between the Ugelstad laboratory, University of Alberta, University of Bergen, IFE and several international partners.

Multiphase Flow Assurance Innovation Centre (FACE) – Centre for Research-Based Innovation (SFI) 2006-2014

An increasing fraction of hydrocarbon reserves are difficult or impossible to produce and process today mainly due to the complexity of the fluids. Production of these reserves will require new and innovative technologies. FACE will develop the knowledge base for the new predictive tools that will be essential in order to develop the new, innovative production solutions. It is expected that new SMB's will be generated based on knowledge and technology from the centre as well as development of new or improved products in existing companies. The research is focused on transport and separation aspects of three thematic topics, i.e. heavy crude oils, dispersed systems (emulsions), and solid particulate suspensions (hydrates, wax, sand and fines).
We will use existing laboratories to perform both small-scale and high-pressure, large-scale flow experiments in pipes and separators.
This project is a collaborative effort between NTNU, SINTEF, IFE and UiO.

Produced Water Management – fundamental understanding of the fluids (2010-2014)

Good practical expertise in PW management exits among the oil and gas producers and in the related vendor industry. However, most of the expertise has been gained through trial-and-error approaches to solve field specific problems. There is a clear lack of fundamental understanding on the microscopic and molecular level with respect to the mechanisms that govern separation efficiency of dispersed components and the injectivity of the PW fluids.

The overall objective in this project is to provide a tool for industrial companies involved in PW management in terms of fundamental knowledge of interaction properties between dispersed components (oil/solids/gas) present in PW streams. The project is currently supported by 5 industrial sponsors.

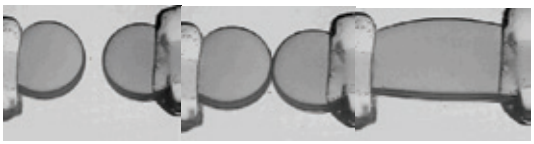


Figure: Coalescence of two oil droplets (Images: Dr. B.Gawel)

Shut-in and Restart of Waxy Crude Pipelines: Software Module Development (KMB with NFR 2010 – 2013)

Waxy crude oil is commonly found on the Norwegian Continental Shelf and elsewhere. The waxy production fluids will then tend to form a structured gel-like plug inside the pipeline. It is therefore essential to design and operate the pipeline such that restart is possible in a safe and timely fashion. It has been observed that when the inlet pressure is increased it can take days or weeks for the gel to start moving. Detailed rheological measurements will be performed on gelled oil properties and on the removal of gelled oil a pipelines. A model will be developed to encapsulate a physical understanding of the gel-breakage process into a useful simulation tool. The model will account for chemicals injected to reduce wax formation, and thus enable optimal dosaging. In addition, a large thrust of the project will be to develop more effective pour point depressants (PPDs) and yield point depressants (YPDs) in conjuction with chemical manufacturers and chemical suppliers.

This project is a collaborative effort between the Ugelstad laboratory, the Institute for Energy Technology (IFE) and industrial partners.

Prediction of Ca-Naphthenate Deposition in Water-Oil Systems (JIP-2:4 2011 – 2013)

During the past years, extensive work has focused towards naphthenate precipitation from acidic crude oil. Due to a rise in crude pH, the naphthenic acids

dissociate and react with divalent cations, especially calcium. These compounds accumulate at the oil/water interface and might cause costly shutdowns. This program is a continuation of two previous JIP projects run in the past 6 years. Several key elements about calcium naphthenate were identified. Procedures and methods were developed as well which give the JIP members a technological lead in the naphthenate treatment. The continuation of the project, JIP2-4, was developed towards the establishment of a model predicting calcium naphthenate deposition in oil/water system based on interfacial conditions together with advanced techniques to detect calcium naphthenate formation in an early stage (on a nanogram scale). We intend to establish critical conditions for gel formation.

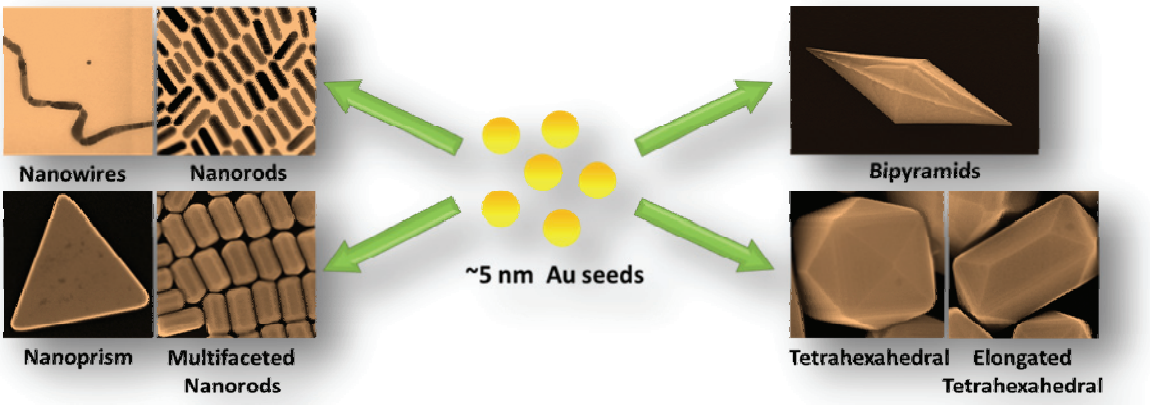
This project is a collaborative effort between the Ugelstad laboratory and several international partners.

A Combined Surface-Colloid Chemical and Rock-Fluid Interaction Approach towards more Efficient Enhanced Oil Recovery Strategies

The Research Council of Norway has granted a new project within enhanced oil recovery, which will start in 2012. The primary objective of the project is to provide essential knowledge of how surfactants can improve low salinity water flooding processes by taking all the categories of indigenous crude oil components into account. The studies will range from molecular level to fluid-rock interaction and dynamic displacement studies.
The project is a collaborative effort between Ugelstad Laboraory, Department of Petroleum Engineering and SINTEF Petroleum Research, and is supported by 4 industrial sponsors.

Anisotropic Gold Nanostructure

Anisotropic noble metal nanostructures have been the focus of intense attention owing to their size-and shape-dependent physical and chemical properties. These properties have driven their numerous applications in areas such as spectroscopy, catalytic, sensor, energy, and biomedicine. In recent years, synthetic routes have been explored for metal nanostructure with high index facets which possess a high density of low-coordinated atoms serving as active sites for breaking and forming chemical bonds. Therefore, such nanostructures significantly enhance catalytic activity and stability than to flat plane nanostructure where the atoms are closed-packed i.e., atoms are saturated. It is, however a great challenge to synthesis such nanostructures with tunable size or geometry because of high surface energies without any size or shape separation. Our group investigate a novel seed mediated method by using binary surfactants to grow a variety of nanostructure including pyramids, tetrahexahedral, elongated tetrahexaderal, nanoprism, and multifaceted nanorods. The aim of this work is to understand the role of different halide ions present in secondary surfactant which acts as structure directing agent in the formation of various shaped nanostructures along with cetylammonium bromide (CTAB) as a primary surfactant. We further measure optical properties and electrochemical catalytic activity of these nanostructures.

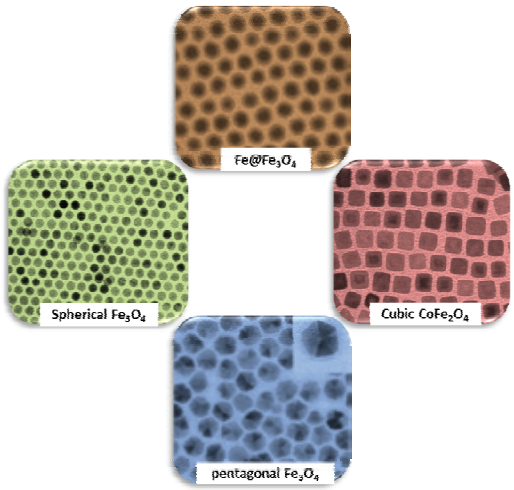


Scheme illustrating the growth of various shaped gold nanostructures via seed mediated approach in the presence of different halides and silver ions

Magnetic Nanoarchitecture

Wet chemical approaches have especially been recognized for their capability to produce a variety of

magnetic nanoparticles with highly controlled size, shape, and composition by careful regulation of thermodynamic parameters and growth kinetics in liquid media under the assistance of selected solvents, ligands, surfactants and catalyst additives. Such magnetic nanomaterials exhibit unique size/shape dependent magnetic properties, and find applications in target drug delivery, MRI imaging, therapy in biomedicine, recoverable catalysis, and storage devices, etc. However, synthesis of shaped controlled magnetic nanoparticles with high magnetic moment still imposes a challenge limiting their practical applications. Our group mainly focus on investigating new mechanistic approaches for the various shaped nanoparticle synthesis with improved magnetic properties. Recently, we discovered that the selection of appropriate surfactant is mandatory to tune the magnetic properties at nanoscale exhibiting ferromagnetic behavior at room temperature. In order to design multiresponsive materials for biomedical applicatons, we also explore various strategies to modify the surface chemistry yielding with molecules such as dopamine, polyethylene glycol, bovine serum albumin, GFP, and temperature/pH responsive polymers.

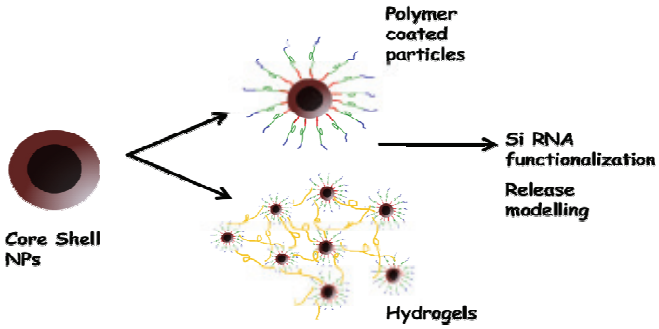


Design of magnetic nanoarchitecture of various shapes and composition by a thermal decomposition approach

Smart and Multifunctional Core-shell Nano-particles (NPs) for Drug Delivery.

Core-shell nano-particles (NPs) represent a new class of materials, possessing tunable multifunctional properties for which they find wide applications in electronics, catalysis, separations, drug delivery and medical diagnostics. The field of medical diagnostics and drug delivery is one of the most important application fields of such nano-constructs. This comes with the need to unite various functionalities like contrasting, targeting, imaging into a single nanostructured system, integrating the strengths of individual modalities in order to produce multifunctional constructs.

The project aims at synthesizing and characterizing core-shell NPs suited to targeted drug delivery applications. The optimized NPs would therefore be screened for surface functionalization with multiresponsive block copolymers, synthesized in-house to target drugs and small molecules. Molecular dynamics studies will be carried out to simulate release kinetics in vitro and then validated against experimental results. These nano-constructs will be tested in regards to magnetic resonance imaging (MRI) contrast agent, targeted drug delivery and other pertinent applications. These nanomaterials will have multifunctional applications in diagnostic and therapeutic fields.

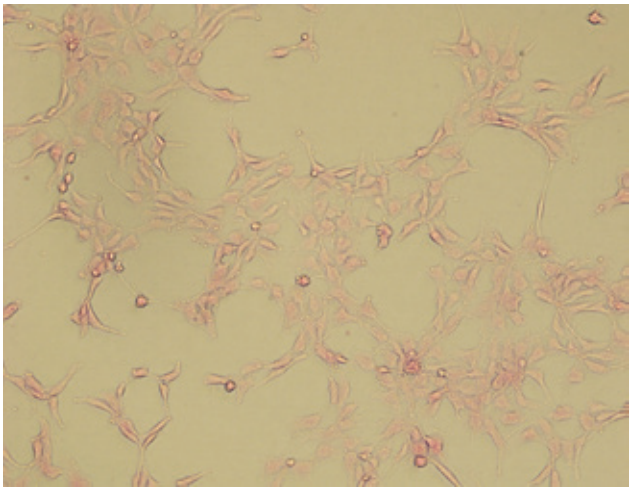


Overall Schematic of the project

***In vitro* toxicity of protein-gold nanoparticle constructs and gold coated iron nanoparticles (2012-2013)**

Proteins, such as bovine serum albumin (blood serum transport protein) and transferrin (transports iron into cells), can reduce aqueous gold (III). As the gold ions are reduced, they grow on the protein backbone, changing the tertiary structure of the protein. The combination of protein and gold give rise to novel optical properties. Our group has shown that these constructs have high affinity towards lipid membranes. *In vitro* toxicity of protein-gold nanoparticles on different neural stem cells are currently being performed at the Department of Circulation and Medical Imaging. Recent results show that protein-gold nanoparticle constructs can cause a massive disruption on cell membranes at higher concentrations. At lower concentrations, the disruption of cell membranes is less prominent. However, the constructs have been shown to assemble around the cell body, were they can be visualized by standard immunostaining excitation wavelengths.

Nanoparticles that do not disrupt the cell membrane, but is taken up, can possibly be used as vehicle for targeted drug delivery. Synthesis of iron nanoparticles with an outer shell of gold (core-shell nanoparticles) can be modified with poly(ethylene glycol) (PEG) for *in vitro* studies (see figure). Iron and gold both have magnetic properties that can be used as contrast agents in MRI.



Gold coated iron nanoparticles modified with PEG were added to olfactory ensheating cells (neuronal cells) and colored with Prussian blue. Intracellular and extracellular dark areas indicate iron nanoparticles.

Industrial Partners of Ugelstad Laboratory

- Akzo Nobel
- BASF
- BP
- Champion Technologies
- Clariant
- ConocoPhilips Inc.
- Det Norske oljeselskap
- Du Pont
- ENI
- GDF Suez
- Hamworthy
- Institute for Energy and Technology
- Kemira
- Lundin Norway
- Paper and Fibre Research Institute
- Petronas
- Petrobras
- REC Wafer
- REP
- Saudi Aramco
- Schlumberger Norge AS
- Schlumberger MI EPCON
- Shell Global Solutions
- Shell Technology Norway
- SINTEF
- Statoil ASA
- Total

Colloid- and Polymer Group

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Second row from left: *Mehdi Benmekhbi, Bartlomiej Gawel, Jens Normann, May Grete Sætran*
Third row from left: *Wilhelm Glomm, Bicheng Gao, Thomas Tichelkamp, SerkanKeleşoğlu*
Fourth row from left: *Sebastien Simon, Albert Barrabino, Sreedhar Subramaniann Meysam Nourani*
Fifthe row from left : *Aristides Katto, Gisle Øye, Johan Sjöblom*

PROCESS SYSTEMS ENGINEERING GROUP

Academic staff
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Professor Heinz A. Preisig
Associate professor Tore Haug-Warberg
Associate professor Nadi S. Bar
Adjunct professor Krister Forsman (from July 2012)
Professor emeritus Terje Hertzberg

Post Doc.
Johannes Jäschke

PhD candidates
Chriss Grimholt
Deeptanshu Dwivedi (PhD defence 18 Jan. 2013)
Esmaeil Jahanshahi
Håkon Dahl-Olsen
Jørgen Skancke (until Nov. 2012)
Maryam Ghadrdan
Naresh Doni Jayavelu
Ramprasad Yelchuru (PhD defence 12 June 2013)
Vinicius de Oliveira
Vladimiros L. Minasidis

Guests
Nabil Magbool Jan, visiting PhD student from IIT Madras, Chennai, India (until 29 June 2012)
Sridharakumar "Sridhar" Narasimhan, Visiting Professor from IIT Madras, Chennai, India (June-July 2012)
Sungwon "Bao" Boksuwan. Visiting PhD student from Univ. of Electro-Communications, Chofu, Japan (Sep. 2012)

Profile:
Process systems engineering deals with the overall system behaviour, and how the individual units should be combined to achieve optimal overall performance. Important topics are process modelling on all scales, operation and control, design and synthesis, and simulation, statistics and optimization. The group closely cooperates with other systems-oriented departments at the university, including Engineering Cybernetics, Energy and Process Engineering and Industrial Ecology, and also with SINTEF. The process systems engineering activity at NTNU (PROST) holds high international standards and was already in 1994 recognized as a strong-point centre, both by NTNU and SINTEF.

