DEPARTMENT OF CHEMICAL ENGINEERING, NTNU

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CHAPTER 1: INTRODUCTION

Introduction to Annual Report 2009

By Øyvind Weiby Gregersen (Head of Department)

The aim of this report is to sum ut the activity at the departement in 2009, as well as providing more general information abaout the departement. We hope you find it useful

During 2009 the department has continued the trends from the last years delivering excellent research and being continuously more international. The last point is illustrated by our 20 students in the international master program and Ph.D.candidates from more than 27 nations. Further 6 of our Norwegian students spent at least one semester abroad and we had 32 visiting students. This is a desired development, which in the long run will serve a more international industry structure well. However, an important challenge in the years to come will be to recruit sufficient numbers of Norwegian Ph.D. 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 research output, as expressed by the number of graduated Ph.D. candidates and publications, was equally good as in the record breaking year 2007. The number of credited publications in international journals was 109 (2009) whereas it in the five previous years were 48 (2004), 76 (2005), 74 (2006), 109 (2007) and 84 (2008).

Furthermore, 14 Ph.D. candidates graduated in 2009, which is about the same as previous years. Since the average time to complete a PhD is about 4-5 years (including leaves of absence), we can infer from the table on the next page that the PhD production may drop slightly the next year, but will then increase sharply because of the record number of 38 new PhD students in 2008, of which many are funded by the new GASSMAKS program of the Norwegian Research Council (NFR).

The Department has over the past 8 years had a low number of students in the *Chemical Engineering and Biotechnology* program. To improve the situation we are working actively on recruiting students and improving the quality of our study program. The student laboratories are upgraded, and we are planning a new subject in modeling and programming. The teaching of basic subjects shall be rotated among the faculty and each subject shall have a group of at least two faculty members who can step in at short notice. The use of Ph.D. candidates for teaching is also being 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. The goal of the department is to recruit at least 50% of the students in the Chemical Engineering and Biotechnology program.

In terms of plans and faculty recruitment, we have followed quite closely the Departments strategic plan from 2003. In 2009 a new faculty position focusing on CO_2 absorption was announced. The position will be filled during the spring semester 2010 and will represent a much needed position in a research field of global importance where our department has an internationally leading position. To support teaching and research quality we have also been working on recruiting two research engineers and one student advisor. A new strategic plan is being made during 2010.

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 and hall D is currently taking place. We expect to move in before summer 2010.

The paper machine in the basement of K4, which was officially opened by King Olav in 1965, has been removed to make place for new laboratories for the expanding CO_2-separation activities. The rest of the pulping and biorefinery pilot equipment is moved to the joint experimental hall, which the department share with PFI in the PFI building. The funding for the renovation comes from the Government Financial Crisis Package (120 mill. NOK), and the university, (25 mill. NOK). 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.

In 2009 the Department received the evaluation report from the Research Council of Norway as part of an evaluation of all chemistry research in Norway. The evaluation was very positive for the Department, and the committee writes: *"The Committee was very favourably impressed by the research in this department, and further believes that the close interactions with SINTEF and other research entities are highly beneficial. The Committee can therefore make no major general recommendations for changes, other than that the Committee is in favour of maintaining current directions and plans."* In light of this the only adjustment to our research strategy, is promoting that each PhD student should have an internal co-supervisor to enhance quality an internal co-operation further.

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* (M.Sc.) 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 Ph.D. 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, namely Pulp and Paper Chemistry (T*reforedlingskjem*i, 1946), Chemical Engineering (K*jemiteknikk*, 1949) and Industrial Chemistry (I*ndustriell kjemi,* 1950). These merged in 1999 to the present Department of Chemical Engineering (K*jemisk prosessteknologi*).

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 2009 included

- 20 technical/administrative
- 19 academic, incl.13 Professors and 6 Associate Professors (*Førsteamanuensis*)

The non-permanent staff in 2009 included

- 4 technical
- 4 Adjunct Professors (*Professor II*) (20% *position)*
- 85 PhD students
- 30 Post Doc.s and researchers

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

Student production

Year	MSc	PhD
1995	79	2
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

(*) Transition from 4.5 to 5 year program.

MSc students 2009/10

5th year	40 (incl. 9 International Master)
4th year	44 (incl.11 International Master)
3rd year	23

New PhD students (exchange students not included)

2003	20
2004	10
2005	9
2006	18
2007	15
2008	38
2009	18

New Post Doc.s/Scientists

2006	10
2007	25
2008	28
2009	6

CHAPTER 2: RESEARCH
CATALYSIS GROUP

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

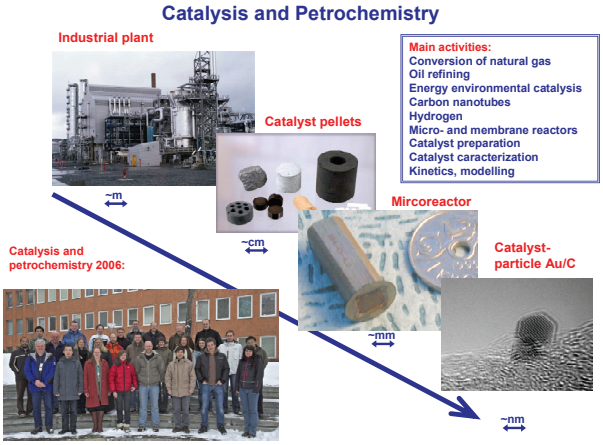
Post Docs.
Espen Standal Wangen
Estelle Vanhaecke
Hongmin Wang
Tiejun Zhao
Jun Zhu (from 01.07.09)

PhD candidates
Alexej Voronov
Anh Hoang Dam
Asmira Delic (from 08.06.09)
Astrid Lervik Mejdell (until 31.01.09)
Daham Sanjaya Gunawardana (from 28.07.09)
Eleni Patanou
Fan Huang
Fatemeh Hayer
Hamidreza Bakhtiary Davijany
Hassan Jamil Dar
Ilya Gorelkin
Ingvild Tronstad
Jia Yang
Li He
Miroslav Surma
Navaneethan Mutuswamy
Nikolaos Tsakoumis
Oana Mihai
Paul Radstake
Saima Sultana Kazi
Sara Boullosa Eiras
Šárka Zárubová (until 13.11.09)
Shreyas Pandurang Rane
Tayyaba Noor
Xuyen Kim Phan

Technical staff
Karin Wiggen Dragsten (from 07.10.09)

Guests
Christine Balonek (PhD student from University of Minesota, USA)
Fernando Bimbela (PhD student from Zaragoza, Spain)
Sara Lögdberg (PhD student from KTH, Sweden)
Wayne Blaylock (PhD student from University of Minesota, USA)
Yian Zhu (visiting researcher from East China University)

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 students graduate each year (M.Sc.). The group participates extensively in international networks; research programs etc., and cooperate 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: 5 Professors, 2 Adjunct professors, about 10 fulltime research scientists holding Ph.D's, 4 Post Doc.'s and about 25 Ph.D 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 and by industry, and spans from fundamental studies of ideal surfaces to studies of real catalysts to process development work in small pilot plans.

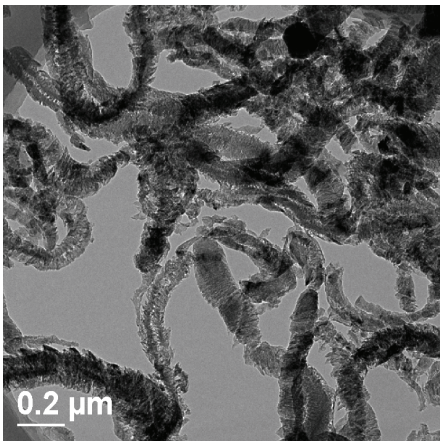
The projects
A more detailed description of the Group as well as further details of all the projects, are given in our Annual Report.

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 Innovation (SFI-inGAP) focusing on the use of natural gas.

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 specalized functional materials is an important industry. Understanding the preparation methods, and developing new techniques is therefore a central research area.This programme deals with new methods to prepare supports and catalysts such as flame spray pyrolysis and spray drying, as well as the preparation and use of structured, mesoporous supports. This work is done in collaboration with the Ugelstad laboratory and SINTEF.