The activity of the group has been strengthened by the appointmen of Krister Forsman as Adjunct Professor (Professor II) in Process Control in July 2012. Krister Forsman received his PhD in control theory from Linköping University in 1991 working with Professors Ljung and Glad. He worked about 10 years with ABB focusing on process control in the pulp and paper industry. Since 2005 he works with the Perstorp Chemicals group in Sweden where he presently is Corporate Specialist Process Control. He has worked with process and control optimization at around 60 different plants in almost 20 countries, including France, Germany, England, Holland, USA, Australia, Singapore, Canada, South Africa, Chile, India and Indonesia. Krister has over the years maintained close contacts with academia and is involved in several joint projects with universities. He has more than 50 publications and several patents and has written a textbook on process control (Studentlitteratur, 2005, in Swedish). In February 2012, he was awarded the "Big Automation Prize" at the Swedish Automation Days in Stockholm.

Process Control Activities
Industrial use of advanced process control increases rapidly, and candidates who combine process knowledge and control expertise are in high demand in industry. Control is an enabling technology, thus basic for any industry-based society. The use of advanced control is transforming industries previously regarded as "low-tech" into "high-tech". In process control (Sigurd Skogestad and Heinz Preisig), the objective of the research is to develop simple yet rigorous tools to solve problems significant to industrial applications.

Up to now, the design of the overall "plant-wide" control structure has been based on engineering experience and intuition, whilst the aim has been to develop rigorous techniques. The concept of "self-optimizing control" provides a basis for linking economic optimization and control (Sigurd Skogestad). For example, for a marathon runner, the heart rate may be a good "self-optimizing" variable that may be kept constant in spite of uncertainty. Control is done in a hierarchical construct. At the bottom of the hierarchy, the main issue is to "stabilize" the operation and follow the setpoints provided by the layer above. Further up in the hierarchy one finds optimising control co-ordinating the control of units and plants. A special case is sequential control, which is used to implement recipes in batch operations but also is the basics of handling start-up and shut-down as well as all fault and emergency handling. Another important concept is controllability, which links control and design. Here the main focus is on applications, which currently include reactor and recycle processes, distillation columns, gas processing plants, cooling cycles including liquefied natural gas (LNG) plants, low-temperature polymer fuel cells and anti-slug control. Small-scale experimental rigs have been built to study anti-slug control and novel distillation arrangements. In most cases, control is an "add-on" to enable and improve operation, but the anti-slug rig demonstrates how control in some cases can be used to operate the system in a completely different manner.

At the 2012 Annual Meeting of the Ameican Institute of Chemical Engineers (AIChE) in Pittsburg it was announced that Sigurd Skogestad has been elected Fellow of AIChE.

Process Modelling Behaviours
The centre piece of process systems engineering is the model. Modelling is generally seen as a difficult and time consuming operation. The step-wise approach developed in this group has transformed the art of modelling into a nearly procedural operation, which has been captured in a program environment (Preisig). The modelling operation is thereby lifted up from writing equations to choosing concepts and mechanisms. The equations are then generated and assembled automatically taking the applicable equations from a data base that has built applying mechanistic descriptions where ever applicable. Multi-scale modelling is supported by enabling order-of-magnitude assumptions, which automatically induce model reduction thereby eliminating structure-related mathematical problems. The overall objective in the group is to develop efficient object-oriented software tools that implement this method and assist in developing consistent and structurally solvable process models on different scales that match the particular application. The technology is physics-based with extensions to allow for grey-box modelling. It aims at replacing various graphical interfaces to simulators and generates code for the major chemical engineering simulators such as gProms, Matlab, Modelica etc. but will also be able to generate stand alone, application-tailored simulators. The fourth generation of a high-level modelling tool (Preisig) incorporates object-oriented tools for efficient thermodynamic modelling, which extend into the efficient computation of thermodynamic information. Rather than a traditional implementation of activity or fugacity coefficients, emphasis is put on the use of structured equation sets governed by thermodynamic consistency rules (Haug-Warberg).

The thermodynamic models are implemented in symbolic form with automatic differentiation capabilities and serves as the basis of several industrial strength simulations (YASIM, CADAS) and energy accounting tools (HERE) in co-operation with StatoilHydro and Yara (Haug-Warberg). A primary aspect of thermodynamic (and other physics) modelling is the required consistency of physical units. We have a procedure to obtain self-consistent models, including automatic generation of gradients. This technique has so far been tested up to sixth order gradients, which are needed for higher-order critical point calculations.
In cooperation with Yara AS we have implemented a thermodynamic stream calculator “Yasim”. It has a gentle learning curve using the familiar Excel worksheet interface whilst using state-of-the-art thermodynamic methods. All model information including mass balances, energy balances, chemical and phase equilibrium relations are defined in symbolic form. Differentiations are done in symbolic form. These properties add unsurpassed flexibility to Yasim that is not found in any other software of its kind. The ease of use should make it ideally suited for training and use in an industrial environment.

Model-Process Interface
The model generally needs to be fitted to experimental data, and the group has always has a strong focus on statistical methods and experimental design (Hertzberg). Although Professor Hertzberg retired in 2007, he is still active in this area, and in particular, in teaching.

Systems biology
The system biology activity in the group is new, and we here provide a more detailed status on it. Whereas the rest of the Process Systems engineering group looks at any process, whether it is a large industrial scale process or a smaller parts of the process, and strive to model, optimize and control it, the systems biologist in the group (Nadav Bar and coworkers) use similar tools to achieve the same in processes from the world of biology. This includes understanding the biological system, modelling it qualitatively and quantitatively, analysing the models to find hidden properties, and ultimately developing control applications in order to drive the system towards more desired objectives. We use mathematical and computer tools, and we rely on the cooperation with our partners for experimental results. The activities in system biology aee presently in four main research areas:

Cancer research
We are involved in a large integrated project led by two groups from St. Olav's hospital (Astrid Lægreid, Liv Thommason), who possess a large laboratory. This lab conducts clinical experiments on cancer (taken from human patients) and on mammalian (usually mice) cells. They conduct micro-array measurement of gene expression, in addition to NMR and other methods that evaluate gene expression. Their problem is the millions of data points generated in the last 10 years, which they are unable to process without more advanced mathematical tools systems biology We apply tools from network component (NCA) and matrix analysis to systemize large quantities of data. Recently (2012), we managed to identify several components in this huge network that regulates gene expression. This includes new exciting results that enables extension of the original NCA method to predict large amount of these 'regulators' of gene expression, making it much more usefull in biology than it was before. Additionally, it also forms a basis for the quantitative modelling we plan for the Gastrin network in the coming years. Since the NCA tells us about the kinetics of the genes and their regulators, it can be utilized to estimate unknown parameters.

Bat behaviour
In corporation with two groups from Israel, (Nachem Ulanovsky at the Weizman institute, and Yossi Yovel at Tel Aviv University) we developed a dynamic model that describe the flight pattern of the bat that wants to catch a moving target (insect). We found that that the bat uses a controller with derivative control effect. However, this amplifies the noise and reduces the ability to detect the target while flying, increasing the chance to loose its food.

Aquaculture modelling
This important project, which was also part of Associated Professor Bar's PhD work) has presently a low activity, both due to lack of student with required knowledge and temporarily insufficient funds from Forskningsrådet and EU. The Aquaculture modelling project extends its activity to modeling hunger and feed intake, a very important factor in fish growth and a significant factor in the aquaculture activity and economical benefits. We wish to be able to control the appetite of the fish in rearing conditions (such as Salmon) through the effect of the balance of the food ingredients, without adding any artificial additives such as hormones. Since this industry produces very large quantities of fish every year, even a small increase in daily feed intake will result in a massive increase in fish production and large profits to both the feed manufacturers and the fish farmers.

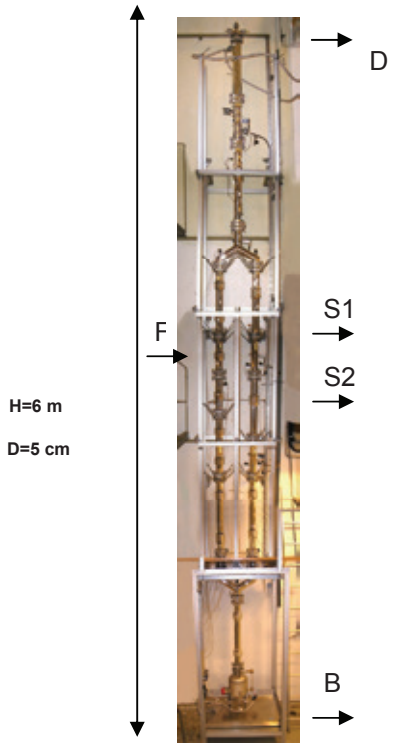
Prediction of gene expression
This project started is in cooperation with the other system biology groups at the Faculty, namely those of Martin Kuiper (Department of Biology) and Svein Valla (Department of Biotechnology). Using bioinformatics tools, we want to show how the bonds between the DNA and the mRNA are correlated to gene regulation. During 2011 we conducted experiments at the Department of Biotechnology. The expression data acquired enables us to compare the simulations and conclude about the mechanisms involved.

Education
Associate Professor Nadav Bar has developed 3 new courses at the Master and PhD level, and an"Experts in Team" course on modelling and analysis biological processes. The courses provide control, modeling and analysis tools for complex biological networks.

Equipment in the systems group
The Kaibel distillation column (see picture) is 6 meter high and 5 cm in diameter and can be used to study "thermally coupled" columns, including the three-product Petlyuk column and the four-product Kaibel column. Dr. Ivar Halvorsen from SINTEF and Sigurd Skogestad manage this integrated distillation project. An automatic drink robot is used for demonstration purposes and to study sequence control based on automata theory (Heinz Preisig). In 2011 we built a new two-phase "mini-loop" to test anti-slug control strategies.

The group also has a control teaching laboratory, which currently includes three thermal/air flow processes, a pseudo flash and a mixing process.

Funding Source
Funding comes from the The Research Council of Norway, the Gas Technology Centre at NTNU and SINTEF, Gastrocenteret at the St, Olav's Hospital, from industry (StatoilHydro, Gassco, Siemens, Biomar) and from the EU (ProMatch program).



Kaibel Distillation column.

PROCESS SYSTEMS ENGINEERING GROUP

First row from left: *Anne Sofie Nilsen, Helene Paulsen, Ola Sæterli Hjetland, Siri Hofstad Trapnes, Sigurd Skogestad, Tore Haug-Warberg*

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Third row from left: *Vladimiros Minasidis, Axel Lødemel Holene, Chriss Grimholt, Johannes Jäschke, Vinicius de Oliveira, Stian Aaltvedt, Knut Arne Wuttudal Hildenes*

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Professor Hugo A. Jakobsen
Professor Magne Hillestad
Associate Professor Jens-Petter Andreassen
Associate Professor Hanna Knuutila
Associate Professor Liyuan Deng
Adjunct Professor Geert Versteeg
Adjunct Professor Jon Samseth
Professor Emeritus Olav Erga

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Eddie Setekleiv (from
Emmanuel Mba Orji (until 03.03.2012)
Muhammad Usman (from 22.10.2012)
Naveed Asif

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Kumar Ranjan Rout (from 11.12.2012)
Mohammad Washim Uddin (from 22.05.2012)
Ralf Beck
Xuezhong He
Qiang Yu
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Arlinda Çiftja
Camilla Berge Vik (from 06.08.2012)
Diego Di Domenico Pinto
Divina D. Kaombe
Hamid Mehdizadeh
Inger Lise Alsvik
Jamil Ahmad
Jannike Solsvik
Juliana Monteiro
Karen Nessler Seglem
Koteswara Rao Putta (from 05.09.2012)
Lijuan Wang
Margrethe Nergaard
Mayuri Gupta
Muhammad Saeed (from 01.05.2012)
Muhammad Washim Uddin (until 30.04.2012)
Nina Enaasen
Nuria Tavera Valero
Paris Klimantos
Peter Bruder (until 31.01.2012)
Rafael Sánchez
Solrun Johanne Vevelstad
Shahla Gondal
Tom-Gøran Skog
Vajiheh Nafisi
Xiao Luo (until 21.05.2012)
Xiaoguang Ma
Zhongde Dai (from 05.11.2012)
Zhongxi Chao (until 17.12.2012)
Zsolt Borka
Øystein Jonassen

Technical staff
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Gøril Flatberg (from 08.08.2012)
Yulia Flid

Guests
Agata Zarebska (PhD student from DTU, Denmark)
Maria Teresa Guzman Guitierrez (Guest researcher from Universidad Nacional Autónoma de México (UNAM))
Muhammad Waseem Arshad (PhD student from DTU, Denmark)

Environmental engineering and reactor technology is the largest research group in the department covering interests in the fields of chemical reactor research, process design, acid gas absorption, membrane research, and crystallization and particle design. Our group is involved in research projects for the capture of CO_2. One example is the BIGCCS – International CCS Research Centre which is one of eight centres established The Research Council of Norway, under the scheme of Environmentally Friendly Research Centres (CEER).

The BIGCCS Centre focuses on sustainable power generation from fossil fuels based on cost-effective CO_2 capture, safe transport, and underground storage of CO_2. The members of the environmental and reactor technology group are involved in topics like separation of CO_2 with membranes, capture of CO_2 in systems with simultaneous crystallization of solids, dynamic modelling of absorption processes, and modelling and simulation of sorption enhanced steam methane reforming operated in fixed and circulating fluidized bed reactors.

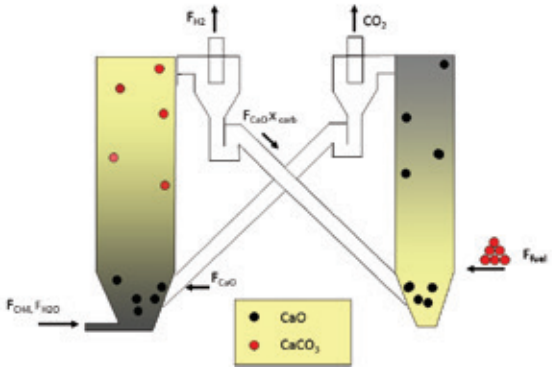
Chemical Reactor Research

The activity on reactor engineering has been concentrated in fields directly supporting the design and development of chemical reactors and reactive separations. The most important research areas are:

- Mathematical modeling of chemical reactors.
- Multiphase flow modeling.
- Design of novel solution methods and algorithms.
- Experimental analyses of fluid flow, fluid particle coalescence and breakage, CO_2 sorption by adsorbents and heat- and mass transfer in chemical reactors.
- Experimental validation of numerical models.
- Analysis and design of reactors for environmentally friendly chemical processes.

The research in these fields comprises both experimental and theoretical studies, but emphasis is placed on modeling, development of numerical methods and in-house software for multi-phase reactor simulations.

The simplest models considered are normally implemented in the programming language Matlab, whereas the computationally demanding models are implemented in FORTRAN 90 and C++. Application areas are special chemicals reactors, polymer production, sorption enhanced steam methane reforming, conventional synthesis gas and methanol synthesis, membrane reactors, wood gasification and chemical looping combustion.



A circulating fluidized bed reactor used for studies of sorption enhanced steam methane reforming (SE-SMR).

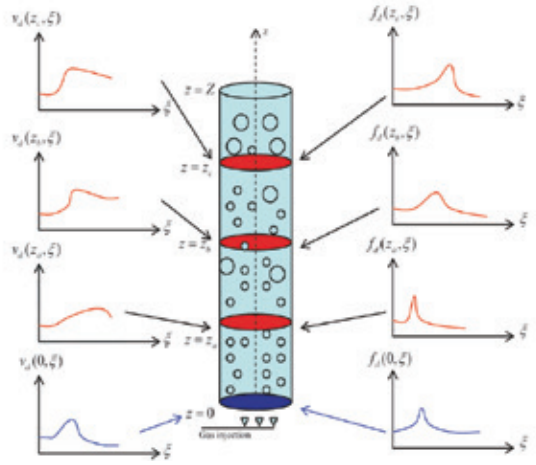
Educationally the main objective of our group is to educate MSc for the Norwegian industry and to raise the national scientific competence in our field of research through PhD studies.

Research activities

The most important research projects are described in the following paragraphs. For a more comprehensive description, see: (www.ntnu.no/kjempros/miljoreaktor)

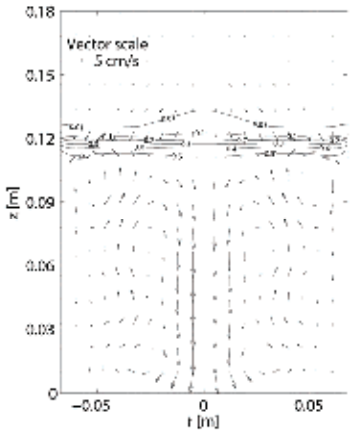
Modeling of multi-phase reactors

We have for more than 20 years been developing in-house CFD codes for simulating multiphase flows in chemical reactors. Lately, our main focus has been put on developing modules for bubble/droplet break-up and coalescence within the population balance equation (PBE) framework.



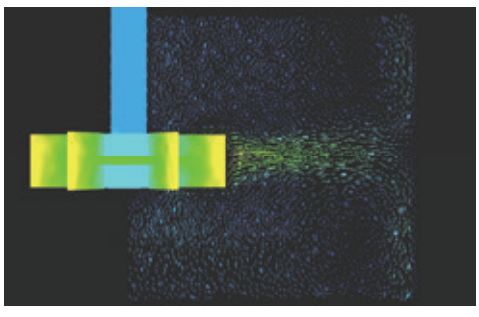
A cold flow bubble column used for studies of bubble breakage and coalescence mechanisms.

The PBEs are solved accurately by efficient spectral and spectral-element methods designed for this particular purpose.



Flow pattern in a bubbling fluidized bed.

We are also investigating the performance of chemical reactive systems like fluidized beds, fixed bed reactors and agitated tanks. At present we are working with the design of suitable reactors for sorption enhanced reaction processes (SERP) like steam reforming with absorbents for CO_2.



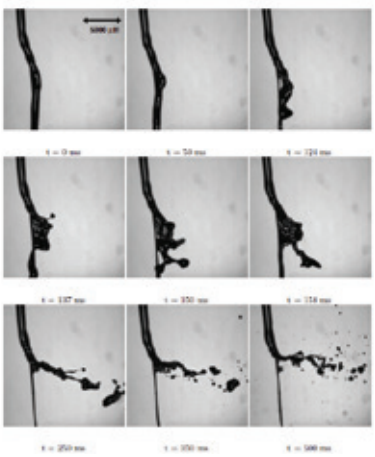
Simulation of the flow pattern from a turbine impeller.

The conventional 1D and 2D steady-state reactor models are normally run on standard PCs whereas the more computationally demanding dynamic 2D and 3D single and multiphase flow simulations are run on the national super-computers located at the university.

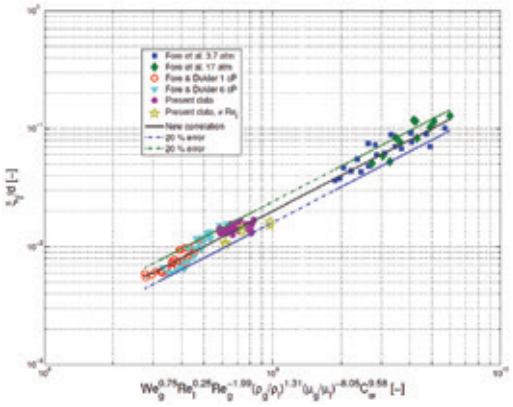
Advanced Modeling and Simulation of Chemical Reactors
The activity in this area is mainly founded by the Norwegian Research Council through the GassMaks program. The work in this project is focused on modeling of chemical reactors like fixed packed bed-, bubble column-, and fluidized bed reactors by the complete multifluid model containing a population balance equation for the fluid particle size distribution for the multiphase reactors. The model equations are solved by the modern least squares spectral element method. In the next phase of the project the novel in-house codes will be applied analyzing the chemical reactor processes utilizing natural gas as feedstock.

CO_2 capture and droplet removal

Removal of droplets from high pressure gases
An area of great importance for the Norwegian gas producing industry is the separating out of droplets from high pressure gases. Downstream process equipment e.g. compressors, separation processes or chemical reactors suffer disturbed operation or break-down if gases are not droplet free. Today's units are not good enough at high pressures, and robust and reliable solutions must be found in particular for sub-sea completions. The projects HiPGaS, HiPGLS and now HiPGLSII were established for studying the phenomena governing such separations. In collaboration with ten industrial partners separation rigs have been established for both low and high (<150 bar) pressures at NTNU and at the Statoil research center at Rotvoll. Tests within the projects have also been performed at semi-industrial scale at the K-lab facility at Kårstø. Results from the high pressure rigs are unique and form a basis for model validation. In an established laser laboratory we study droplet/droplet and droplet/surface collisions and the stability and break-up of liquid jets and surfaces leading to re-entrainment of droplets. There is a strong interaction between experiments and numerical models. Examples are shown below for the breakup of liquid film on a thread, typical of what happens on a mesh pad separator.

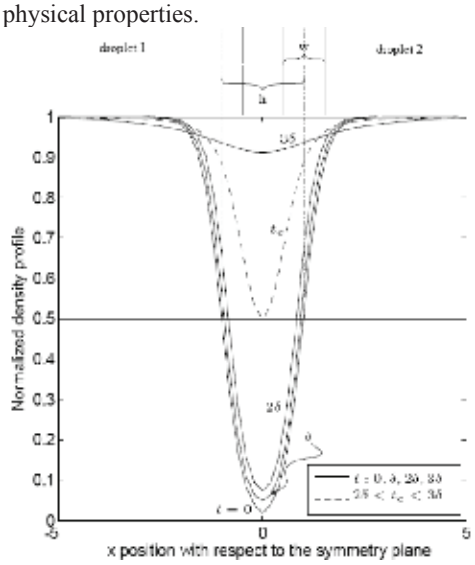


Effect on liquid film stability by increasing gas flow

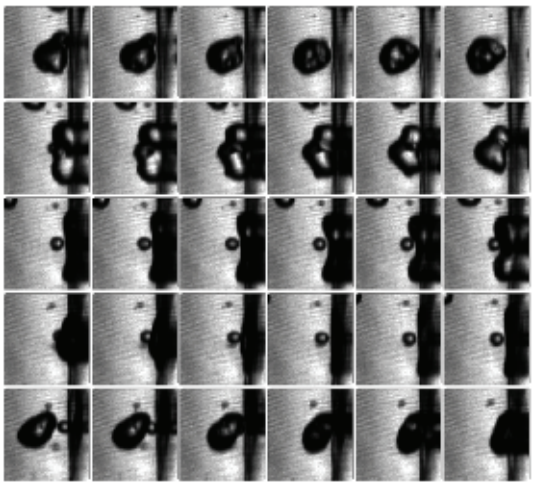


A new correlation for estimating entrained droplet size

A new and more general correlation for predicting droplet size distributions, valid for several geometries has been developed.
In the area of droplet collision outcomes a more fundamental model has been developed based on lattice Boltzmann and a Cahn-Hilliard/free energy approach to treat the interface having a thickness depending on physical properties.



Interfacial coalescence using the Cahn-Hiliard model



High speed video of partial deposition for the CO_2-CO_2 system at 70 bar

The model is extended for the particular case of multiscale simulations. Modelling real droplets with real interfaces is critical for predicting coalescence behaviour. Simulations for interface thickness to droplet radius ratios of more than two orders of magnitude were performed. The model is a first in its kind where coalescence and pinch off effects can be captured without adding additional closure laws, only through an energy description that takes into account non-uniform systems. Droplet deposition studies were performed at relatively high pressures (<70 bar) and the CO_2 system was found to provide a very good test system as interfacial tension down to 1 mN/m could be achieved. The figure above shows partial deposition in the CO_2 system. Interfacial tension in high pressure hydrocarbon systems are measured with a pendant drop technique, and modelled using gradient theory for an inhomogeneous interface.

CO_2 capture from exhaust gases and natural gas sweetening.
One of the most fundamental problems facing the earth today is global warming. The emissions of CO_2 contribute about 75% to the greenhouse gas effect and must be reduced, e.g. by CO_2 Capture and Storage (CCS).

We have many research projects in this area funded by the Research Council of Norway, the industry, and the European Union. Our work is concentrated along two axes, one studying CO_2 capture from off gases from fossil fueled power plants and from the iron and steel-making industry, and the other directed toward the removal of acid gases from natural gas. We were heavily involved in EU FP6 projects, e.g CASTOR and CAPRICE. This work has continued in the EU FP7 CESAR project, as coordinator of the EU FP7 iCap project and partner in the OCTAVIUS project. Of the national projects on CO_2 capture, the largest is SOLVit, a JIP with Aker Clean Carbon (ACC). Other projects are VOCC, REACT, RENICUV and the Research Council financed BIGCO2, now BIGCCS. In the CCERT project, a JIP with Research Council financing and four industrial partners, fundamental problems are addressed.

The work we do involves all steps from theoretical screening of new absorbents by use of computational chemistry, through experimental screening, testing of environmental properties, characterization of equilibrium, thermal properties, transport properties and kinetics, degradation rates and mechanisms up to testing in laboratory scale pilot plants. We have also studied nitrosamine decomposition with UV-light on pilot scale. In parallel with the experimental work we develop models ranging from simple models for physical properties to rigorous kinetic and thermodynamic models, based on the electrolyte NRTL and extended UNIQUAC model frame-works. All these models are then implemented in our own SINTEF/NTNU in-house simulator CO2SIM to simulate the whole absorption-/regeneration process. Experimental data from our reaction calorimeter and equilibrium experiments can be compared with model predictions as shown in Figures 1 and 2. In a similar way the equilibrium model provide individual species concentrations which are compared with analytical data from NMR, see Figure 3.

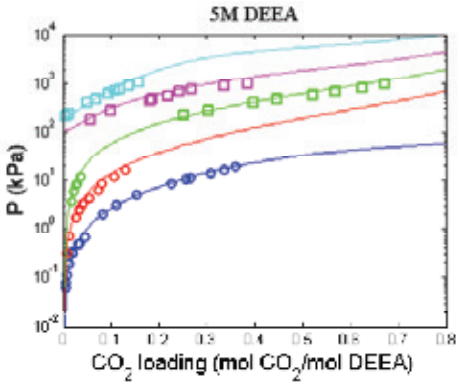


Figure 1: Example of equilibrium data obtained and modeling ing the e-NRTL model

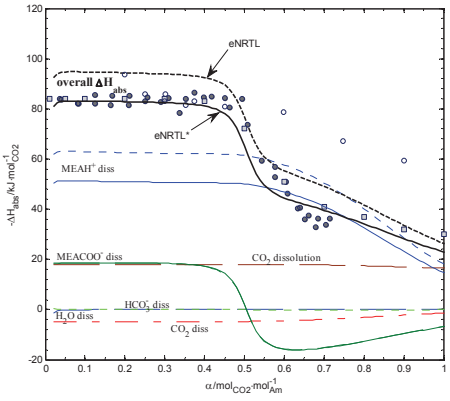


Figure 2: Comparison between experimental data and model predictions for heat of absorption

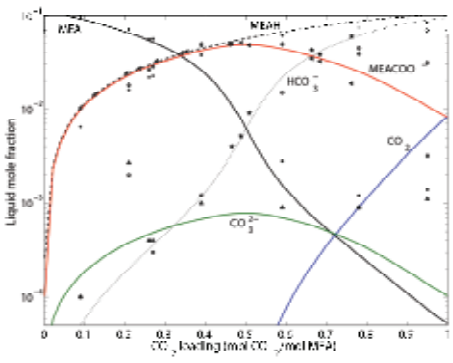


Figure 5: Comparison experimental and predicted species distribution at 40°C in a mixture of 30 wt.% MEA

Figure 3: Comparison of experimental and predicted species distribution at 40 °C in a mixture of 30wt% MEA

Degradation of absorbents is of great concern and we work on identification of degradation products and reaction mechanisms. Environmental effects are studied through eco-toxicity and bio-degradation tests.

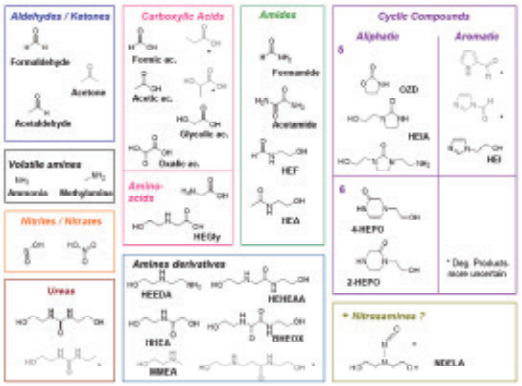


Figure 4: Examples of identified degradation products

CO2SIM is a full rate based simulator for the whole absorption/desorption process and improved models for combined mass and heat transfer are being developed. All experimental results and submodels are implemented in CO2SIM and the simulation results are validated through pilot plant tests.
Project and MSc student can be involved in all areas of our work and we always aim at providing a mixture of experimental and modeling work.

Figure 5: Pilot rig in Hall C

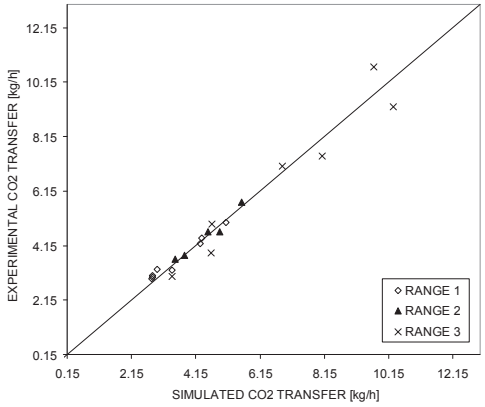


Figure 6: Comparison between experimental and predicted mass transfer rates

Process Design

A process design is to a large extent a consequence of developments on catalyst, choice of reaction routes, selection of solvent system, fluid type etc. At this level of development the structure of the chemical system and the kinetics are determined. Much research is focused on these topics because even incremental improvements may have large economical consequences. The next major step is to find a suitable reactor and process in which to deploy the system on a larger scale. The traditional way of doing design of new processes is by selecting reactor type and process configuration based on comparison to a similar known system. Design choices are often made on the basis of past experience or trial-and-error using laboratory tests and repeated simulations. These activities are necessary. However, it is not likely that the traditional way alone will lead to the best possible process configuration and design. Complementary tools and methods are needed to lead the design engineer onto the path of optimal design. Deviations from the optimal design will lead to unnecessary loss of product yield, unnecessary large volumes and loss of energy. Within the conceptual process design activity some of the most important

choices are made, which have large consequences on the profitability and environmental loads of the final process technology. According to Douglas (1988)[1] the conceptual design of an integrated plant can be broken down into a hierachy of decisions and organized into different levels of activities. Among the levels of activities are reactor-separator-recycle structures, heat integration, and separation train sequence design. A method in focus here is a systematic procedure based on shortcut models. A path is a line of production on which basic operations or functions take place. Reactants pass through a series of functions or basic operations to form the desired products. The basic operations are represented by design functions on the volume path. The design functions are fluid mixing (dispersion), distribution of extra feed points, distribution of heat transfer area and coolant temperature, catalyst dilution distribution and more. The conceptual reactor design problem is solved as an optimal control problem.
Parameterization of the design functions and the state variables are applied. The realization is a staged process string of multifunctional units.

Douglas, J. M., Conceptual Design of Chemical Processes, McGraw Hill, 1988.

Membrane Research

Membranes for gas separation and osmotic processes
More information about the Memfo
(Membrane Research activities)

In fall 2011 a new associate professor joined the membrane research group. The activities have thus been extended with membrane research in more fields, firstly a broader focus on membrane contactors for CO_2 capture, using for example ionic liquids.
The membrane research programs have extensive activities both on basic membrane material development, as well as membrane gas separation processes, modelling and simulations. The main focus for the research is CO_2 capture by membranes (from flue gas, natural gas sweetening, biogas upgrading) and hydrogen recovery from various mixed gas streams. In addition to these energy focused gas applications, there is also ongoing research on membranes for other gas mixtures, chlorine separation included. The membrane materials in focus are various types of polymers, nano-composites, carbon membranes, and modified glass membranes.
The international network is extensive, with co-operation both within EU-projects, USA, China, Japan, the Nordic countries and Russia.

Brief description of sample gas separation projects

FSC-Membrane /Climit (Gassnova)/ Statoil: Membrane development for selective CO_2 capture
The membrane material being developed in this project contains a specific "carrier" which makes it selective for CO_2 while other gas components are being retained. The material is based on a polymer containing fixed amine groups as carriers. A significant progress was achieved during 2012 in this Innovation-project, and within the current FSC-project the membrane is being tested out on a small pilot scale to verify the good performance both with respect to CO_2-flux and selectivity compared to the other components in a mixed gas. The obtained results have drawn international attention with extremely high permeance and selectivity documented. The membrane is patented, and there are big expectations for the upscaling taking place; for CO_2 capture from coal fired or gas fired power plants as well as other CO_2 containing gas streams. The project is divided in two phases, the first one ended in 2012. Two research scientist and one Post doc. have been working on the project. Project partner is Statoil, and with additional funding from Climit- Gassnova. There is also interest from industry on other applications where CO_2 is present in the gas stream (natural gas sweetening, process industry, CO_2 removal from anaesthetic gas...**).** A Phase 2 of the project together with membrane producer for upscaling of the membrane module and international partners are planned for starting in 2013.