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)

Novel 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 such as partial oxidation and oxidative dehydrogenation. The work on microstructured reactors, where channels micrometer dimensions (1-1000µm) and up-scaling by parallelization is applied to enable new properties/possibilities, is performed in collaboration with Forschungzentrum Karlsruhe 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 environmental 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 syngas adjustment, residual hydrocarbon reforming and Fischer-Tropsch synthesis.

In the EU project "GreenSyngas" the Catalysis group works on reducing the methane and tar contents in the syngas from the gasifier in Güssing (Austria) where woodchips is the raw material.

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. Photocatalysis is also introduced as an important topic in the group.

Catalysis Group

1st row: Navaneethan, Hassan Jamil, Li, Xuyen Kim, Estelle, Sara, Fatemeh, Oana, Tayyaba, Saima, Charitha, Nicla, Hilde
2nd row: Karin, Ingvild, Paul, Fan, Daham, Shreyas, Anna, Nina, Camilla, Merete, De, Ingvar, Rune, Tiejun, Hongmin.
3rd row: Alexey, Asmira, Ilya, Svatopluk, Miroslav, Torbjørn, Magnus, Anders, Edd, Hamidreza, Eleni, Nikolas, Rune, Håkon, Asbjørn, Espen.

OLLOID- AND POLYMER CHEMISTRY GROUP (UGELSTAD LABORATORY)

Academic staff
Professor Johan Sjöblom
Professor Gisle Øye
Associate professor Wilhelm R. Glomm
Professor emeritus Arvid Berge
Professor emeritus Preben C. Mørk
Professor II emeritus Per Stenius

Scientists
Sebastien Simon
Brian Grimes
Cédric M. Lesaint
Kristofer Paso
Bartlomiej Gawel (from 01.03.09)

Post Docs.
Yanru Fan (until 20.11.09)
Sondre Volden

Phd candidates
Asal Amiri
Umer Farooq
Serkan Keleşoĝlu
Erland Nordgård (Post Doc.. from 25.09.09)
Agnethe Knudsen (until 29.07.09)
Nils van der Tuuk Opedal
Klodian Xhanari
Andreas Lyng Nenningsland (from 17.08.09)
Mehdi Benmekhbi (from 28.09.09)
Sina Maria Lystvet (from 23.03.09)

Technical staff
Signe Håkonsen
Caterina Lesaint
Iva Králová
Camilla I. Dagsgård (from 01.04.09)
May Grete Sætran

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 Ph.D. 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 2009 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/

Improved Oil recovery by Low Salinity Waterflooding: Surface Chemistry and SCAL Studies (VISTA 2007 – 2010)
The project focuses on how the surface chemistry of reservoir surfaces can contribute to improved oil recovery by low salinity waterflooding. An important goal is to understand the interaction mechanisms between the solid surfaces and surface active components in crude oils as the extension of the electrical double layer varies. This project is a collaboration together with the Department of Petroleum Technology and Applied Geophysics.

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). Fluid characterization is a central tool to describe complex fluids within the three thematic topics and a necessary input to hydrodynamic modeling.

We will use existing laboratories to perform both small-scale and high-pressure, large-scale flow experiments in pipes and separators. These experiments will be

accompanied by multidimensional model development and their verification.

Collaborative effort between NTNU, SINTEF, IFE and UiO.

An Integrated Approach to Interfacial/Surface Processes in Crude Oil Systems (NFR PETROMAKS)
In crude oil production and processing heterogeneous systems play an important role in the whole value chain, starting from oil recovery from the reservoir and ending with crude oil refining in the refineries. A rational definition of heterogeneous systems is systems with either interfaces or surfaces or both. A brief survey of such systems and processes reveal wettability of the mineral surfaces in the reservoir as extremely important in the recovery of oil, chemical composition of the interface between water and oil as important for the separation process (and droplet-droplet coalescence) with consequences for both oil and waste water quality, corrosion inhibition of steel surfaces to prevent corrosion to deteriorate pipelines and the contamination of solid surfaces to poison catalysts. A general problem including most of the sub-processes in the exploitation of crude oil is a proper lack of instrumentation and competence to undertake a proper characterization of surface structures and concentrations in order to improve the understanding of oil recovery and especially enhanced oil recovery, separation technology and maintenance of pipeline integrity and transport.

Nanosized cellulose fibrils as stabilizers of emulsions
The project is collaboration with the Paper and Fibre Institute (PFI) and focuses on using MFC as stabilisers in emulsions.

Development of nanostructured microreactor-based reaction technologies for continuous in situ production of food and drug intermediates from renewable resources. Case studies of synthesis of gluconic acid and enantiopure components of natural flavors (Polish-Norwegian Research Fund) 2008-2010
The project aims at developing novel family of high performance technologies for the in situ production of valuable chemicals – natural intermediates for food and pharmaceuticals synthesized from renewable resources, e.g. cellulose materials. The development of effective, high throughput technologies for in situ (local) production of valuable chemical intermediates from renewable resources is one of the top priorities of EU for sustainable development.

Thermoresponsive Polymer Brushes on Nanoparticles and Surfaces (NFR FRINAT 2007-2010)
An interesting category of amphiphilic polymer systems are those who undergo phase transitions in response to environmental stimuli such as temperature and pH. These have been widely investigated for drug delivery, separations and diagnostics applications. The aim of this project is to develop an understanding - both mechanistic and applied - of different thermo-responsive polymers adsorbed to planar surfaces and particle substrates. Changes in structural and dynamic properties of the systems under various conditions will be examined.

This project is a collaborative effort between the Ugelstad laboratory and Dept. of Chemistry, UiO, with several international partners.

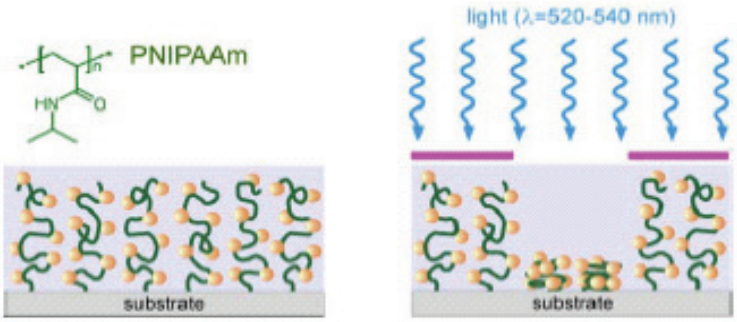


Figure 1: Schematic illustration of the "T-jump" modulated conformational transitions in surface-anchored PNIPAAm brushes. Gold nanoparticles will be loaded inside the brush and will attach to the NIPAAm monomers via H-bonds. Light having a wavelength close to the plasmon band of Au will be used to locally heat the particles, which in turn will cause collapse of the PNIPAAm chains. Through employment of a mask placed between the light course and the polymer, the PNIPAm collapse can be spatially modulate

Colloid- and Polymer Group

First row: *Bicheng, Camilla, Bartlomijei, Kristofer, Umer, Asal, Iva, Signe, Brian, Sondre and Marius*

Second row: *Sebastien, Kalle, Andreas, Cédric, Nils Gisle, May Grete, Sina, Erland, Wilhelm and Johan*

PROCESS SYSTEMS ENGINEERING GROUP

Academic staff
Professor Sigurd Skogestad
Professor Heinz A. Preisig
Associate professor Tore Haug-Warberg
Associate professor Nadav Skjøndal-Bar
Professor emeritus Terje Hertzberg

Post Docs.
Mohammad Samsuzzoha

PhD candidates
Andreas Linhart (until 02.10.09)
Deeptanshu Dwivedi (from 12.01.09)
Elvira M.B. Aske (until 27.03.09)
Esmaeil Jahanshahi (from 02.06.09)
Henrik Manum
Håkon Dahl-Olsen
Ivan Dones
Jens Petter Strandberg
Johannes Jäschke
Jørgen Skancke
Magnus Glosli Jacobsen
Maryam Ghadrdan
Mehdi Panahi
Olaf Trygve Berglihn
Ramprasad Yelchuru

Guests
Nitin Kaistha, (Visiting profesor from Indian Institute of Technology, Kampur, India) 05.06-21.07.09
Daniel Hernandez, (Researcher from University of Zaragoza, Spain) 15.03-27.6.09
Ronald Abbas, (PhD student from University of Witswaterrand, Johannesburg, South Africa 15.03-08.06.09
Weiwei Qiu (PhD student from Petroleum University of China, Beijing. From 13.10.09)

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 multi-scale process modelling, 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. At present, the main activities in the group are within process control and process modelling including efficient thermodynamic calculations. A new interdisciplinary branch focusing on systems biology is currently being initiated (Nadav Skjøndal-Bar) enriching the NTNU biology effort with a systems component.