BIP GASSMAKS / NFR project NAGAMA
The project started late 20011 and will go for 3 years. The objective is CO_2 removal from high pressure natural gas streams using a polymeric blend membrane; using as one of the polymers in the blend the patented PVAm facilitated transport membrane – other materials suitable for high pressure applications are also considered. The project includes material development, pilot construction, durability tests and simulations. The main challenge in this project is to maintain the good performance at high pressures (→100 bar). Advanced high pressure test rigs have been built, one for permeation tests and one for durability tests. Special restrictions for HMS are needed in this operating range. Industrial partners are Statoil and Petrobras.

EU FP7 project DECARBit
The project is coordinated by Sintef and had kick-off in Feb 2008. The focus is pre-combustion separation of CO_2 and H_2 at high temperatures (>300°C). Carbon membranes were tailored for this separation, but our involvement ended 2011. The project coordinator was SINTEF Energy.

Memfo = Membrane Forskning (Membrane Research)

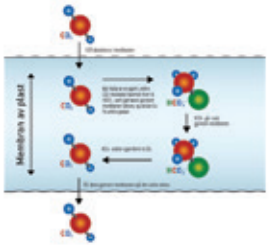
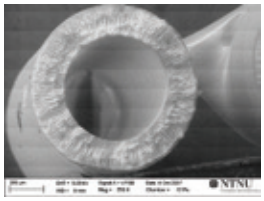


Illustration of the mechanism in the patented CO_2 facilitated transport membrane

Bundle of hollow fibre membranes in an industrial module–packing densities can be up to 30 000 m^2/m^3
Illustration of the mechanism in the patented CO_2 facilitated transport membrane



SEM-picture showing a membrane. D0-DI: 1-6 mm cut though a hollow fibre

KMB Petromaks / NFR A Green Sea
The project started in 2010, and Sintef Energy is the coordinator. The project has activities within four alternative technologies for natural gas sweetening. Memfo's activity within the project is development of a nanocomposite membrane material for a membrane contactor. The other technologies are development of sorbents, alternative absorbents and low temperature separation. Process integration is also an important activity. There is one PhD-student within Memfo working on the project.

MCIL-CO2 / NFR /CLIMIT
The project started in the middle of 2012 with focus on the development of a novel membrane contactor process using ionic liquids as absorbents for pre-combustion CO_2 capture. The project is scheduled for 3 years and finances 2 PhD-students within Memfo. The research activities include (1) build up a lab scale setup and simulation modules to demonstrate the proposed process and (2) provide knowledge and experimental data for the further up-scaling of the process.

Brief description of a sample liquid separation project

KMB NANOMAT / NFR project: Membranes for osmotic processes – POPMOP
Reverse osmosis is today one of the major methods for desalting ocean water into freshwater. Osmotic effects demands that a high pressure on the saltwater side of the membrane modules must be applied to override the osmotic pressure difference between sea water and freshwater. If the applied pressure in the cells is lower than the osmotic pressure the water flow is reversed and freshwater flows into the saltwater compartment, thus increasing the volume of moderately pressurized saltwater. This is the principle of Pressure Retarded Osmosis (PRO), which may be used to produce electric energy as the surplus water on the saltwater side may be run through turbines for power production. The potential for power production at the outlet of every river that flows into the ocean is very large.
Towards the end of 2007 Memfo was granted a KMB project from Nanomat/NFR supported by Aqualyng, Statkraft and Statoil. The project is aiming at studying and optimizing the synthesis of polymers for osmotic processes. This development includes both optimisation of the support membrane, as well as the thin film membrane itself. One PhD student has been working on the project in 2012, in addition to collaboration with Sintef. The PhD-student defended her thesis in 2012 and spent 2011 as guest researcher at Yale University in USA.

Various projects on Nanocomposites
The group has additionally several smaller research projects focusing on development of hybrid materials; in 2012 four PhDs have been involved in this topic.

The Memfo researchers work very much as a team in addition to be dedicated to individual projects. Hence the simulation of processes is handled whenever needed by those who have the competence. Likewise; the concern for environmental issues, leads to the focus also on biogas upgrading to vehicle fuel quality (biomethane). Carbon membranes has proved to be suitable for upgrading of biogas; documented by experiments and discussed in publications.

A Collaboration with University of Dar es Salaam (UDSM), Tanzania, has resulted in a project funded by NUFU. The focus is on bioenergy; with certain aspects of the production of bioethanol and biodiesel from local raw materials. There are 2 PhDs at UDSM and 2 at NTNU attached to this project. One PhD-student at

NTNU defended his thesis with success in 2011. A new Tanzanian PhD-student joined in 2010, and will finish her degree in 2013.

We have several well equipped laboratories available for the membrane research; both for membrane material development as well as membrane characterization. The membrane research on CCS is especially strong, and completes the research on CCS activities in collaboration within the Environment and Reactor Group.

A spin-off company from the research on carbon molecular sieve membranes was established in 2008 with the support of the Technology Transfer Office (TTO) at NTNU. The name of the company is *MemfoACT* (= Membranes for Advanced Clean Technology, http://www.memfoact.no)
This company won 3 prizes for creativity and innovation in 2009/2010, and additionally one in 2011.

Crystallizaton and Particle Design

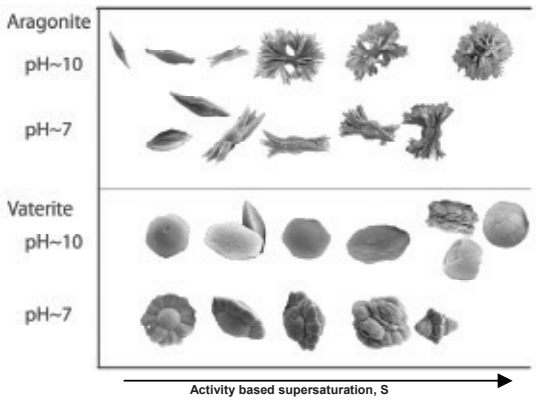
The research within crystallization is focused at kinetics of nucleation, crystal growth, and agglomeration in order to predict and control the particle size distribution and shape of crystalline particulate products for scale prevention, improved solid-liquid separation, CO_2-capture in precipitating systems, and for nano-particle production. The crystallization group also investigates fundamental mechanisms in the early formation of solid particles, mechanisms for growth of polycrystalline particles and interaction between biopolymers and mineral formation.

Improved Glycol Loop Operation – bulk precipitation and scaling of carbonates in natural gas processing.
The aim of the project is to develop a simulation tool for glycol loops in processing of natural gas. This necessitates a deep understanding of the precipitation and crystallisation behaviour of salts and scale-forming carbonates in ethylene glycol (MEG) and water mixtures. Kinetics of calcium carbonate precipitation, scaling on heated surfaces and separation of salts in the on-shore glycol reclamation systems will be the main research tasks. The project is in collaboration with Institute of Energy Technology, Norway (IFE) and financed by several international oil and gas companies and the Research Council of Norway (NFR). The first part of the project was finalized in 2010 and a new 3 year application was granted. So far the studies performed in the crystallization group have shown that MEG significantly affects the precipitation of calcium carbonate by lowering the growth rate and by shifting the polymorphic composition. Kinetic expressions have been developed to be implemented into computer simulator for particle formation control within glycol loops. The project is continuing (with 1 PhD and 1 postdoc at NTNU) by studies of surface scaling and bulk precipitation in presence of relevant impurities.

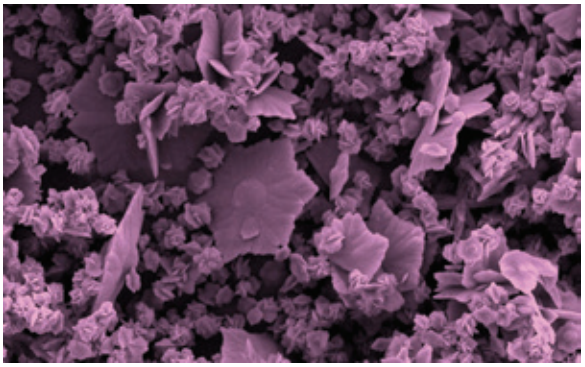
Fundamentals of crystal growth
By proper coupling of the thermodynamic driving force (supersaturation) with the morphology development of calcium carbonate crystals we have shown that the precipitation of calcium carbonate can be explained by classical crystal growth concepts rather than the non-classical aggregation based explanations that are frequently propsed in the recent literature. In such a way complex morphologies of both mono- and polycrystalline nature can be precipitated without additives, contrary to the claim of the non-classical paradigm.

Biomineralization
Structural biocomposites found in nature often have a well-defined organization on the nanometer scale. For mineralized materials, interactions between organic and inorganic phases are important for controlling crystal size, morphology, and spatial arrangement, which is a requirement when structural biomaterials are designed. In a joint project with department of biochemistry, lead by the physics department, we have been studying the formation of nanoparticles of calcium carbonate and calcium phosphate in polysacchraride (alginate) networks as model systems for bone formation. The mineral formation within alginate gel beads is a complex precipitation phenomenon resulting from diffusion of ions through the networks and simultaneous competition for calcium by the gelling process. However, as we have shown by crystal growth rate studies in presence of different alginate oligomers, these molecules are strong crystal growth modifiers overriding the effect of mixing and diffusion and thereby facilitating the production of very small crystals within the networks. The variation in the oligomer composition was also shown to have great effects on the polymorphic composition of calcium carbonate, results that beside their fundamental significance can provide insight into mineral scale mitigation strategies in industry as well as to design hybrid materials. A new project was granted in 2012 to develop mineralized, hierarchical, bioinspired materials for tissue engineering based on calcium phosphate and alginate constructs.

CO_2-capture in precipitating systems
Crystallization processes during carbon dioxide absorption can influence the kinetics and capacity of the capture process. In 2012 studies were conducted to investigate solids formation in piperazine and carbonate absorbents during loading and stripping of CO_2 to elucidate how these systems will perform in industrial operation. It was shown at which concentrations and temperatures solidification of the process stream will arise due to cooling of the lean solvent prior to a new absorption cycle.



The development of complex biomimetic morphologies of calcium carbonate in absence of additives, merely as function of thermodynamic driving force



Flower-like crystals of the calcium carbonate polymorph vaterite

Environmental- and Reactortechonology Group on a skiing/sledge tour to Skistua

In front:	*Jens-Petter Andreassen*
First row from left:	*Lijuan Wang, Liyuan Deng, Divina D. Kaombe, Muhammad Saeed, Washim Uddin, Hallvard Svendsen, Ardi Hartono, Maria Teresa Guzman Guitierrez, Vajiheh Nafisi*
Second row from left:	*Xuezhong He, Zhongde Dai, Xiaoguang Ma, Qiang Yu, Jannike Solsvik, Lu Bai, Georgios Fytianos, Juliana Monteiro, Koteswara Rao Putta, Tom-Gøran Skog, Diego de Domenico Pinto, Rafael Sánchez*
Third row from left:	*Camilla Berge Vik, Hugo A. Jakobsen, Karen Nessler Seglem, Eddie Setekleiv, Margrethe Nergaard, Magne Hillestad, Øystein Jonassen, Anastasia Trollebø, Gøril Flatberg, Hanna Knuutila*

BIOREFINERY AND FIBRE TECHNOLOGY GROUP

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Associate Professor Størker Moe
Professor Emeritus Torbjørn Helle

Post Docs.
Laura Alexandrescu (until 30.09.2012))
Sara Paunonen (until 31.10.2012)
Swarnima Agnihotri

PhD candidates
Collin Ching Tyn Hii
Hanne Narvestad
Tuan-Anh Nguyen

Guests
Seyed Rahman Djafari Petroudy, PhD from Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

Teaching

The Biorefinery and Fiber Technology group educate chemical engineers and PhD for the Norwegian pulp, paper and biorefinery industry. The estimated need from the industry is 6-8 engineering graduates and about 2 PhD candidates per year. During 2012 one PhD student, Collin Ching Tyn Hii, defended his thesis within wet pressing of paper. We have now developed the curriculum of our courses in the 4th and 5th year to include bioenergy and biorefinery concepts on an equal basis with pulp and paper. This reflects a similar change in our research focus and starting industrial development.

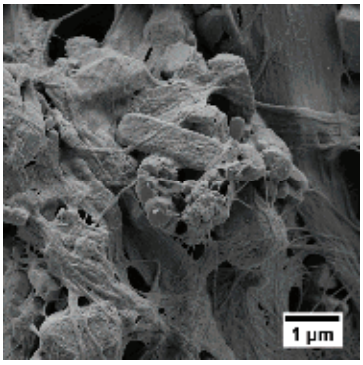
Partners

The Biorefinery and Fibre technology group, Paper and Fibre research Institute (PFI) and parts of the Ugelstad laboratory (colloid and surface chemistry) are located in the same building on the NTNU Gløshaugen campus and are working in close cooperation. In addition Sintef, Innventia (Stockholm), UIB and MIUN (Sundsvall) are important research partners. We also cooperate closely with industry partners such as Norske Skog, Södra Cell, Borregaard, Peterson, Dynea, and Statoil.

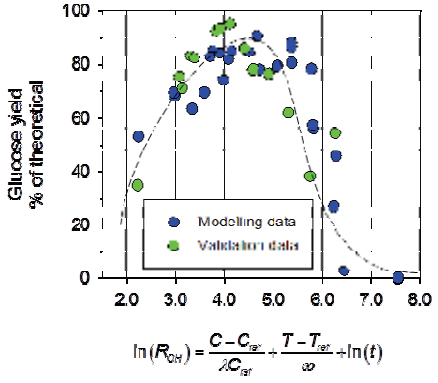
Research

Our research is focused on bioenergy/biorefinery, improvements in the pulp and paper process and on improved end product quality. Our main research activity is done through PhD and Post Doc. fellows. Examples are:

- Optimal pre-treatment for the hydrolysis of lignocellulose for biofuel and biorefinery processes
- Formation of inhibitory degradation products during pretreatment and depolymerisation of lignocellulose for biofuel and biorefinery processes
- Barrier properties of microfibrillated cellulose and chemically modified microfibrillated cellulose.
- Properties of adhesives containing microfibrillated cellulose.
- The relation between the mechanical properties and permeability of laminated board and the performance of heavy duty food transport boxes.
- Reduced energy consumption and/or better fibre properties of mechanical pulp through high intensity refining, co-refining of different raw materials or pre-treatment of wood chips.
- The effect of furnish composition and sheet structure on wet pressing efficiency.
- The effect of ion content on brightness stability and electric properties of wood containing paper



$CaCO_3$ particles bond together in paper by a thin network of microfibrillar cellulose (C. Hii, PhD thesis 2012)



Evaluation of a combined severity model for the concentrated acid hydrolysis of lignocellulosic biomass for biofuel production (K. Janga, PhD thesis 2011)

A main focus is now to establish new research projects. The current though times for the Norwegian pulp and paper industry make it necessary to look for new partners and new fields of research. Currently we are working with establishing a bio-fuel project to aid bio-fuel competence build up in South East Africa. We are also trying to establish a nanocellulose project aiming at

exploiting the beneficial properties of nanocellulose in membranes for air filtration.

Moving the pilot plant

Due to the renovation of chemistry building KIV and the need for laboratories and pilot plants for CO_2 separation research, the pulp and paper pilot plant and paper machine has been removed. Most of the equipment (but not the paper machine) was installed in the pilot hall of the PFI building during 2010.

New adjunct professor in the group

On January 1st 2013, Dr.Ing. Kristin Syverud became a member of our research group as an adjunct professor. Kristin has a main position as a senior scientist at PFI where she has been a driving force in developing the nanocellulose research of the research institute. Kristin will work with student supervision, give lectures and contribute in developing the research profile of the Biorefinery and Fibre technology group of IKP.

Trends

The last years the focus of our research has shifted from exclusively pulp and paper to including research on bio-fuel, microfibrillar cellulose and bio-composite materials. Cellulose based particles in film and composite materials can give better oxygen barrier and mechanical properties to the materials. An overall goal in this research is replacing non-renewable packaging materials (plastics, aluminium foil) with cellulose based (renewable) materials.

Biofuel manufacturing processes are regarded as a first stage in the development of biorefinery processes for the manufacture of energy, chemicals and materials from renewable resources. Together with PFI we are conducting research on the use of wood and agricultural waste materials for the production of biofuel and chemicals.