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.

Modelling Behaviours:
The centre piece of process systems engineering is the model. Modelling is 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. 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 is presently being developed (Heinz Preisig), which we aim to apply to large-scale plants, including the Mongstad refinery. It 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).

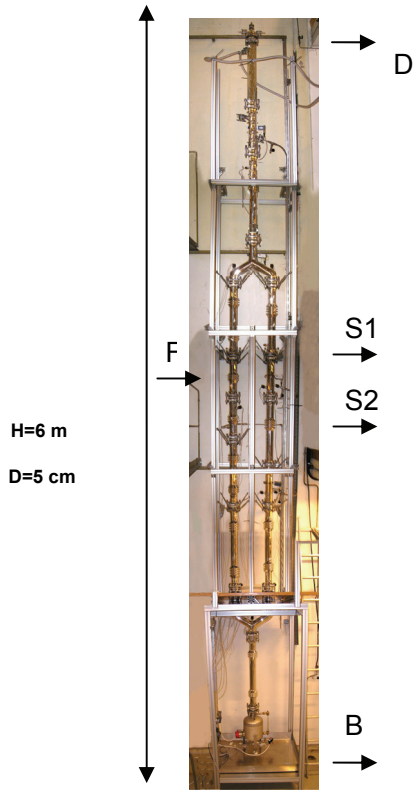
The thermodynamic models are implemented in symbolic form with automatic differentiation capabilities and serves as the basis of several industrial strength simulations (YASIM, CADAS) and energy accounting tools (HERE) in co-operation with StatoilHydro and Yara. A primary aspect of thermodynamic (and 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 Tore Haug-Warberg 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 had a strong focus on statistical methods and experimental design (Hertzberg). Although Terje retired as professor in 2007, he is still active in this area, and in particular, in teaching.

Equipment:
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. The group also has an automatic drink mixer, which is used for demonstration purposes and to study sequence control based on automata theory (Heinz Preisig).

Funding Resources:
Funding comes from the Norwegian Research Council, the Gas Technology Centre at NTNU and SINTEF, from industry (StatoilHydro, Gassco) and from the EU (ProMatch program).



Kaibel Distillation column.

PROCESS SYSTEMS ENGINEERING GROUP

Getting ready to move back to building K4.

From left: Esmaeil, Ramprasad, Nadi, Heinz, Sigurd, Håkon, Weiwei, Robert, Magnus, Martin, Maryam, Tore, Johannes, Dag-Erik, Mehdi, Elisabeth, Jørgen, Shams, Filip, Deeptanshu, Ivar

ENVIRONMENTAL ENGINEERING AND REACTOR TECHNOLOGY GROUP

Academic staff
Professor Hallvard Svendsen
Professor May-Britt Hägg
Professor Hugo A. Jakobsen
Professor Magne Hillestad
Associate professor Jens-Petter Andreassen
Adjunct professor Didrik Malthe-Sørenssen
Adjunct professor Jon Samseth
Professor emeritus Olav Erga
Professor emeritus Gunnar Thorsen

Scientists
Qiang Yu
Taek-Joong Kim
Tom-Nils Nilsen

Post Docs.
Ameeya Kumar Nayak
Arshad Hussain
Geir Watterud (until 31.05.09)
Hélène Lepaumier (from 20.04.09)
Jon Arvid Lie
Jorge Mario Marchetti
Yuefa Wang

PhD candidates
Ahmad Rafiee
Ali Zakeri
Anastasia Trollebø (from 17.08.09)
Ardi Hartono (postdoc from 01.07.09)
Arlinda Çiftja (from 01.03.09)
Eddie Setekleiv
Ellen M. Flaten
Erik Troøien Hessen
Federico Sporleder
Hamid Mehdizadeh (from 13.07.09)
Hanna Knuutila (until 31.03.09)
Hans Kristian Rusten
Inger Lise Alsvik
Ingvild Eide-Haugmo
Inna Kim (until 31.01.09)
Jamil Ahmad
Jannike Solsvik (from 17.08.09)
Kalim Deshmukh
Kando Kalifa Janga
Kumar Ranjan Rout
Lijuan Wang (from 26.10.09)
Liyuan Deng (postdoc from 01.11.09)
Luciano Patruno
Marius Sandru (postdoc from 01.11.09)
Martin Votrubec (until 13.11.09)
Mehdi Karimi
Mohammad Washim Uddin
Pablo Dupuy
Paris Klimantos (from 01.10.09)
Peter Bruder
Ralf Beck (researcher from 13.12.09)
Rune Engeskaug
Silje Kufaas Tellefsen (until 30.07.09)
Solrun Johanne Vevelstad (from 11.05.09)
Tom Dagstad
Tone Borge
Ugochukwu Edwin Aronu
Xiao Luo
Xuezhong He
Zhengjie Zhu (until 31.03.09)
Zhongxi Chao
Zsolt Borka (from 14.09.09)

Technical staff
Andrea Asunción Mingot
Øystein Jonassen (from 05.10.09)

Guests
Feng Qin (PhD student from Tsinghua University, China)

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. The group is heavily involved in research projects for the capture of CO_2, like in the BIGCCS – International CCS Research Centre which is one of eight centres established by the Norwegian Research Council 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. In 2009 the members of the environmental and reactor technology group got involved in topics like separation of CO_2 with polymer 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.

Group trip to nearby ski resort Oppdal with about two thirds of the group members.

Back from left :Rafael, Hallvard, Tom-Gøran, Ugo, Zsolt, Qiang, Xuezhong, Inger-Lise, Pablo, Lijuan, Ralf, Magne, Eddie,Tom-Nils, Hélène, Ingvild, Dick and Yuefa.
In the middle: Anastasia, Ameeya, Jorge, Kando, Kumar, Hugo, Marius, Teak-Joong, Ali, May-Britt, Arlinda, Solrun, Ahmad
Sitting in front: Hamid, Peter, Washim, Liyuan and Jannike

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, and heat- and mass transfer phenomena 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 and we have a large range of well instrumented cold flow multi-phase reactors, as well as in-house software for multi-phase reactor simulations.

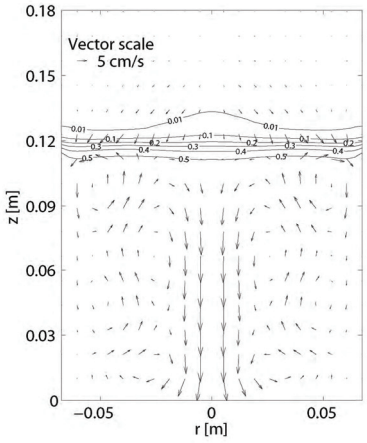
We are active users of Matlab, however, the computationally demanding models are implemented in FORTRAN 90 and C++. Application areas are special chemicals reactors, polymer production, sorption enhanced steam methane reforming, conventional synthesis gas and methanol synthesis, membrane reactors, wood gasification and chemical looping combustion.

A stirred tank used for studies of heat transfer and flow phenomena.

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.

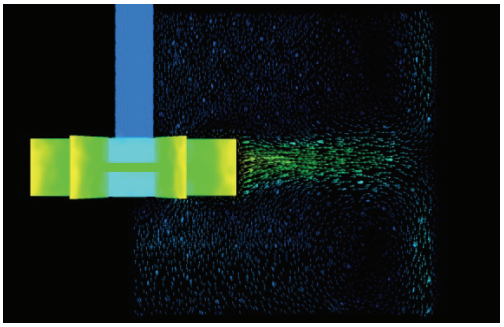
Research activities
The most important research projects are described in the following paragraphs. For a more comprehensive description, see our home pages: (http://www.chemeng.ntnu.no/research/reactmod/).