The short-term goal is cost-effective production of bio-oil and fuel ethanol from wood, while the long-term goal is the development of a viable biorefinery industry based on domestic or foreign non-fossil raw materials.

Due to increasing energy prices, energy effective production is one of the primary concerns of the pulp and paper industry and thus also an important research area now and in the future.

Here we are engaged in research on energy effective TMP refining, looking into the effect of wood chipping and wood raw material properties on the energy consumption. For paper production the drying of the paper consumes most energy, to reduce this we work with optimizing paper furnish composition and sheet structure to make dewatering during pressing as efficient as possible.

BIOREFINERY AND FIBRE TECHNOLOGY GROUP

First row from left: *Hanne Narvestad, Sara Paunonen, Swarnima Agnihotri, Divina Kaombe*
Second row from left: *Øyvind W. Gregersen, Berit Borthen, Størker T. Moe, Collin Ching Tyn Hii, Kando Janga, Tuan-Anh Ngyen*

Other research activity at Department of Chemical Engineering

MEDXENSE
continuous glucose monitoring

Staff full time at IKP
Research Manager Sondre Volden
Biomedical Scientist Tine Almås Hunt

Part time (not at IKP)
General Manager Nicolas Elvemo
Scientist Susana Villa Gonzales
Advisor Dag Roar Hjelme
Advisor Dan Östling
Advisor Reinold Ellingsen
Advisor Kjell Arne Ingebrigtsen
Administrative Maja Aursand Andersen
Administrative Erik Fuglseth
Administrative Eivind Andersen

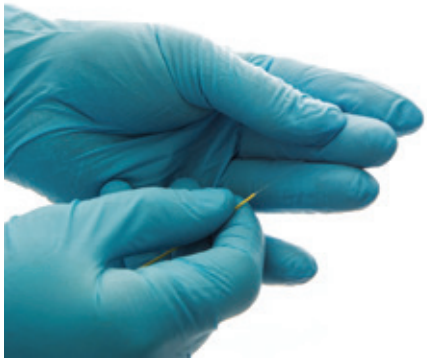
MedXense AS is a start-up company originating from various research environments present at NTNU and HiST, involving Department of Electronics and Telecommunication, Department of Chemistry, and Department of Chemical Engineering. The main foundation is based on optical and chemical nanotechnology. The company was founded in 2011, and is currently residing in laboratories in the PFI-building. The laboratory facilities have been located at the Department of Chemical Engineering ever since the founding of the company.

The primary research-goal of medXense is to develop an intravascular probe/sensor which can measure blood sugar levels continuously over a period of several days.
Blood sugar levels in patients undergoing, or having recently undergone, surgery can vary greatly and if these fall outside the normal levels it can be life threatening. Traditional methods for measuring blood glucose are based on point measurements wherefrom it may not be immediately apparent whether the blood glucose level is rising or falling, which complicates therapeutic measures. It is therefore desirable to measure the blood glucose continuously. Blood glucose levels are often elevated and unstable in hospital intensive care unit (ICU) patients. This leads to costly infections, increased length of stay in the ward and a potentially increased mortality of patients. The medXense intravascular sensor delivers continuous and accurate information on the patient's blood glucose level, enabling better control of normalization of glucose levels, without the risk of sudden and dangerously low blood sugar levels.

Scientists Sondre Volden and Tine Hunt

In this project we combine optical technology with responsive hydrogels which swell or shrink when they come in contact with sugar molecules. By attaching a small hydrogel droplet (µm-scale) on the end of an optical fiber, and by means of analyzing the interference pattern originating from reflection from the boundary between the fiber and the hydrogel as well as from the border between the hydrogel and the surrounding environment (blood), the length of the hydrogel can be measured. When glucose molecules bind to specific receptors in the

hydrogel, the gel undergoes a change in volume and length which can be measured on the nanometer level. The optical fiber is so small that it can easily be placed in the bloodstream via a catheter



The size of the optical fiber and hydrogel sensor illustrated

During 2012, the researchers at medXense have optimized the optical and biophysical responses of the hydrogels employed. The company has so far attracted close to 10 million NOK in funding, from investors and from the Norwegian Research Council. The start-up of the company has been greatly facilitated by the Department of Chemical Engineering providing laboratory facilities for medXense.

CHAPTER 3: PUBLICATIONS

PUBLICATIONS IN REFEREED JOURNALS

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Interparticle interactions and structure formation of colloidal particles at oil-water interface. International Association of Colloid and Interface Scientists (IACIS2012); 2012-05-13 - 2012-05-18

115. **Uddin, Mohammad Washim; Hagg, May-Britt.**
Effect of Entrained Glycols and Higher Hydrocarbons on the CO_2-CH_4 Separation Performance of a PVAm/PVA Blend Composite Membrane. the Euromembrane 2012; 2012-09-23

116. **Venvik, Hilde Johnsen.**
Co surface science revisited. NordForsk network on "Atomistic design of new catalysts"; 2012-11-29 - 2012-11-30

117. **Venvik, Hilde Johnsen.**
Hvordan kan ressursene i nord best utnyttes?. Barentshavkonferansen; 2012-04-23 - 2012-04-25

118. **Vevelstad, Solrun Johanne; Grimstvedt, Andreas Magnar; Knuutila, Hanna; Svendsen, Hallvard Fjøsne.**
Degradaton of amines. 1st University of Texas Conferance on Carbon Capture and Sequestration; 2012-01-25 - 2012-01-27

119. **Vevelstad, Solrun Johanne; Grimstvedt, Andreas Magnar; Knuutila, Hanna; Svendsen, Hallvard Fjøsne.**
Thermal degradation on already oxidatively degraded solutions. The Greenhouse Gas Control Technologies (GHGT 11); 2012-11-18 - 2012-11-22

120. **Voss, Georg Johannes Bernhard.**
The state of promoters in cobalt Fischer-Tropsch Catalysts. Syngas Convention 2012; 2012-04-01 - 2012-04-04

121. **Voss, Georg; Voronov, Alexey; Tsakoumis, Nikolaos; van Beek, Wouter; Rønning, Magnus.**
THE STATE OF PROMOTORS IN FISCHER-TROPSCH CATALYSTS. Norwegian Synchrotron and Neutron User Meeting; 2012-01-30 - 2012-01-31

122. **Walle, Lars Erik; Aase, John F.; Farstad, Mari Helene; Svenum, Ingeborg-Helene; Andersen, Trine H.; Gustafson, Johan; Andersen, Jesper N.; Lundgren, Edvin; Borg, Anne.**
Oxidation of the PdCu(100) surface. 25. Symposium on surface science; 2012-03-11 - 2012-03-17

123. **Wang, Lijuan; Beck, Ralf; Andreassen, Jens-Petter.**
The induction time and growth morphology of gold particles precipitated by reduction with ascorbic acid at different pH values. 19th International Workshop on Industrial Crystalliation (BIWIC 2012); 2012-09-07 - 2012-09-09

124. **Yang, Jia; Chen, De; Holmen, Anders.**
New approach for kinetic modeling of Fischer-Tropsch on cobalt based catalyst. 15th International Congress on Catalysis (ICC 2012); 2012-07-01 - 2012-07-06

125. **Yang, Jia; Zhu, Jun; Lillebø, Andreas Helland; Chen, De; Holmen, Anders.**
Effects of interfacial properties of hierarchically structured Co catalysts on Fischer-Tropsch synthesis. International Symposium on Alternative Clean Synthetic Fuels (SynFuel 2012); 2012-06-29 - 2012-06-30

126. **Zhu, Jun; Chen, De; Yang, Minglei; Yu, Yingda; Zhou, Xinggui; Holmen, Anders.**
Selective C-H Bond Activation of Propane on Platinum Nanoparticles with Different Sizes and Shapes. 15th International Congress on Catalysis (ICC 2012); 2012-07-01 - 2012-07-06

127. **Øyaas, Karin; Johnsen, Ingvild Andersen; Hoff, Bård Helge; Opedal, Mihaela Tanase; Toven, Kai; Gulbransen, Tore A..**
Hot water extraction of hemicellulose from softwood and sugarcane bagasse using microwave heating technology. 4th Nordic Wood Biorefinery Conference in Helsinki; 2012-10-23 - 2012-10-25

128. **Øye, Gisle.**
Bubbles and drops. How the surroundings and their ageing influence their properties - Interfacial properties, coalescence, influence of the chemistry of water and oil. Produced Water Management 2012; 2012-01-24 - 2012-01-25

CHAPTER 4: EDUCATION

Chemical Engineering

The specialization in Chemical Engineering starts in the third year with the basic technological courses in Separation Technology, Reaction Engineering, Thermodynamics, Process Design, and Process Modelling. In the fourth year the students elect further specializations for the remaining of the studies.
The students choose between 5 specializations: Catalysis, Colloid and Polymer Chemistry, Environmental Engineering and Reactor Technology, Process Systems Engineering and Biorefinery and Fibre Technology.

The goal of the education is a Master (MSc) at a high international level in Chemical Engineering.
Students with a bachelor degree in a relevant area from colleges can be admitted to the fourth year of the MSc-degree programme (2 year MSc programme). The degree provides the candidates qualifications for jobs in a wide range of industries, as well as the public sector and in research. It is also the basis for admission to the PhD-studies in Chemical Engineering.

Master courses given in 2012:

Course code	Course title	Credits	Year	Registered	Passed
TKP4100	Fluid Flow and Heat Transfer	7.5	2	67	51
TKP4105	Separation Technology	7.5	3	52	44
TKP4106	Process Modelling	7.5	3	16	16
TKP4110	Chemical Reaction Engineering	7.5	3	82	74
TKP4115	Surface and Colloid Chemistry	7.5	3	73	67
TKP4120	Process Engineering	7.5	1	153	139
TKP4130	Polymer Chemistry	7.5	4	47	44
TKP4135	Chemical Process Dynamics and Optimization	7.5	4	6	4
TKP4140	Process Control	7.5	4	57	53
TKP4145	Reactor Technology	7.5	4	21	17
TKP4150	Petrochemistry and Oil Refining	7.5	4	35	31
TKP4155	Reaction Kinetics and Catalysis	7.5	4	73	62
TKP4160	Transport Phenomena	7.5	4	61	33
TKP4165	Process Design	7.5	4	33	29
TKP4170	Process Design, Project (autumn)	7.5	4	45	45
TKP4171	Process Design, Project (spring)	7.5	4	4	4
TKP4175	Thermodynamic Methods	7.5	3	43	35
TKP4180	Bioenergy and Fiber Technology	7.5	4	12	8
TKP4185	Nuclear Power, Introduction	7.5	4	19	17
TKP4190	Fabrikasjon og anvendelse av nanomaterialer	7.5	4	24	18
TKP4195	System Modeling and Analysis in Biology	7.5	4	2	2
TKP4510	Catalysis and Petrochemistry, Specialization Project	15	5	4	4
TKP4511	Catalysis and Petrochemistry, Specialization Project	7.5	5	0	0
TKP4515	Catalysis and Petrochemistry, Specialization Course	7.5	5	14	13
TKP4520	Colloid and Polymer Chemistry, Specialization Project	15	5	12	12
TKP4521	Colloid and Polymer Chemistry, Specialization Project	7,5	5	6	6
TKP4525	Colloid and Polymer Chemistry, Specialization Course	7.5	5	19	19
TKP4530	Reactor Technology, Specialization Project	15	5	14	14
TKP4531	Reactor Technology, Specialization Project	7,5	5	2	2
TKP4535	Reactor Technology, Specialization Course	7,5	5	31	30
TKP4550	Process Systems Engineering, Specialization Project	15	5	15	15
TKP4551	Process Systems Engineering, Specialization Project	7.5	5	2	2
TKP4555	Process Systems Engineering, Specialization Course	7.5	5	22	21
TKP4560	Paper and Fibertechnology, Specialization Project	15	5	3	3
TKP4561	Paper and Fibertechnology, Specialization Project	7.5	5	-	-
TKP4565	Paper and Fibertechnology, Specialization Course	7.5	5	3	3
TKP4850	Experts in Team, Biofuels – A good Solution ?	7.5	4	22	22
TKP4852	Experts in Team, CO_2 Capture	7.5	4	25	25
TKP4500	Final Year Design, for Spanish students	60	5	0	0
TKP4900	Chemical Process Technology, Master Thesis	30	5	45	45

Master thesis 2012 total 46 (19 female and 27 male)

First row	*Carina Renee Strand, Astrid Odland Barland, Torunn Kvam, Christina Carlsen, Anette Midttveit, Charlotte Kleven Krossholm, Petra-Kristine Johannessen*
Second row:	*Stian Tangen, Stine Johansen, Jenny Kristin Håseth, SigneMarie Nielsen Stavnes, Sophie Anne Amelie Glas, Anita Bersås, Nina Tung Gynnild, Marie Odilie Prache, Roald Bæck Leer*
Third row:	*Anders Sørheim, Saddam Hussain, OleKristian Nordvåg, Muhammad Usman, Fridtjof Finsnes Henriksen, Hassan Ali, Aristides Robert Katto, Rafiq Ahmad*
Forth row:	*Lasse Svenkerud Aasgaard, Sebastian Roll, Alexei Pylilo, Knut-Arne Rademacher Munkebye, Sindre Håvik, Amir Shadman Far, Jørund Elnan, Knut Arne Wuttudal Hildenes, Iakov Dolgov, Alexandre Leruth, Ivar Nesje, Eivind Berstad, Stig Erik Nogva*

Master thesis

Aasgaard, Lasse Svenkerud
Literative Sub-Network Component analysis
Supervisor: Nadi Skjøndal-Bar

Ahmad, Rafiq
Vapor Liquid Equilibrium (VLE) in H_2O-Amine-CO_2 system
Supervisor: Hallvard Svendsen

Ali, Hassan
Cloud Pint Depressants
Supervisor: Johan Sjöblom

Ayuso Virgili, Gerard
Kinetic study of oxychlorination process
Supervisor: De Chen

Bandyopadhyay, Sulalit
Biodegradable Nano-Clusters as drug delivery vehicles
Supervisor: Wilhelm Glomm

Barland, Astrid Odland
Nucleation Kinetics of carbonate particles in natural gas production
Supervisor: Jens-Petter Andreassen

Berstad, Eivind
Testing and optimization of PVAm/PVA blend membranes for biogas upgrading
Supervisor: May-Britt Hägg

Bersås, Anita
Vapour-liquid equilibrium in the monoethylene glycol - methane system at elevated pressures
Supervisor: Hallvard Svendsen

Carlsen, Christina
Hydrotreating of Bio-Oils over Metal-Phosphide Catalysts
Supervisor: Edd A. Blekkan

Dolgov, Iakov
Influence of Feed Rate on Temperature Controllers in Multicomponent Distillation Columns (in cooperation with Statoil/Gassco at Kårstø)
Supervisor: Sigurd Skogestad

Evenrud, Vegar
Nickel Promoted Cobalt Fischer-Tropsch Catalysts
Supervisor: Magnus Rønning

Glas, Sophie Anne Amelie
Catalytic partial oxidation of methane at moderate temperatures
Supervisor: De Chen

Gynnild, Nina Tung
Synthesis of Fischer-Tropsch Catalysts in an Autoclave System
Supervisor: Magnus Rønning

Henriksen, Fridtjof Finsnes
Modeling of Amine Degradation in a CO_2 Absorption Column at Test Centre Mongstad
Supervisor: Hallvard Svendsen

Herauville, Virginie Marie Therese
Catalytic Dehydrogenation of Propane
Supervisor: Edd A. Blekkan

Hjorth, Ida
Organic Electrolytes for Thermoelectric Devices and CNT Electrode functionalization by Nitrogen-doping
Supervisor: De Chen

Hussain, Saddam
Characterization and Modelling of Vapor Liquid Equilibrium of 1,3-Diaminopropane for CO_2 Capture: Using e-NRTL framework
Supervisor: Hallvard Svendsen

Håseth, Jenny Kristin
Decrystallization of Lignocellulosic Biomass using Ionic Liquids
Supervisor: Størker Moe

Håvik, Sindre
SiC supported Co catalysts for the Fischer-Tropsch synthesis
Supervisor: Anders Holmen

Johannessen, Petra-Kristine
Preparation of PVAm/PSf composite hollow fibers for flue gas applications
Supervisor: May-Britt Hägg

Johansen, Stine
Development of CO_2 Selective Composite Hollow Fiber Membranes for Natural Gas Sweetening
Supervisor: May-Britt Hägg

Katto, Aristides Robert
Carbon dioxide separation from flue gas by FSC (Fixed-Site-Carrier) membranes
Supervisor: May-Britt Hägg