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.
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.



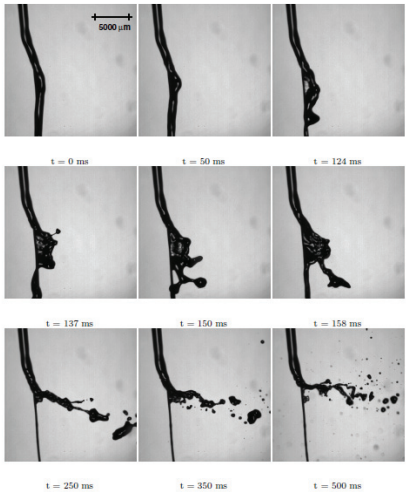
Simulation of the flow pattern from a turbine impeller.

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.

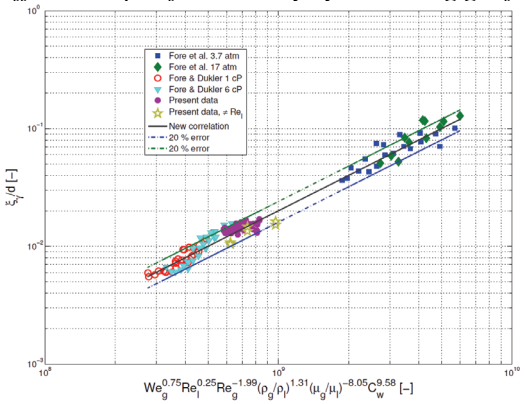
Advanced Modeling and Simulation of Chemical Reactors
The activity in this area is mainly founded by the Norwegian Research Council through the GassMaks program. The work in this project is focused on modeling of chemical reactors like stirred tanks, fixed packed bed-, bubble column-, and fluidized bed 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 and now HiPGLS 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 StatoilHydro research center. 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.



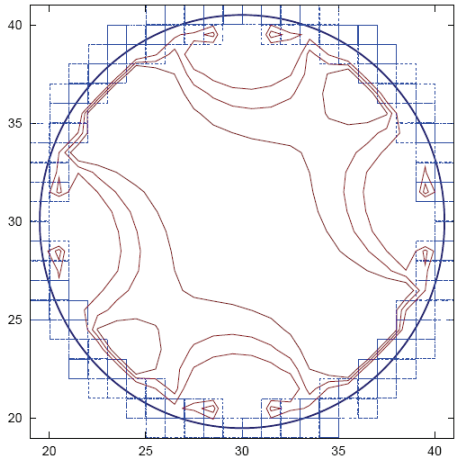
Effect on liquid film stability by increasing gas flow



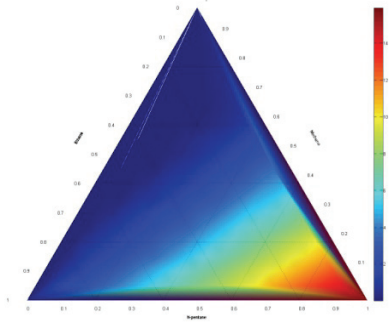
A new correlation for estimating entrained droplet size

A new and more general correlation for predicting droplet size distributions, valid for several geometries has been developed.

In ther 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. 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. A case of a stationary droplet is show in next figure:



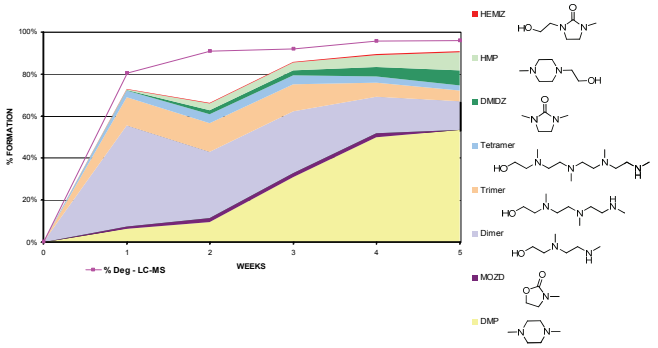
Modelling of droplet interface.



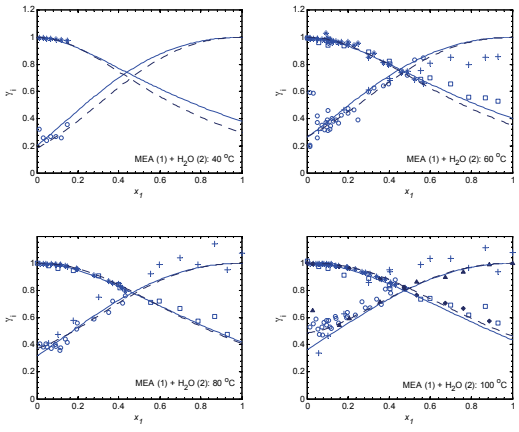
Ternary interfacial tensions diagram of methane + ethane + n-pentane

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. One of the most fundamental problems facing the earth today is global warming. The emissions of CO_2, the most important greenhouse gas 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 the EU FP6 projects, e.g CASTOR and CAPRICE. This work continues in the EU FP7 CESAR project, and recently as coordinator of the EU FP7 iCap project. This work involves all the steps from theoretical screening by use of computational chemistry, through experimental screening, testing of environmental properties, characterization of equilibria, thermal properties, transport properties and kinetics, degradation and mechanisms, to testing in laboratory pilot plants.



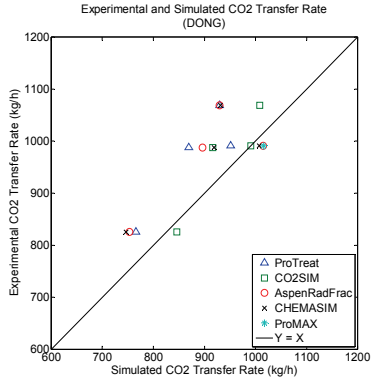
Degradation products and mass balance for MEA



Measured and modelled activity coefficients

In parallel we develop rigorous thermodynamic models, based on electrolyte NRTL and extended UNIQUAC model frameworks. Improved models for combined mass and heat transfer are also under development.

In addition we have developed a full rate based simulator for the whole absorption/desorption process, CO2SIM



Experimental and simulated mass transfer(Esbjerg, CAPRICE)

The largest project on CO_2 capture is SOLVit, a JIP with Aker Clean Carbon (ACC). Other projects in this area are EU FP6 ULCOS, 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.

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.

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

Membrane Research

Membranes for gas separation and osmotic processes

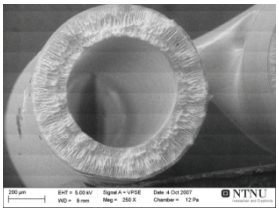
(more information about the Memfo (Membrane Research) activities is found on the groups website: www.chemeng.ntnu.no/memfo)

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, Japan, the Nordic countries and Russia.

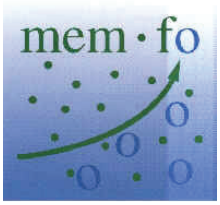
Brief description of sample gas separation projects

a) EU FP6 project NaturalHy (www.naturalhy.net)
The project involves about 40 partners, and the main idea is to investigate the possibility of using the European gas network for co-transport of hydrogen with natural gas. Realising that the society only slowly will convert to hydrogen based energy, the idea is that hydrogen may be injected into the gas net at various places where it is produced, and then separated from the natural gas at points along the line where pure hydrogen is needed (e.g. for fuel cells). The task into which Memfo is doing research, is development of a suitable membrane for hydrogen recovery. Carbon molecular sieve membranes are investigated for this purpose. One post doc is engaged in the research, and very promising results have been documented. The project continues for 1 more year. The project co-ordinator is Gasunie in the Netherlands.
The project was completed in 2009 with good results

b) KMB RENERGI / NFR project CEPEME
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 has been achieved during the last couple of years, 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. The membrane is patented, and there are big expectations for the further development; for CO_2 capture from coal fired or gas fired power plants as well as other CO_2 containing gas streams. The project ended in 2008. Preparation for small scale pilot scale testing is now being done. One research scientist and one PhD student have been working on the project. A focus on process development has also been initiated. Project partners have been NFR, AlstomPower and Statoil. The project is followed up in 2010 with funding from Gassnova and Statoil, following up the promising results with a pilot project for scale up of the membrane process. There is also interest from industry on other applications where CO_2 is present in the gas stream (natural gas sweetening, CO_2 removal from anaesthetic gas...)



SEM-picture showing a membrane. DO-DI: 1 -0.6 mm cut through a hollow fibre



Memfo = Membrane Forskning (Membrane Research)

Bundle of hollow fibre membranes in an industrial module–packing densities can be up to 30 000 m^2/m^3

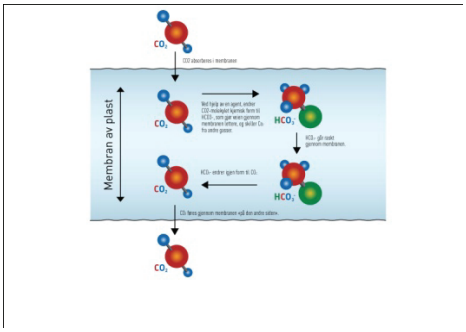


Illustration of the mechanism in the patented CO_2 facilitated transport membrane

c) EU FP6 project NanoGloWa (www.nanoglowa.com)
The project started November 2006 and is focusing on "Nano-structured membranes against Global Warming" (NanoGloWa). Memfo is a major partner in the project; task leader for two work packages focusing on development of carbon membranes and polymeric materials for CO_2 capture from power plants. The project also includes spinning of hollow fibres, module development and durability tests. One Post Doc.. and one PhD student were attached to the project in 2008. The project coordinbator is KEMA in The Netherlands.

d) 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 are being tailored for this separation. The project also includes module development and durability tests. The project coordinator is SINTEF Energy

e) KMB GASSMAKS / NFR project RECCO2
The project started late 2007. 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 the performance at high pressures (→100 bar). Special restrictions for HMS is needed in this operating range. Industrial partner is Statoil.

Brief description of a sample liquid separation project

f) 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 ptimisation of the support membrane as well as the thin film membrane itself. Two PhD students and one research scientist have been working on the project in 2009

***g)* VARIOUS PROJECTS ON NANOCOMPOSITES**
The group has additionally several smaller research projects focusing on development of hybrid materials; in 2009 three 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.

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 1 at NTNU attached to this project.

There are 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 2 prizes for creativity and innovation in 2009.

Crystallizaton and Particle Design

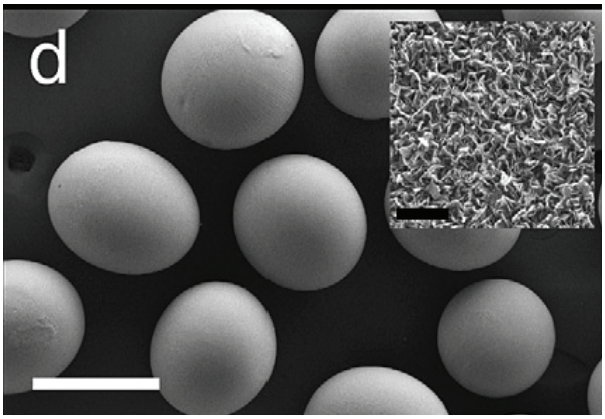
The research within crystallization is focused at kinetics of nucleation, crystal growth, and agglomeration in order to predict and control the particle size distribution and shape of crystalline particulate products for scale prevention, improved solid-liquid separation, CO_2-capture in precipitating 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.

Optimisation of Glycol Loop Design and Operation
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 in the glycol injection point off-shore and the crystallization and separation of salts in the on-shore glycol reclamation units 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). Glycol injection point off-shore and the crystallization and separation of salts in the on-shore glycol reclamation units will be the main research tasks. Studies performed in the crystallization group in 2009 have shown that the 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 was finished in 2009 and will be continuing by studies of surface scaling and bulk precipitation in presence of relevant impurities.

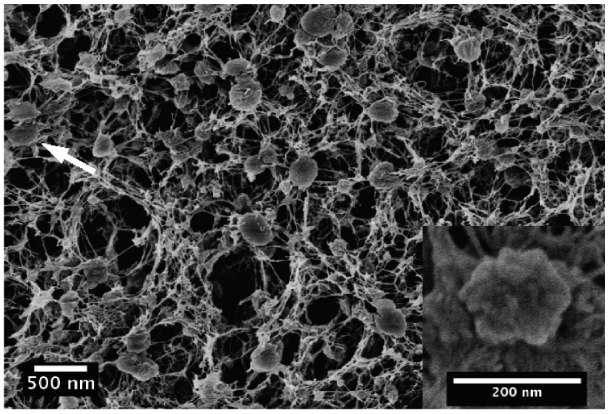
Industrial Crystallization and Powder Technology
The goal of this project is to relate solid/liquid separation characteristics and resulting dry powder flow properties to the underlying growth and agglomeration phenomena. It involves studies of inorganic salts and pharmaceuticals, and the primary target for the activity at NTNU is to link the parameters in the crystallisation process to the subsequent filtration step by focusing on common mechanisms for these selected systems. The project is in collaboration with POSTEC at Tel-Tek and is financed by the Research Council of Norway (NFR) and Norwegian industry partners.

The project finished by the end of 2009. We have identified a general mechanism of crystal growth switching whereby the particle shape is dramatically altered for several systems differing widely in their chemical nature. This is illustrated for the precipitation of sodium glutamate by switching from the well-known needle crystals of β-glutamic acid to spherical particles of the same polymorph. Filtration resistance measurements as well as powder flow properties measured by uniaxial testing has shown that these spherical particles are unwanted, and in some cases the conditions can be met to avoid their formation.

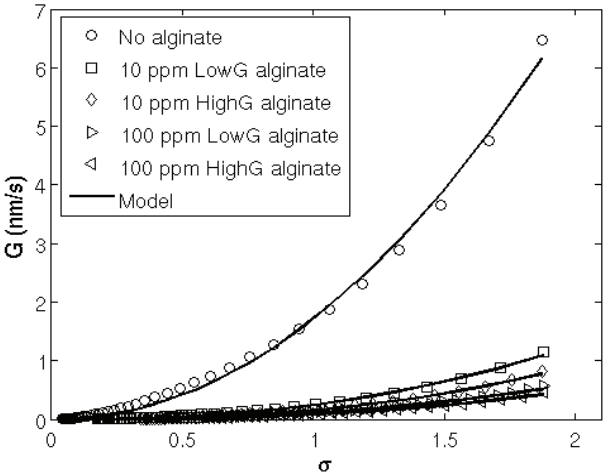
Biomineralization
Structural biocomposites found in nature often have a well-defined organization on the nanometer scale. For mineralized materials, interactions between organic and inorganic phases are important for controlling crystal size, morphology, and spatial arrangement, which is a requirement when structural biomaterials are designed. In a joint project with departme nt 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 careful crystal growth rate studies in presence of different alginate polymers, 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.



Gel beads of alginate mineralized with calcium phosphate, the scale bar is 500 μm. The inset shows nanocrystals on the bead surface, scale bar 300 nm.



Nanoparticles of calcium carbonate distributed within an alginate gel network.



Reduction in growth rates of calcium carbonate in presence of small amounts of different alginates.