Kjos-Hanssen, Øyvind Jacob
Treatment of a Waste Water Pharmaceutical by Fenton Oxidation
Supervisor: Hallvard Svendsen

Krossholm, Charlottte Kleven
Crystal Growth Kinetics of Calcium Carbonate Particles in Natural Gas Production
Supervisor: Jens-Petter Andreassen

Kvam, Torunn
Precipitation in Pre-Treatment for Regeneration of Ethylene Glycol
Supervisor: Jens-Petter Andreassen

Leer, Roald Bræck
Self-Optimizing Control Structures for Active Constraint Regions of a Sequence of Distillation Columns
Supervisor: Sigurd Skogestad

Leruth, Alexandre
Heat exchanger network self-optimising control
Supervisor: Sigurd Skogestad

Lesaint, Caterina
Interfacial characterisation of dispersed components in produced water
Supervisor: Gisle Øye

Martin Montoya, Julio Guillermo
Adsorption Properties of Supported Cobalt Catalysts Studied via Microcalorimetry
Supervisor: Edd A. Blekkan

Midttveit, Anette
Ordered Mesoporous Alumina as a Support in Nickel-promoted Cobalt Fischer-Tropsch Catalysts
Supervisor: Magnus Rønning

Moran-Rico, Elena
Multifunctonal Gold nanoparticles for targeted drug delivery
Supervisor: Wilhelm Glomm

Munkebye, Knut-Arne Rademacher
Residence time distributions: Conductivity measurements on experimental Tubular Mixing Reactor
Supervisor: Henz A. Preisig

Nesje, Ivar
Design of an interface to Thermodynamic Equations
Supervisor: Tore Haug-Warberg

Nogva, Stig-Erik
High pressure equation of state for condensed phase thermodynamics
Supervisor: Tore Haug-Warberg

Nordvåg, Ole Kristian
Modelling and optimization of a Gas-to-Liquid plant
Supervisor: Magne Hillestad

Prache, Marie Odile
Investigation of New Polymeric Membranes with Controlled Architecture for CO2 Capture
Supervisor: May-Britt Hägg

Pylilo, Alexei
Chemical Quenching
Supervisor: Edd A. Blekkan

Roll, Sebastian
Ontology-based Computer-aided modeling Tool
Supervisor: Heinz A. Preisig

Saz Perez, Pablo
Testing of large-scale CNF synthesis reactor
Supervisor: Magnus Rønning

Shadman Far, Amir
Alumina supported cobalt catalysts for Fischer-Topsch synthesis
Supervisor: Anders Holmen

Sheng, Juejing
Simulation of Sorption Enhanced Steam Methane Reforming for Use in Technology Assessment of Pre-combustion CO_2 Capture
Supervisor: De Chen

Stavnes, Signe Marie Nielsen
Reinforcing Effects of Nanoalumina in an Epoxy Matrix
Supervisor: Wilhelm Glomm

Strand, Carina Renee
Catalytic combustion control
Supervisor: Sigurd Skogestad

Sørheim, Anders
Testing and Optimization of Nano Particles Reinforced PVAm/PVA Blend FSC Membranes for High Pressure Natural Gas Sweetening
Supervisor: May-Britt Hägg

Tangen, Stian
On the Solution of the Pellet- and Reactor Model for the Steam Methane Reforming Process Using the Methods of Weighted Residuals
Supervisor: Hugo A. Jakobsen

Usman, Muhammad
Kinetics study of CO_2 absorption in AMP and Piperazine solutions
Supervisor: Hallvard Svendsen

5th year students 2012/2013 Total 65, 36 female and 29 male

Aleksandersen, Hanne R.
Amiri, Mandana
Asphaug, Sindre
Awais, Muhammad
Baidoo, Martine Francisca
Behrens, Eivind Joo
Berstad, Sigrun Dyvik
Bjørgen, Cecilie
Brodtkorb, Thea Wilhelmine
Cesak, Ondrej
Correia, Joana Catarina
Djuve, Eirik
Duus, Ane Cecilie
Ekrheim, Hilde Bråtveit
Esmaeilpour Abardeh, Mahnaz
Fiske, Thomas Haukli
Foss, Kristine Bentzen
Foss, Martin Skjærvø
Hayfron-Benjamin, Ebenezer
Hjetland, Ola Sæterli
Hodneland, Solveig
Holene, Axel Lødemel
Houge, Emilie Øritsland
Hove, Hanne Ekeberg
Hyllestad, Ketil
Håbrekke, Åshild
Haarsaker, Trine Vilde
Jevne, Ivar Magnus
Johansson, Emma Matilda
Johnsen, Birgit
Kaasa, Jonas Reier
Kjemperud, Jostein
Kløcker, Kaja Neeb
Knutsen, Kristine Tomte
Kvamme, Andre Urke
Landrø, Ståle Overby
Lefsaker, Martine
Liland, Ingvild Skeie
Lindersen, Peter Johan Bergh
Lindgren, Camilla
Majeed, Hammad
Martinez Sanchez, Guillermo
Marvik, Tor Anders
Nilsen, Anne Sofie
Næss, Henriette Sæd
Olhaye, Mohammed Omar
Paulsen, Helene
Pettersen, Sigurd Rolland
Rashidan, Mahla
Selvaag, Kristian
Shoukat, Usman
Snarvold, Kristin S.
Stewart, Nicola Josefine
Subramanian, Sreedhar
Susort, Nils Arne
Tomasa, Tina
Trapnes, Helle Hofstad
Trapnes, Siri Hofstad
Urazgaliyeva, Gaukhar
Vanek, Petr
Vu, Yen
Øien, Marianne

Østbye Pedersen, Eirik
Aaltvedt, Stian
Aanonsen, Charlotte

4th year students 2012/2013 Total 36, 19 female and 17 male

Bolstad, Jon
Børde, Elisabeth
Didriksen, Ingrid
Elve, Arne Tobias
Eraker, Øyvind Juvkam
Gjertsen, Fredrik
Hammersland, Kine
Hanstad, Lars Emil
Haugen, Morten Rostad
Haugland, Christer
Heggernes, Tine Bergitte
Hov, Ingrid Karlsen
Hval, Karoline Nåvik
Jenssen, Kaia Andersson
Karolius, Sigve
Liland, Shirley Elisabeth
Lopez, Vanessa Valle
Mathisen, Bjørn Tore
Melbø, Henrik Kaald
Melsæther, Emily Ann
Mortensen, Henriette Iselin
Nisja, Trine
Nordbø, Jørgen
Nyeng, Trine
Nystrand, Sofie
Omdahl, Nina Helene
Pram, Christoffer Stundal
Risa, Kamilla Opheim
Simonsen, Rannei Solbak
Skanke, Even Evju
Skogstad, Vegard
Sonerud, Kjetil Bohman
Straume, Hanne Marie
Teigen, Erlend
Trondsen, Gaute Tolås
Wigum, Stine Hagen
Årrestad, Anne Bjerke

3rd year students 2012/2013 Total 23, 12 female and 11 male

Amundsen, Paul Magne
Andenes, Sigmund
Bache, Therese
Bernhardsen, Ida Mortensen
Bertheussen, Are
Bland, Martin Jonathan
Bruvoll, Lin Gunhild Rygg
Dalane, Kristin
Fenes, Endre
Forthun, Linn-Therese M.
Hole, Nils-Olav Andersen
Jensen, Lise Saue
Leirpoll, Anders Tyseng
Linnestad, Kasper Johnsen
Mørkve, Marte Sørtveit
Nannestad, Åsne Daling
Neteland, Marte
Storrvik, Hanna Marie
Strømsnes, Lars Moen
Tyvold, Preben Fürst
Verheyleweghen, Adriaen
Wigum, Stine Hagen
Witzøe, Trine

International masterstudents (MSchemeng) autumn 2012, total 16, 6 female and 10 male

Abdollahi, Reza, Iran
Aslankhani Khameneh, Niloofar, Iran
Bahmani, Samira, Iran
Brenna Bekkhus, Paul Rune; Norway
Canelas, Manuel, Honduras
Casalegno Garduño, Mario Ernesto, Mexico
Cesak, Ondrej, Czech Republic
Farzad, Reza, Iran
Hussain, Aqeel, Pakistan
Johnsen, Anja, Norway
Khanam, Ambari, India
Kure, Milly, Uganda
Nazarpour Alizad, Rasa, Iran
Reyes Lua, Adriana, Mexico
Sarfaraz, Mohammad Vahid, Iran
Vanek, Petr, Czech Republic

Two year domestic Master degree Program autumn 2012, total 17, 8 female and 9 male

Andersen, Marte Kee
Annfinsen, Steffen
Christiansen, Ida
Espenes, Marius
Fagerdal, Stine
Johannesen, Bengt Arild
Trine Johansen
Mai, Hieu Trung
Moen, Kristoffer
Rennemo, Rune
Salmi Stavrum, Malin Kristina
Shepherd, Thomas Vikran
Solvik, Marie Stokke
Svendsen, Elizabeth Martine
Svoren, Elisabeth
Tolgensbakken, Eirik
Åbø, Karl Magnus

Student mobility 2012

25 exchange students visited our Department (9 females and 16 males)

Name	University/Country	Group located
Ayuso Virgili, Gerard	Universitat Rovira I Virgili, Tarragona, Spain	Catalysis Group
Chapon, Maéva	National Polytechnic Institute of Lorraine, France	Colloid and Polymer Group
Dascălu, Anamaria	Gheorghe Asachi Technical University, Romania	Biorefinery and Fibre Technology Group
Dascălu, Aurelian-Alexandru	Gheorghe Asachi Technical University, Romania	Biorefinery and Fibre Technology Group
Engelbeen, Jeroen	Ghent University, Belgia	Colloid and Polymer Group
Freychet, Guillaume Leon	University Pierre and Marie Curie, France	Colloid and Polymer Group
Garcia, Vitor	Federal University of Rio Grande do Norte, Brazil	Colloid and Polymer Group
Guarrera, Alfonso	Politecnico di Milano University, Italy	Process System Engineering Group
Gleinser, Moritz Daniel	University of Munich, Germany	Process System Engineering
Herauville, Virginie M. T.	Institute National Polytechnique de Lorraine, France	Catalysis Group
Kawale, Durgesh	Delft University ot Technology, The Netherlands	Colloid and Polymer Group
Lemainque, Joseph Francois Vincent	University Paris Sud Orsay, France	Colloid and Polymer Group
Martin Montoya, Julio Guillermo	University of Valladolid, Spain	Catalysis Group
Maupilier, Anne Marie	National Polytechnic Institute of Lorraine, France	Environmental and Reactor Technology Group
Morán Rico, Elena	Universidat Politechnica de Valencia, Spain	Colloid and Polymer Group
Nascimento, Priscila	Federal University of Paraná, Brazil	Colloid and Polymer Group
Negre, Leo Andre	University Pierre and Marie Curie, France	Colloid and Polymer Group
Orlandi, Ezequiel	Federal University of Paraná, Brazil	Colloid and Polymer Group
Pattyn, Ibe	Ghent University, Belgium	Colloid and Polymer Group
Pichler, Birgit Elvira	Graz University of Tehcnology, Austria	Colloid and Polymer Group
Prache, Marie Odilie	Institut National Polytechnique de Lorraine, France	Environmental and Reactor Technology Group
Reynders, Pieter	K.H. Kempen University Collegen Belgium	Colloid and Polymer Group
Saz Perez, Pablo	Universidat Politechnica de Valencia, Spain	Catalysis Group
Staudinger, Christoph	Graz University of Tehcnology, Austria	Colloid and Polymer Group
Tillaut, Charlene Aurelie	National Polytechnic Institute of Toulouse, France	Environmental and Reactor Technology Group

34 students from our Department (23 females and 11 male) on exchange in 2012

Name	To institution	Program	Period
Børde, Elisabeth	University of California, Santa Barbara, USA	Bilateral	01.09.12 – 30.06.13
Didriksen, Ingrid	University of California, Santa Barbara, USA	Bilateral	01.09.12 – 30.06.13
Duus, Ane Cecilie S.	Technical University of Denmark (DTU), Denmark	Erasmus	01.09.11 – 30.06.12
Djuve, Eirik	University of California, Santa Barbara, USA	Bilateral	01.01.12 – 30.06.12
Elve, Arne Tobias	Vienna University of Technology, Austria	Erasmus	01.09.12 – 30.06.13
Foss, Kristine Bentzen	Polytechnic University of Valencia, Spain	Erasmus	01.01.12 – 30.06.12
Hammersland, Kine	University of California, Santa Barbara, USA	Individ	01.08.12 – 30.06.13
Hanstad, Lars Emil	University of California, Santa Barbara, USA	Bilateral	01.09.12 – 30.06.13
Houge, Emilie Øritsland	Technical University of Denmark (DTU), Denmark	Erasmus	01.09.11 – 30.06.12
Hove, Hanne Ekeberg	University of California, Santa Barbara, USA	Bilateral	01.09.11 – 30.06.12
Hval, Karoline Nåvik	Newcastle University, UK	Bilateral	01.08.12 – 30.06.13
Hyllestad, Ketil	University of Cape Town, South-Africa	Individ	01.09.11 – 30.06.12
Håbrekke, Åshild	Heriot-Watt University, Edinburgh, UK	Individ	01.09.11 – 30.06.12
Haarsaker, Trine Vilde	Illinois Institute of Technology, Chicago, USA	Erasmus	01.09.11 – 30.06.12
Karolius, Sigve	University of California, Santa Barbara, USA	Bilateral	01.08.12 – 30.06.13
Kjemperud, Jostein	University of California, Santa Barbara, USA	Bilateral	01.01.12 – 30.06.12
Kjos-Hanssen, Øyvind J.	ENSIACET Toulouse, France	Erasmus	01.09.11 – 30.06.12
Kløcker, Kaja Neeb	University of California, Santa Barbara, USA	Bilateral	01.01.12 – 30.06.12

Knutsen, Kristine Tomte	University of Melbourne, Australia	Individ	01.09.11 – 30.06.12
Lefsaker, Martine	Technical University of Denmark (DTU), Denmark	Erasmus	01.09.11 – 30.06.12
Liland, Ingvild Skeie	University of California, Santa Barbara, USA	Bilateral	01.01.12 – 30.06.12
Liland, Shirley Elisabeth	University of California, Santa Barbara, USA	Individ	01.08.12 – 30.06.13
Nilsen, Anne Sofie	Newcastle University, UK	Bilateral	01.01.12 – 30.06.12
Nordbø, Jørgen	Technische Universität München, Germany	Erasmus	01.09.11 – 30.06.12
Næss, Henriette Sæd	University of California, Santa Barbara, USA	Bilateral	01.09.11 – 30.06.12
Omdahl, Nina Helene	University of California, Santa Barbara, USA	Bilateral	01.08.12 – 30.06.13
Paulsen, Helene	University of Melbourne, Australia	Individ	01.09.11 – 30.06.12
Risa, Kamilla Opheim	University of Melbourne, Australia	Individ	01.01.12 – 30.06.12
Selvaag, Kristian	University of California, Berkeley, USA	Erasmus	01.09.11 – 30.06.12
Simonsen, Rannei Solbak	University of California, Santa Barbara, USA	Bilateral	01.09.12 – 30.06.13
Skanke, Even Evju	University of Technology, Munich, Germany	Erasmus	01.01.12 – 30.06.12
Stewart, Nicola J. Ø.	University of Melbourne, Australia	Individ	01.09.11 – 30.06.12
Øien, Marianne	Heriot-Watt University, Edinburgh, UK	Individ	01.09.11 – 30.06.12
Aaltvedt, Stian	Unoversity of California, Santa Barbara, USA	Individ	01.09.11 – 30.06.12

Students on exchange celebrated 17th of May in Cape Town

And in Santa Barbara, USA

PhD in Chemical Engineering

The Department of Chemical Enginerring offers a PhD-programme, which gives a higher education within the field of Chemical Engineering.
The PhD program in Chemical Engineering will provide training in how to generate and publish new knowledge in the field, as well as help strengthen the catidates acdemic horizont in Chemical Engineering.