BIOREFINERY AND FIBRE TECHNOLOGY GROUP

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Post Doc.s.
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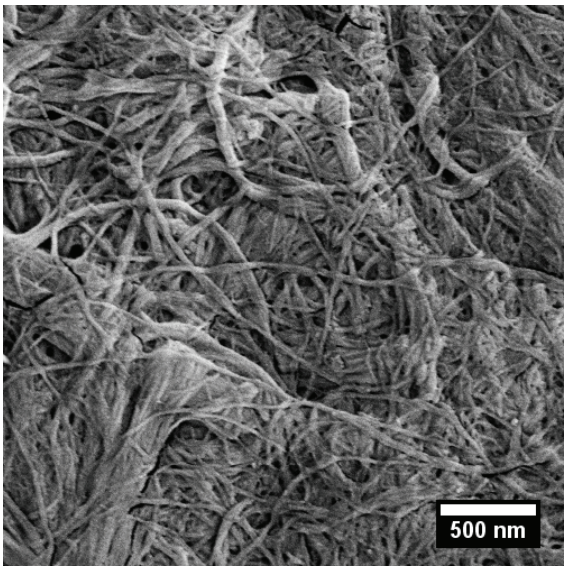
Marco Iotti

PhD candidates
Collin Ching Tyn Hii (from 01.04.09)
Galina Rodionova
Marius Rusu
Mihaela Tanase
Sara Paunonen
Tuan-Anh Nguyen (from 07.08.09)



FE-SEM image of a the surface of a microfibrillar cellulose film produced by homogenization (Syverud et al 2009)

Teaching

The Biorefinery and Fiber Technology group provides chemical engineers and PhDs for the Norwegian pulp and paper industry. The estimated need from the industry is 8-10 engineering graduates and about 2 PhD candidates per year. 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.

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), HUT (Helsinki) 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.

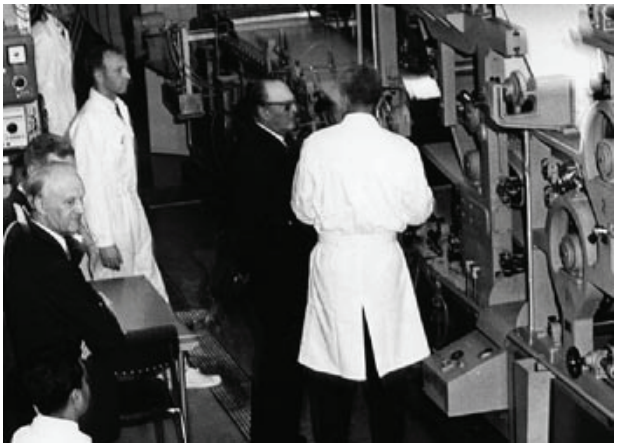
Research

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:

- Pre-treatment and conditions for hydrolysis of wood for bioethanol production
- Production of bioethanol from wood
- Better strength and surface properties of wood-containing paper by use of microfibrillated cellulose as an additive.
- 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.
- Improved runnability of printing paper by use of fracture mechanics as a tool in paper quality optimization.
- 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.
- Energy effective production of mechanical pulp
- Energy effective paper production

Moving the pilot plant

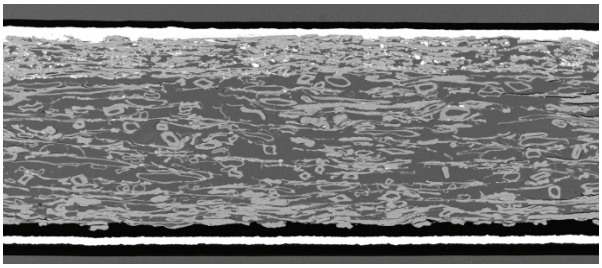
Due to the renovation of chemistry building KIV and the need for laboratories and pilot plants for CO_2 separation research, the pulp and paper pilot plant and paper machine has been removed. Most of the equipment (but not the paper machine) will be installed in the pilot hall of the PFI building during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



The paper machine which was opened by King Olav in 1965 had become technically obsolete and had to yield ground to a new pilot hall for CO_2 separation research.

Trends

The last years a new activity on use of cellulose based particles in composite materials have started. Both better oxygen barrier and mechanical properties may be obtained by using cellulose fibres or fibrils as reinforcement in thermoplastic composites.
Together with PFI a new research activity on the use of wood based biofuel production have also started. The goal is cost effective production of biodiesel and ethanol from wood.
Further, 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.



The mechanical and barrier properties of a paper material depend on the material choice and structure. The SEM image of the cross section of a liquid board shows (from top) a Polyethylene (PE), mineral coating, kraft pulp, CTMP, kraft pulp, PE, Aluminium layer and PE.

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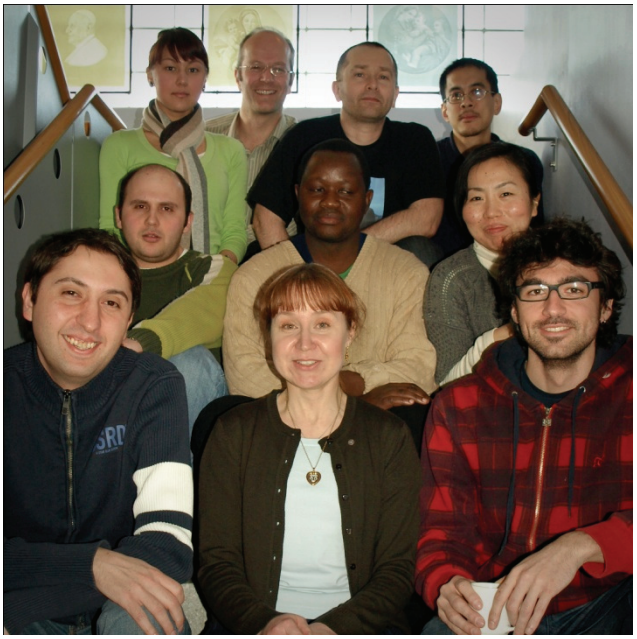

First row: Marius, Sara and Marco
Second row: Klodian, Kando and Asuka
Third row: Galina, Øyvind, Størker and Collin

CHAPTER 3: PUBLICATIONS

PUBLICATIONS IN REFEREED JOURNALS

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75. **Lind, Anna Maria; Holmen, Anders; Eri, Sigrid; Skagseth, Torild Hulsund; Rytter, Erling.**
Spray drying of porous alumina support for Fischer-Tropsch catalysis. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

76. **Lualdi, Matteo; Lögdberg, Sara; Järås, Sven; Holmen, Anders.**
Direct use of H2-poor syngas in the Fischer-Tropsch synthesis. 21st North American Catalysis Society Meeting; 2009-06-07 - 2009-06-12

77. **Lystvet, Sina Maria.**
Interactions between BSA-gold nanoparticle constructs and a phospholipid monolayer. The French-Norwegian Interdisciplinary Symposium on Nano and Micro Frontiers in Biology and Medicine; 2009-08-31 - 2009-09-02

78. **Lystvet, Sina Maria; Volden, Sondre; Halskau, Øyvind; Glomm, Wilhelm.**
Interactions between BSA-gold nanoparticle constructs and a phospholipid monolayer. Nano and Micro Frontiers in Biology and Medicine; 2009-08-31 - 2009-09-02

79. **Manenti, Flavio; Buzzi-Ferraris, Guido; Dones, Ivan; Preisig, Heinz A..**
Generalized class for nonlinear model predictive control based on BzzMath library. ICheaP-9; 2009-05-10 - 2009-05-13

80. **Marchetti, Jorge Mario.**
INTERACCION DE METALES E HIDROGENO CON UN CLUSTER DE FeTiFe. Tercer Congreso nacional - Segundo Congreso Iberoamericano de Hidrógeno y Fuentes Sustentables de Energia - HYFUSEN 2009; 2009-06-08 - 2009-06-12

81. **Marchetti, Jorge Mario.**
Past, Present and Future Scopes in Biodiesel Industry. World Congress on Science, Engineering and Technology - WCSET 2009; 2009-07-29 - 2009-07-31

82. **Marchetti, Jorge Mario; González, E.; Jasen, P.; Brizuela, G. P.; Juan, A..**
Interaction of Pt and H with a (110) and a (111) FeTiFe Cluster. 94° REUNIÓN NACIONAL FE FISICA; 2009-09-14 - 2009-09-18

83. **Marchetti, Jorge Mario; Jakobsen, Hugo Atle; Svendsen, Hallvard Fjøsne.**
Study of Multi-Breakage of Liquid Droplets with An Ideal Mesh Pad. 2009 AIChE Annual Meeting; 2009-11-08 - 2009-11-13

84. **Marchetti, Jorge Mario; Patruno, Luciano E; Jakobsen, Hugo Atle; Svendsen, Hallvard Fjøsne.**
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85. **Marchetti, Jorge Mario; Patruno, Luciano E; Jakobsen, Hugo Atle; Svendsen, Hallvard Fjøsne.**
Mathematical framework for higher order breakage scenarios. 1st Trondheim Gas Technology Conference; 2009-10-21 - 2009-10-22

86. **Marchetti, Jorge Mario; Tonetto, Gabriela M.**
Biodiesel Production From Esterification and Transesterification Reactions Using Homogeneous as Well as Heterogeneous Catalysts. 2009 AIChE Annual Meeting; 2009-11-08 - 2009-11-13

87. **Matam, Santhosh Kumar; Hammer, Nina; Rønning, Magnus; Holmen, Anders; Chen, De; Walmsley, John C; Øye, Gisle.**
The nature of active Cr species in Cr-catayst for dehydrogenation of propane: Neew insights by a comprehensive spectoscopi study. EuropaCar IX : Catalysis for a Sustainable Wold; 2009-08-30 - 2009-09-04

88. **Mejdell, Astrid Lervik; Peters, Thijs A.; Bredesen, Rune; Chen, De; Venvik, Hilde Johnsen.**
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89. **Mihai, Oana; Chen, De; Holmen, Anders.**
Comparative study regarding preparation methods of perovskite-type oxides $LaFeO_3$ catalysts for methane partial oxidation. inGAP-NANOCAT Summer School; 2009-06-21 - 2009-06-26

90. **Mihai, Oana; Chen, De; Holmen, Anders.**
Synthesis of perovskites using carbon nanotubes as templates and their applications in methane partial oxidation. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

91. **Muthuswamy, Navaneethan; Ochal, Piotr; Gomez, Jose Luis de la Fuente; Tsypkin, Mikhail; Rønning, Magnus; Sunde, Svein; Chen, De.**
Electro-oxidation of CO and methanol on Ru-Pt core-shell nanoparticles supported on carbon materials. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

92. **Myrstad, Rune; Eri, Sigrid; Pfeifer, Peter; Rytter, Erling; Holmen, Anders.**
Fischer-Tropsch synthesis in a microstructured reactor. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

93. **Noor, Tayyaba; Lind, Anna Maria; Holmen, Anders; Chen, De.**
Synthesis and characterization of Ni hydrotelcite catalyst for hydrogen production using co-prcipitation, spray drying, microemulsion method. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

94. **Nordgård, Erland; Landsem, Eva; Sjøblom, Johan.**
Model compoounds for indigenous crude oil components. Synthesis, characterization and comparison. Organisk kjemisk vintermøte 2009; 2009-01-08 - 2009-01-11

95. **Olderøy, Magnus Østgård; Xie, Minli; Østnæs, Simen; Andreassen, Jens-Petter; Strand, Berit Løkensgard; Sikorski, Pawel.**
Alginate/CaCO3 Biomaterials. Bone-Tec 2009; 2009-10-08 - 2009-10-11

96. **Panahi, Mehdi; Skogestad, Sigurd.**
Self-optimizing Control of a GTL Process. 1st Trondheim Gas Technology Conference; 2009-10-22

97. **Patanou, Eleni; Chen, De; Blekkan, Edd Anders.**
Microcalorimetry and mikrokinetic modelling of catalytic reactions. InGap –Nanocat Summerschool in Heterogeneous catalysis: Nano designed catalysts: from molecules to industrial processes; 2009-06-21 - 2009-06-26

98. **Patruno, Luciano E; Dorao, Carlos Alberto; Jakobsen, Hugo Atle; Svendsen, Hallvard Fjøsne.**
Statistical modelling of mist flows. OMAE09 – International Conference on Ocean, Offshore and Arctic Engineering; 2009-05-31 - 2009-06-05

99. **Patruno, Luciano E; Dupuy, Pablo Matias; Dorao, Carlos Alberto; Svendsen, Hallvard Fjøsne; Jakobsen, Hugo Atle.**
A Regularization Method for Recovering a Breakage Rate Function Model using Bounded Data Uncertainties. 1st Trondheim Gas Technology Conference; 2009-10-21 - 2009-10-22

100. **Patruno, Luciano E; Marchetti, Jorge Mario; Dorao, Carlos Alberto; Jakobsen, Hugo Atle; Svendsen, Hallvard Fjøsne.**
Droplet Size Distribution after Liquid Entrainment in Horizontal Stratified Two-Phase Three-Field Dispersed Flow. 1st Trondheim Gas Technology Conference (TGTC-1); 2009-10-21 - 2009-10-22

101. **Patruno, Luciano E; Marchetti, Jorge Mario; Dorao, Carlos Alberto; Svendsen, Hallvard Fjøsne; Jakobsen, Hugo Atle.**
Modelling of Droplet Entrainment in Annular Two-Fluid Three-Phase Dispersed Flow. 13th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-13); 2009-09-27 - 2009-10-02

102. **Paunonen, Sara Inkeri.**
Strength properties of solid board for transport of fish and vegetables. Nordisk treforeldingssymposium i Trondheim; 2009-10-08 - 2009-10-09

103. **Paunonen, Sara Inkeri; Gregersen, Øyvind Weiby.**
Modeled and measured bending stiffness of polyethylene coated multi-layer paperboard at two moisture contents. 6th International Symposium on Moisture and Creep Effects on Paper, Board and Containers; 2009-07-14

104. **Peters, Thijs A.; Stange, Marit; Venvik, Hilde Johnsen; Bredesen, Rune.**
Properties and application of supported Pd-23%Ag membranes for H2 production and separation. Hydrogen and Fuel Cells in the Nordic Countries - 2009; 2009-11-24 - 2009-11-26

105. **Phan, Xuyen Kim; Myrstad, Rune; Venvik, Hilde Johnsen; Thormann, Janina; Pfeifer, Peter; Holmen, Anders.**
Experimental study of methanol synthesis in a PdCeO2 stacked microchannel reactor. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

106. **Phan, Xuyen Kim; Yang, Jia; Bakhtiary, Hamidreza Davijany; Myrstad, Rune; Venvik, Hilde Johnsen; Holmen, Anders.**
Studies of Macroporous structured Alumina based Cobalt Catalysts. EuropaCat IX : Catalysis for a Sustainable World; 2009-08-30 - 2009-09-04

107. **Preisig, Heinz A..**
Event-Dymanic Assumptions in First-Principle Network Models and Model Reduction. ESCAPE 19; 2009-06-14

108. **Radde, Nicole; Bar, Nadav; Tresch, Achim.**
A comparison of likelihoods for dynamic stochastic models of biological networks. Sixth International Workshop on Computational Systems Biology, WCSB 2009; 2009-06-10 - 2009-06-12

109. **Radstake, Paul Bernard; Håkonsen, Silje Fosse; Rønning, Magnus; Holmen, Anders.**
Oxidative Dehydrogenation of Ethane at Short Contact Times. 3rd International Conference on Structured Catalysts and Reactors; 2009-09-27 - 2009-09-30

110. **Radstake, Paul Bernard; Håkonsen, Silje Fosse; Rønning, Magnus; Holmen, Anders.**
Oxidative dehydrogenation of ethane at short contact times. inGAP-NANOCAT Summer School; 2009-06-21 - 2009-06-26

111. **Rafiee, Ahmad; Hillestad, Magne.**
The Effect of Manufacturing Costs on the profitability of a Gas-to-Liquid Plant. 1st Trondheim Gas Technology Conference; 2009-10-22

112. **Rane, Shreyas Pandurang; Borg, Øyvind; Rytter, Erling; Holmen, Anders.**
Effect on cobalt particle size, alumina and its porosity on hydrocarbon selectivity in Fischer-Tropsch synthesis. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

113. **Rane, Shreyas Pandurang; Tveten, Erik Zakarias; Borg, Øyvind; Rytter, Erling; Holmen, Anders.**
Performance of supported Co catalysts fro Fischer-Tropsch synthesis. 21st North American Catalysis Society Meeting; 2009-06-07 - 2009-06-12