The PhD proggram in Chemical Engineering are connected to the Departments research groups:

- Catalysis
- Colloid- and Polymerchemistry
- Process- Systems Engineering
- Environmental Engineering and Reactor Technology
- Biorafinery and Fibre Technology

PhD courses given at Department of Chemical Engineering:

Cours code	Course title	Credits	Registered	Passed	Semester
KP8100	Advanced Process Simulation	7.5	2	2	Fall 12
KP8102	Wood Chemistry in Pulping and Paper Making	7.5	-	-	Fall 13
KP8105	Methematical Modelling and Model Fitting	7.5	-	-	Fall 13
KP8106	Gas Cleaning with Chemical Solvents	9.0	5	4	Spring 12
KP8107	Advanced Course in Membrane Separation Process	9.0	3	3	Spring 12
KP8108	Advanced Thermodynamics: With applications to Phase and Reaction Equilibria	9.0	1	1	Fall 12
KP8110	Membrane Gas Purification	9.0	3	3	Spring 12
KP8115	Advanced Process Control	7.5	3	3	Spring 12
KP8117	Paper Physics and Paper Chemistry	9.0			Spring 13
KP8128	Advanced Reactor Modelling	12.5	-	-	Spring 13
KP8129	Colloid Chemistry for Process Industry	7.5	9	7	Spring 12
KP8130	Systembiology, Modelling and Analysis	7.5	-	-	Fall 12
KP8131	Crystallization and Particle Design	7.5	-	-	Spring 13
KP8132	Applied Heterogeneous Catalysis	7.5	-	-	Fall 13
KP8133	Characterization of Heterogeneous Catalysts	7.5	-	-	Fall 14
KP8134	Surfactants and Polymers in Aquous Soutions	7.5	3	3	Fall 12
KP8135	Surface, Colloid and Polymer Chemistry Special Topics	7.5	12	10	Spring/fall 12
KP8136	Modelling of Catalytic Reactions	7.5	-	-	Spring 13
KP8137	Design and Preparation of Catalytic Materials	7.5	-	-	Spring 13
KP8901	Chemical Process System Engieering	7.5	2	1	Fall 12
KP8902	Reactor Technology	7.5	1	1	Spring 12
KP8903	Reaction Kinetics and Catalysis	7.5	7	7	Fall 12
KP8904	Transport Phenomena	7.5	5	5	Fall 11
KP8905	Surface- and Colloid Chemistry	7.5	-	-	Spring 14

PdD-Thesis 2012 total 14 – 8 female and 7 male

Alsvik, Inger Lise
Parameter Optimization in Preparation of Membranes for Osmotic Proceses [POPMOP].
Supervisor: May-Britt Hägg

Bruder, Peter
Solvent development and testing for post-combusion carbon dioxide capture.
Supervisor: Hallvard Svendsen

Chao, Zhongxi
Modeling and Simulaton of Reactive Three-phase Flows in Fluidized Bed Reactors: Application to the SE-SMR Process.
Supervisor: Hugo A. Jakobsen

Dar, Hassan Jamil
Gas Phase Oxidative Dehydrogenation of Ethane: Kinetics and Reactor Simulation.
Supervisor: De Chen

Hii, Collin Ching Tyn
The Influence of Furnish Composition, Sheet Structure and Pressing Conditions on Wet Pressing Performance of Newspring.
Supervisor: Øyvind W. Gregersen

Luo, Xiao
Experimental and numerical study of carbon dioxide mass transfer and kinetics in amine solutions.
Supervisor: Hallvard Svendsen

Nenningsland, Andreas Lyng
Extracton, Quantification and Study of Interfacially Active Petroleum Components.
Supervisor: Johan Sjöblom

Patanou, Eleni
Adsorption Microcalorimetry Studies on Supported Cobalt Catalysts
Supervisor: Edd A. Blekkan

Radstake, Paul
Oxygen-Assisted Dehydrogenation of Ethane over Alumina-Supported Pt-Sn Catalysts
Supervisor: Anders Holmen

Rafiee, Ahmad
Optimal design issues of a gas-to-liquid process
Supervisor: Magne Hillestad

Rout, Kumar Ranjan
A Study of the Sorption Enhanced Steam Methane Reforming Process
Supervisor: Hugo A. Jakobsen

Setekleiv, Alf Eddie
Experimental characterization of scrubber internals at low and elevated pressures
Supervisor: Hallvard Svendsen

Uddin, Mohammad Washim
Durability of a PVAm/PVA Blend Membrane in Natural Gas Sweetening.
Supervisor: May-Britt Hägg

Yelchuru, Ramprasad
Quantitative methods for controlled variable selections
Supervisor: Sigurd Skogestad

7 PhD exchange students visited our Department in 2012 (2 female and 5 male)

Name	**University/Country**	**Group located**
Aizpurua Gonzalez, Carlos Ernesto	North Carolina State University, USA	Process System Engineering Group
Arshad, Muhammad Waseem	Technical University of Denmark, Denmark	Environmental Egineering and Reactor Tehnology Group
Djafari, Seyed Rahman	Goran University of Agricultural Sciences and Natural Resources, Gorgan, Iran	Biorefinery and Fibre Technology Group
Gil Matellanes, Maria Victoria	Spanish Council for Scientific Research	Catalysis Group
Hosseini, Seyedali	University of Tabriz, Iran	Catalysis Group Process System Engineering Group
Magbool Jan, Nabil	Madras, Chennai, India	Process System Engineering Group
Zarebska, Agata	University of Southern Denmark, Odense, Denmark	Environmental Egineering and Reactor Tehnology Group

4 PhD students from our Department visited Universities abroad in 2012

Name	**University/Country**	**Period**
Dadgar, Farbod	Karlsruhe Institute of Technology, Germany	01.06. – 30.09.2012
Enaasen, Nina	University of Austin, Texas, USA	27.09.2012 – 27.04.2013
Gunawardana, Daham	Haldor Topsøe AS, Kgs. Lyngby, Denmark	01.05. – 31.07.2012
Volynkin, Andrey	University of Cambridge, UK	01.10.2012 – 01.04.2013

Seminars, conferences and meetings organized by the Department in 2012

PROST seminars in Processcontrol

Professor Bjarne Foss, Department of Engineering Cybernetics, NTNU
Real-time production optimization and reservoir management at the IO center
01.02.2012

Post Doc. Florin Stoican, Department of Engineering Cybernetics, NTNU
Fault-tolerant control (FTC) chemes through set theoretic methods
21.03.2012

Johannes Jäschke, Department of Chemical Engineering, NTNU
Optimal operation of nonlinear systems
29.02.2012

KinCat Gemininsenter - SINTEF - NTNU Seminars in Heterogeneous Catalysis:

Seminar in connection with the appointment of Professor Jens Nørskov, Stanford University, as Honorary Doctor at NTNU, *May 31st 2012*

Professor Anders Holmen:
Professor Jens Nørskov, Honorary Doctor at NTNU.

Professor Jens Nørskov, Stanford University, USA:
Catalysis for sustainable energy solutions.

Post Doc. Jia Yang, NTNU:
New approach for kinetic modeling of Fischer-Tropsch synthesis on cobalt based catalysts.

Post Doc. Ingeborg-Helene Svenum, NTNU:
Modelling of adsorption on Pd3Ag surfaces.

Professor De Chen, NTNU:
Towards better understanding of reaction mechanism of F-T synthesis.

Professor Alessanda Beratta, Department of Energy, Politecnico di Milano, Italy
Kinetic study of the catalytic partial oxidation of Light hyrdrocarbons
28.08.2012

Kinetic Modeling of Fischer-Tropsch Synthesis, Seminar 1:

Dr. Chao'en Li, CSIRO, Australia
Kinetic modelling of Fischer-Tropsch Synthesis
27.09.2012

Dr. Jia Yang, Department of Chemical Engineering, NTNU
Steady-state and transient kinetic modelling for CO methanation on cobalt catalysts
27.09.2012

Kinetic Modeling of Fischer-Tropsch Synthesis, Seminar 2:

Dr. Jun Zhu, Department of Chemical Engineering, NTNU
Compact F-T reactor based on oxide/CNT/carbon felt structured Co catalysts
01.10.2012

Professor Per-Olof Åstrand, Department of Chemistry, NTNU
Brief introduction of kinetic Monte Carlo
01.10.2012

Professor De Chen, Department of Chemical Engineering, NTNU
Microkinetic modelling of GTL process
01.10.2012

Seminar at Ugelstadlaboratory

Tor Austad,
Smart Water Flooding in Sandstones: A New Chemical Understanding of the EOR-potential
12.06.2012

Ugelstadlaboratory, 10th Year Anniversary, 13.09.2012

Professor Gisle Øye, Department of Chemical Engineering, NTNU
Research Related to Produced Water and Enhanced Oil Recovery at Ugelstad Laboratory

Associate Professor Wilhelm Glomm, Department of Chemical Engineering, NTNU
Teaching Old Proteins New Tricks

Associate Professor Brian Grimes, Department of Chemical Engineering, NTNU
Modeling Separation and Interfacial Transport in Emulsion Systems

Professor Emeritus Per Steinus, Department of Chemical Engineering, NTNU
Microfibrillar Cellulose - à Perspective

Adjunct Professor Hans-Jörg Oschman, Champion Technologies Europe BV, The Netherlands – Department of Chemical Engineering, NTNU
Subsea Transport of High Waxy Crude - Risk Assessment and Mitigation Strategies

Researcher Sébastien Simon, Department of Chemical Engineering, NTNU
C80-Tetraacids/Arn: Barely Detectable, Big Effects 7 years of research at Ugelstad Laboratory

Staff Engineer Camilla I. Dagsgård, Department of Chemical Engineering, NTNU
EHS at Ugelstad Laboratory

Researcher Kristofer Paso, Department of Chemical Engineering, NTNU
Ugelstad Wax Strategies

Seminars connected to project JIP-1-2 (Increased Energy Savings in Water/Oil Separation through advanced fundamental Emulsion Paradigms) at Ugelsad Laboratory

JIP-1 + 2, Middle Day, 23.05.2012, Berlin, Germany

Professor Björn Kvamme, University of Bergen, Norway:
Fluid Adsorption on Solid Surfaces and Impact on Hydrate Formations

Professor Subir Bhattacharjee, University of Alberta, Canada
Molecular Dynamics Simulations of Model Petroleum Compounds: Transport and Phase Behaviour

Dr. Roar Skartlien, IFE, Norway
Numerical Simulation of Emulsions

Professor Stig Friberg, Charlottesvile, USA
Spontaneous Emulsification and Phase Diagrams

Professor Zhenghe Xu, University of Alberta, Canada
Understanding Stability of Water in Heavy Oil Emulsions from Interfacial Film Study"

Associate Professor Dr. Brian Grimes, NTNU, Norway
Concepts in Multi-scale Modelling

Researcher Dr. Kristofer Paso, NTNU, Norway
Pipeline Restart Modelling

JIP-1 + 2, Middle Day, 28.11.2012, Barcelona, Spain

Hilde Knapstad, Climate and Pollution Agency, Norway
Chemical Regulations

Professor Krister Holmberg, Chalmers University of Technology, Sweden
Driving Forces for Surfactant Development

Cassandra Smith, Champion Technologies
Trends in Legislation in the North Sea

Per-Erik Hellberg, AkzoNobel Surface Chemistry AB, Sweden
Some Aspects on Biodegradation of Oilfield-Relevant Surfactants

Amir Mahmoudkhani, Kemira Chemicals AS, Norway
Responsible Chemistry for Upstream Oilfield Applications: Realigning the Wheels

Jens Emil Vinstad, Statoil, Trondheim, Norway
Production Chemistry Management in Statoil – Qualifying New Chemicals for Offshore Use

Pieter Vijn, Champion Technologies
A New Class of Biodegradable Demulsifiers for Heavy Oil Emulsions

Onsager Professor and honorary doctor at NTNU

The Department of Chemical Engineering hosted the Onsager Professor in 2012

Professor Richard Spontak from the Department of Materials Science & Engineering, and Department of Chemical & Biomolecular Engineering, North Carolina State University was appointed as Onsager Professor in 2012. He spent three months working with the Environmental Engineering and Reactor technology research group.

Professor Richard Spontak received Onsager-medal, Tuesday 12th of June from Vice Dean Åse Krøkje

Professor Jens Nørskov, Stanford University was awarded Doctor honoris causa (Honorary Doctor) of NTNU in 2012.

He was nominated by the Catalysis Group at the Department of Chemical Engineering.

Professor Jens Nørskov

Receiving the award from the Rector of NTNU Torbjørn Digernes. From Left: Professor Anders Holmen, Truls Gjestland, Jens Nørskov, T. Digenes

CHAPTER 7: ORGANIZATION - ECONOMY

Organization (also see cover page)

The Department Board is the highest decision-making body. The Department Board shall make decisions regarding strategy and budget. The Board has 2-3 meetings each year.
It consists of two external members, a member from the scientific staff, administrative staff, temporary scientific staff (PhD's, Post Doc's) and students. The board is elected for 4 years. The Head of Department is the chair of the board. Head of Department is Professor Øyvind Gregersen, elected in 2009 for a four-year period (mid 2009 – mid 2013).

The scientific staff is divided in to five research groups. Each research group has a representative in the management team. The management team has also representatives from the PhD's, the students and technical staff. The management team meets every second week and discusses running matters, and gives advice to the Head of Department.

In addition to the scientific staff the department has 20 persons in a technical and administrative staff to support teaching and research of all the research groups.

Administrative responsibilities of faculty

Faculty Educational Committee (Department representatives)	Associate Professor Jens-Petter Andreassen deputy: Professor Edd Anders Blekkan
Faculty Research Committee (Department representatives)	Professor Sigurd Skogestad, deputy: Professor Hugo Atle Jakobsen
Study Program Chemical Engineering and Biotechnology (Industriell kjemi og bioteknologi) (Department representatives)	Associate Professor Jens-Petter Andreassen
Exchange of Norwegian students taking courses abroad (approval of course program), and approval of course program for visiting exchange students.	Associate Professor Jens-Petter Andreassen,
International Master program	Associate Professor Jens-Petter Andreassen and Higher Executive Officer Hege Johannessen

Department Economy

The department has three main sources of income:

- Regular funds from the University
- Strategic funding from the University
- External projects.

In terms of external funds, including contributions from the research Council and industry, the situation is good, but has dropped a little in 2012. The gross regular funds from the University were about 49 million NOK in 2012.

These funds are mainly used for salaries to permanent staff, contribution to research projects, equipement and regular operations of the department. In 2012 two investments in infrastructure was postponed and message of large cutbacks in funding for 2013 slowed down the spending at the end of 2012, and we got a substantial surplus.

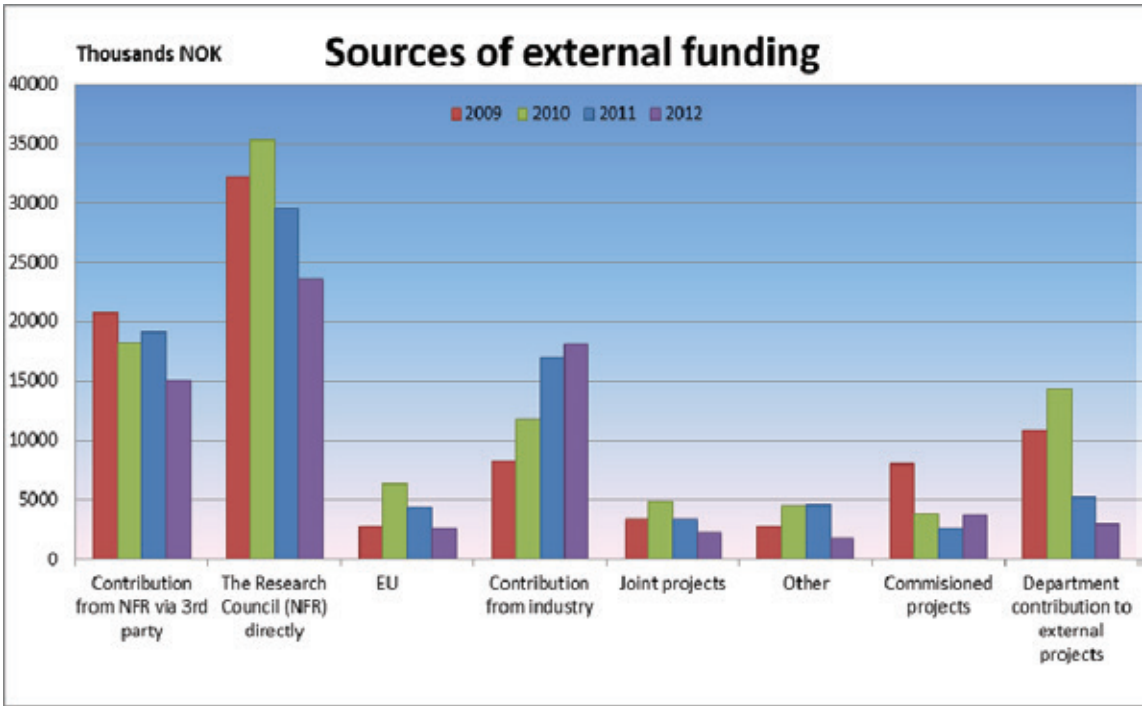
More details are shown in Table 1.

Accounts	2009	2010	2011	2012
Income:				
University funding	39 151 000	44 775 000	47 179 000	48 860 000
Sum income	39 151 000	44 775 000	47 179 000	48 860 000
Expenses:				
Wages	24 726 000	27 543 000	34 116 000	37 649 000
Investment	250 000	6 913 000	3 112 000	1 536 000
Operating expenses	2 684 000	1 648 000	3 622 000	3 945 000
NTNU contribution to ext. projects	9 810 000	7 720 000	6 803 000	3 026 000
Sum expenses	37 470 000		47 653 000	46156 000
Result	1 681 000	951 000	-474 000	2 704 000

Table 1. Department's income from University and spending.

External funding

In addition to the University funding shown in Table 1, the Department has a substantial income from external contributors of approx. 66 million NOK. Details are shown in Tables 2 and 3. In 2012 the external contributions continued to decline after an all time high in 2010. Some of the decrease can be explained as several professors retireing or aree close to retirement and do not start up new projects, and their replacements have still some way to get to their level of external funding. As for the gorvermental funds, the main costs on the projects are related to salary for PhD candidates and Post Docs. The main contributor to the external research activity is The Norwegian Research Council (NFR). Most of these projects are at the Department, but the second largest external source is NFR projects where we contribute as a third party. The level of funding from commissioned research have declined the last years, however the direct contribution from industry has increased. The funding from EU is in the range 3 – 6 MNOK/year. Hopefully we will manage to increase the EU-research in the coming years.
A problem has been that such projects have been underfinanced, but new support routines from the University are helping balance projects. We have several joint industrial programmes with industry partners from countries in Europe, North-America, South America, Africa and Asia. External funding from commissioned research was approx.5.3% in 2012, up from 3.5% in 2011.



Strategic funds from University

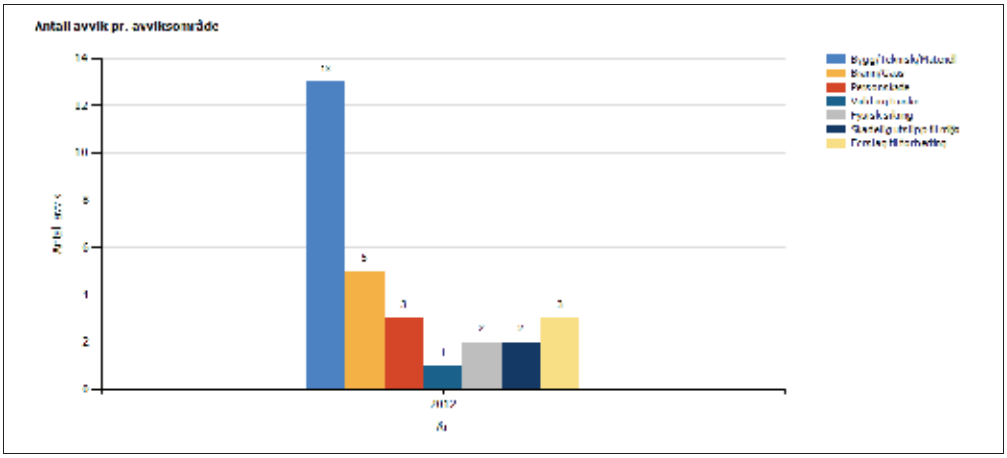
The third source of income is strategic funding from the University, this is earmarked funds to support teaching, research and academic profile. These funds are used for investments in research equipment or PhD or Post Doc. positions.

The Department got some new projects in 2012, mainly as start-up contributions to new academic staff to help them getting started with research. These new projects was in total less than 1 MNOK. The total spending for the segment was approx. 5.9 MNOK in 2012.

CHAPTER 8: HEALTH, ENVIRONMENT AND SAFETY (HES)

Internal HES audit
The general state of our laboratories is evaluated in the annual HES audit. This year the main focus was ventilation hoods and point ventilation in addition to order and cleanliness. The air flow in ventilated hoods was measured and corrective actions taken in some cases. Medicine and chemical storage closets were also checked. The department needs to invest in more closets for chemicals.

External HES-related audits
"Trøndelag Brann og Redningstjeneste" has controlled our buildings, fire equipment and routines. Some gas cylinders were secured after the control. The central gas distribution system has reduced the need for lose gas cylinders.
Statoil ASA has done and HES and Quality system control of NTNU in our catalysis pilot hall laboratories. The audit was done based on our NORSOK s-006 contract with Statoil and the HES standards of Statoil.
None of the HES-audits found major errors and the feedback was largely positive.



Reports of incidents in different categories (left) and for different type of incidences taken from the new incident report system.

In addition annual HES activities are running.
HES Courses: 180 persons have fulfilled our HES course during 2012. The course is compulsory for all new employees, master students, exchange students, 3rd year students doing our laboratory course "Felleslab", and summer students.

We are continuously working with risk evaluation, documentation of laboratory routines for all activity that may pose a risk. Physical and psychological issues are discussed with each employee in the performance reviews and are followed up after this.

Reported incidents during 2012: We had 29 reported incidents during 2012. The incidents included, gas leakage, fire initiation in an instrument, errors in a ventilated hood, and possible exposure to solvents (checked out by the NTNU health care organisation). Errors in the new gas detection system were discovered and these are now being corrected.

Focus areas of 2013
The pilot halls C and D are both starting up experimental activity after renovation. Establishing good routines in these areas with regard to risk assessment, instruction of new people, security routines, alarms and emergency routines is highly important. During 2013 we hope to install a new working alone alarm system. We are proud to be a department with high research activity and a high throughput of PhD and master students. This demands that the focus on HSE-training and attitude must continue to be very high at the department. Training of students and new employees and continued work with establishing a good HES-culture in the department is vital.

New gas-distribution plant has been put into operation

Some pictures of different activities at the Department

Our buildings, from right: K4, K5, Experimental halls, and the PFI-building (blue)

Associate Professor Tore Haug-Warberg received the educational prize for best lecturer in 2012

Margrethe Nergaard with some kids during "Forskerfabrikken" (picture used with permission from guardian)

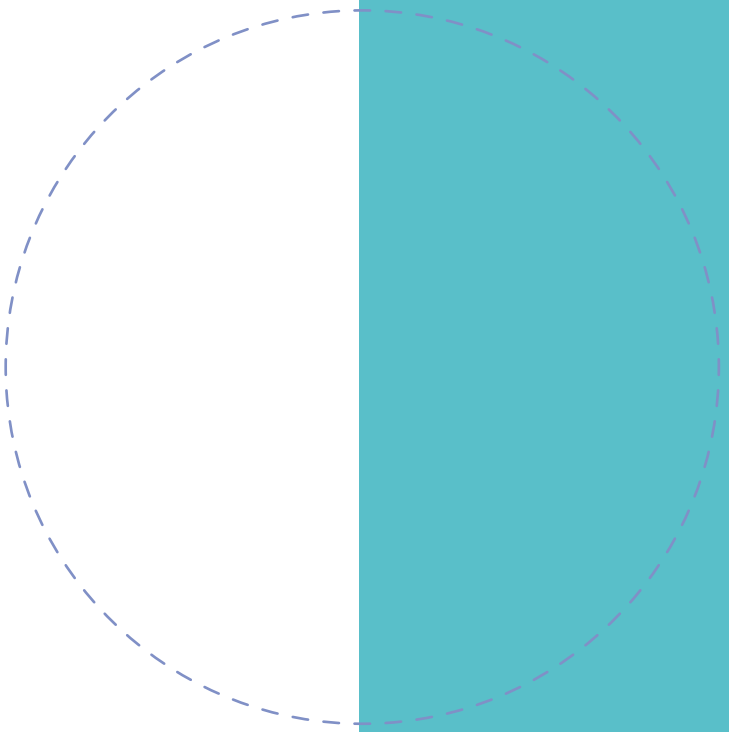
Posterpresentation from the work in Process Design Project

Sara, Karin and May-Britt in competition of making the finest peppercake house at the departments "julelunsj"

Vajiheh and Maria Teresa in the new gas storage room

LIST OF TELEPHONE NUMBERS (06.05.2013)

94209	Andreassen Jens-Petter, Associate Professor	K4-302
50339	Bandyopadhyay, Sulalit, PhD candidate	K5-340
50318	Barø Tove, Executive Officer	K5-101
94137	Barrabino Ponce, Albert, PhD candidate	PFI-3401
94025	Beck Ralf, Post doctor	K4-305
50924	Benmekhbi, Mehdi, PhDcandidate	PFI-3408
94138	Berge, Arvid, Professor Emeritus	K5-M11
94057	Bjerknes, Martha, Higher Executive Officer	K5-101C
94157	Blekkan Edd Anders, Professor	K5-401
91664	Borthen Berit, Chief Engineer	K4167
94144	Brun Harry, Engineer	K5-341
95879	Buan, Marthe Emelie, PhD candidate	K5246
93149	Chen De, Professor	K5-407
	Ciftja, Arlinda, PhD candidate	K4-432
94073	Dadgar, Farbod, PhD candidate	K5-M6
91605	Dagsgård, Camilla, Staff Engineer	PFI-3403
94055	Dai, Zhongde, PhD candidate	K4-213
94112	Deng Liyuan, Associate Professor	K4-225
93691	de Oliveira, Vinicius, PhD candidate	K4-207
	Di Domenico Pinto, Diego, PhDcandidate	K4-408
50327	Doni Jayavelu, Naresh, PhD candidate	K4-232
94156	Dragsten, Karin W., Staff Engineer	K5-432
50924	Eftekhardadkahah, Mona, PhD candidate	PFI-3408
51128	Enger, Bjørn Christian, Post doctor	K5-443
	Enaasen, Nina, PhD candidate	K4-411
94120	Erga Olav, Professor Emeritus	K5-237
91897244	Flatberg, Gøril, Chief Engineer	K4-309
	Flid, Yulia, Laboratory Assistant	K4-307
94143	Fossum Arne, Engineer	K5-019
	Fytianos, Georgios, PhD candidate	K4-308
50540	Gao, Bicheng, Researcher	PFI-3404
94017	Gawel, Bartlomiej, Researcher	K5-336
50372	Ghadrdan, Maryam, PhD candidate	K4-239
94158	Glomm Wilhelm R. Associate Professor	K5-336
	Gondal, Shahla, PhD candidate	K4-309
94029	Gregersen Øyvind, Professor	PFI-2109
90338	Grimes Brian, Associate Professor	K5-339
93691	Grimholt, Chriss, Ph.D candidate	K4-207
94193	Gunawardana, Daham Sanjaya	K5-251
	Gupta, Mayuri, PhD candidate	K4-430
50338	Hartono, Ardi, Researcher	K4-407
94108	Haug-Warberg Tore, Associate Professor	K4-228
94055	He, Xuezhong, Post doctor	K4-213
94031	Helle Torbjørn, Professor emeritus	PFI-2109
50304	Helmersen Tom, Office Manager	K5-101
94113	Hertzberg Terje, Professor Emeritus	K4-333
94122	Hillestad Magne, Professor	K4-437
98354	Hjorth, Ida, PhD candidate	K5-M4
94151	Holmen Anders, Professor Emeritus	K5-430
94026	Hovin Odd Ivar, Engineer	Kh-155
94033	Hägg May-Britt, Professor	K4-339
50372	Jahanshahi, Esmaeil, PhD candidate	K4-239
94132	Jakobsen Hugo Atle, Professor	K5-209
96646	Johannessen, Hege, Study Advisor	K5-101
	Jonassen, Øystein, PhD candidate	K4-307
93691	Jäschke, Johannes, Post doctor	K4-207
50342	Kaombe, Divina, PhD candidate	PFI-3209
94149	Keleşoğlu, Serkan, Post doctor	K5-308
50346	Klimantos, Paris, PhD candidate	K4-406
50325	Kovalchuk, Karina, PhD candidate	K5-333
94119	Knuutila, Hanna, Associate Professor	K4-432
50339	Kumar, Lalit, PhD canditate	K5-340
91897762	Lesaint Caterina,Senior Engineer	PFI-3404
94073	Lillebø, Andreas H., PhD candidate	K5-M6
46940173	Lin, Ling, Controller	K5-101C
98379	Lou, Fengliu, PhD candidate	K5-225
	Ma, Xiaoguang, PhD candidate	K4-209
50325	McDonagh, Birgitte, PhD candidate	K5-333
94153	Mathisen Torgrim, Higher Executive Officer	K4-166
	Mehandzhiyski, Aleksandar, PhDcandidate	K5-239
93691	Minasidis, Vladimiros, PhD canditate	K4-207
94032	Moe Størker, Associate Professor	PFI-2108
	Monteiro, Juliana, PhD candidate	K4-430
94156	Moljord, Kjell, Adjunct Professor	K5-
94125	Muthuswamy, Navaneethan, Post doctor	K5-429
94148	Mørk Preben C., Professor	K5-M11
91807	Nafisi, Vajiheh, PhD candidate	K4-215
50536	Narvestad, Hanne, PhD candidate	PFI-3206
	Nergaard, Margrethe, PhD canditate	K4-307
98379	Noor, Tayyaba, PhD candidate	K5-225
94149	Nourani, Meysam, Post doctor	K5-326
94111	Patanou, Eleni, Coordinator	K5-429
93147	Paso Kristofer, Researcher	K5-304
92807	Preisig Heinz A, Professor	K4-233
	Putta, Koteswara Rao, PhD candidate	K4-411
93138	Qi, Yanying, PhD candidate	K5-251
91686	Rodionova, Galina, Post doctor	PFI-3209
94139	Roel Jan Morten, Principal Engineer	Kh-155
94150	Roel Lisbeth B, Higher Executive Officer	K5-101
94146	Rout, Kumar Ranjan, Post doctor	K5-213
94147	Rytter Erling, Adjunct Professor	K5-M11
94121	Rønning Magnus, Associate Professor	K5-408
94055	Saeed, Muhammad, PhD candidate	K4-213
	Samseth, Jon, Adjunct Professor	K4-333
50331	Sánchez, Rafael, PhD candidate	K5-204
94073	Setekleiv Eddie, Researcher	K5-M6
91657	Simon, Sebastien, Post doctor	PFI-3406
95505	Sjöblom Johan, Professor	K5-301
51279	Skancke, Jørgen, PhD candidate	DU1-126
91807	Skog, Tom-Gøran, PhD candidate	K4-215
94124	Skjøndal-Bar, Nadav, Associate Professor	K4-227
94154	Skogestad Sigurd, Professor	K4-211
94312	Solsvik, Jannike, PhD candidate	K5-206
95879	Strømsheim, Marie Døvre, PhD candidate	K5246<
94106	Sundseth Frode, Engineer	K5-033
94100	Svendsen Hallvard, Professor	K4-402
94039	Svenum, Ingeborg-Helene Post doctor	K5-429
95903740	Syverud, Kristin, Adjunct Professor	PFI-4408
91897764	Sætran, May Grete, Principal Engineer	PFI-3405
94149	Tichelkamp, Thomas, PhD candidate	K5-326
	Trollebø, Anastasia, PhD candidate	K4-308
97018	Tsakoumis, Nikolaos, Post doctor	K5-M12
94126	Udani, Charitha, PhD candidate	K5-250
94055	Uddin, Mohammad, Post doctor	K4-213
92831	Venvik Hilde, Professor	K5-406
50346	Vevelstad, Solrun, PhD candidate	K4-430
94111	Vicinanza, Nicla, PhD candidate	K4-250
94110	Vik, Camilla Berge, PhD candidate	K5-244
94149	Volden Sondre, Researcher	K5-308
94193	Volynkin, Andrey, PhD candidate	K5-249
94187	Voronov, Alexey, PhD candidate	K5-M9
94118	Voß, Georg, PhD candidate	K5-149
94025	Wang, Lijuan, PhD candidate	K4-305
94187	Wang, Xuehang, PhD candidate	K5-M9
94193	Wycisk, Michael, PhD candidate	K5-249
93146	Yang, Jia, Post doctor	K5-411
94136	Yu, Qiang, Post doctor	K4-213
50339	Zhao, Yansong, PhD candidate	K5-340
94208	Zhou, Haitao, Post doctor	K5-M12
94114	Zhu, Jun, Post doctor	K5-247
94135	Øye Gisle, Professor	K5-307



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