114. **Rodionova, Galina; Gregersen, Øyvind Weiby; Lenes, Marianne; Hult, Eva-Lena.**
Surface chemical modification of microfibrillar cellulose: improvement of barrier properties for packaging applications. EPNOE 2009 - Polysaccharides as a Source of Advanced Materials; 2009-09-21 - 2009-09-23

115. **Rusu, Marius; Liukkonen, Sari; Gregersen, Øyvind Weiby; Sirviö, Jari.**
The influence of fibre wall thickness and microfibril angle on fibre development in the TMP process. 4. International Mechanical Pulpinc Conference; 2009-05-31 - 2009-06-04

116. **Rønning, Magnus.**
Catalyst studies at real working conditions. Seminar at Department of Chemical Engineering, University of Zaragoza; 2009-11-10

117. **Rønning, Magnus.**
Characterisation of catalysts at their working conditions. Nanoduramea Summer School - Synthesis and characterisation of carbon supported platinum and platinum alloy catalysts; 2009-06-08 - 2009-06-09

118. **Rønning, Magnus.**
In situ characterisation techniques for studying catalysts at realistic working conditions. Norwegian Synchrotron User Meeting; 2009-06-18 - 2009-06-19

119. **Rønning, Magnus; Tsakoumis, Nikolaos; Voronov, Alexey; Borg, Øyvind; Rytter, Erling; Holmen, Anders.**
Deactivation studies of Co-Re/γ-Al_2O_3 Fischer-Tropsch catalyst. EuropaCat IX : Catalysis for a Sustainable World; 2009-08-30 - 2009-09-04

120. **Rønning, Magnus; Voronov, Alexey Sergeevich; Tsakoumis, Nikolaos; Borg, Øyvind; Hammer, Nina; Rytter, Erling; Holmen, Anders.**
Complimentary in situ characterisation techniques at realistic working conditions for the Fischer-Tropsch synthesis. 14th International Conference on X-ray Absorption Fine Structure; 2009-07-26 - 2009-07-31

121. **Rønning, Magnus; Voronov, Alexey Sergeevich; Tsakoumis, Nikolaos; Borg, Øyvind; Rytter, Erling; Holmen, Anders.**
Decoupling of the deactivation mechanisms in Co-based Fischer-Tropsch catalysts by a wide range of in situ spectroscopies at realistic working conditions. Operando_III, Third International Congress on Operando Spectroscopy; 2009-04-19 - 2009-04-23

122. **Sporleder, Federico; Dorao, Carlos Alberto; Jakobsen, Hugo Atle.**
Simulation of a reactive flow inside a square cavity. 1st Trondheim Gas Technology Conference; 2009-10-21 - 2009-10-22

123. **Sporleder, Federico; Dorao, Carlos Alberto; Jakobsen, Hugo Atle.**
Simulation of Natural Gas Conversion Processes Using the Least Squares Spectral Element Method. 7th International Conference on "Large-Scale Scientific Computations; 2009-06-04 - 2009-06-08

124. **Svendsen, Hallvard Fjøsne.**
Comparison of Process Simulators and Validation against Post Combustion Capture Pilot Plant Data. Det Norske Veritas; 2009-11-04

125. **Svendsen, Hallvard Fjøsne.**
Kjemi og CO_2-fangst - fra molekyler til fullskala fangstanlegg. Kursdagene ; 2009-01-08 - 2009-01-09

126. **Svendsen, Hallvard Fjøsne.**
Perspectives on new solvents for CO_2 capture. Science & Technology Seminar. Amines for post combustion capture; 2009-05-26

127. **Svendsen, Hallvard Fjøsne; Hagg, May-Britt; Bolland, Olav; Eide-Haugmo, Ingvild.**
Carbon Capture Technologies. Innovation Norway Workshop; 2009-10-07 - 2009-10-08

128. **Svendsen, Hallvard Fjøsne; Hoff, Karl Anders; Dindore, Vishwas Y..**
Membrane contactors in gas purification. Nanomat Seminar; 2009-03-16

129. **Svendsen, Hallvard Fjøsne; Luo, Xiao; Knudsen, J. N.; de Montigny, D.; Sanpasertparnich, T.; Idem, R.; Gelowitz, D.; Notz, R.; Hoch, S.; Hasse, H.; Lemaire, E.; Alix, P.; Tobiesen, Finn Andrew; Juliussen, Olav; Köpcke, M..**
CAPRICE: Pilot Plant Data Validation. European Conference on CCS Research Development and Demonstration; 2009-02-10 - 2009-02-11

130. **Svendsen, Hallvard Fjøsne; Røkke, Nils A. Bekken, Sven.**
Norwegian CO_2 Capture Research activities. Innovation Norway; 2009-10-09

131. **Tanase, Mihaela; Stenius, Per Johan; Johansson, Lars; Hill, Jan; Sandberg, Christer.**
Mass balance of extractives around impressafiner in mill and pilot scale. International Mechanical Pulping Conference; 2009-05-31 - 2009-06-04

132. **Tsakoumis, Nikolaos; Borg, Øyvind; Rønning, Magnus; Rytter, Erling; Holmen, Anders.**
Fischer-tropsch synthesis: in situ XRD study throughout reactions start-up. InGap –Nanocat Summerschool in Heterogeneous catalysis: Nano designed catalysts: from molecules to industrial processes; 2009-06-21 - 2009-06-26

133. **Tsakoumis, Nikolaos; Voronov, Alexey Sergeevich; Borg, Øyvind; Rønning, Magnus; Rytter, Erling; Holmen, Anders.**
Deactivation studies on Re promoted Co/γ-Al_2O_3 catalysts for Fischer-Tropsch synthesis. 11th International Symposium on Catalyst Deactivation; 2009-10-25 - 2009-10-28

134. **Tsakoumis, Nikolaos; Voronov, Alexey Sergeevich; Rønning, Magnus; Borg, Øyvind; Rytter, Erling; Holmen, Anders.**
Insights into catalyst deactivation phenomena in Co-based Fischer-Tropsch. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

135. **Uddin, Mohammad Washim; Hagg, May-Britt.**
Durability of CO_2-selective polymeric membrane. 11th Network Young Membrains 2009 (NYM2009); 2009-09-03

136. **Uddin, Mohammad Washim; Kim, Taek Joong; Hagg, May-Britt.**
Durability of PVA/PVAM Blend Membrane in Natural Gas Sweetening. 1st Trondheim Gas Technology Conference; 2009-10-21 - 2009-10-22

137. **Vanhaecke, Estelle Marie M.; Chen, De; Huang, Fan.**
Nanostructured materials based on carbon nanostructures: candidate for solar cells. Opdal Workshop on PV Materials; 2009-03-19 - 2009-03-21

138. **Vanhaecke, Estelle Marie M.; Huang, Fan; Chen, De; Rønning, Magnus.**
Aligned carbon nanotubes array, synthesis and applications in composite design for new energy and energy storage. EuroNanoForum; 2009-06-02 - 2009-06-05

139. **Vanhaecke, Estelle Marie M.; Huang, Fan; Chen, De; Rønning, Magnus.**
Carbon nanostructures synthesis on foils. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

140. **Vanhaecke, Estelle Marie M.; Huang, Fan; Chen, De; Rønning, Magnus.**
Carbon nanotubes Synthesis Composite on Foils. Shinschu University seminar; 2009-03-12

141. **Volden, Sondre; Zhu, Kaizheng; Nyström, Bo; Glomm, Wilhelm.**
Preventing Adsorption of Immunoglobulin G on Polymer Surfaces. Nano and Micro Frontiers in Biology and Medicine; 2009-08-31 - 2009-09-02

142. **Voronov, Alexey Sergeevich; Tsakoumis, Nikolaos; Borg, Øyvind; Rytter, Erling; Holmen, Anders; Rønning, Magnus.**
Deactivation studies in Co-based Fischer-Tropsch catalysts. Norwegian Symposium on catalysis; 2009-11-30 - 2009-12-01

143. **Voronov, Alexey Sergeevich; Tsakoumis, Nikolaos; Borg, Øyvind; Rytter, Erling; Holmen, Anders; Rønning, Magnus.**
Deactivation studies of Co-based Fischer-Tropsch catalysts by in situ spectroscopies at realistic working conditions. 11th International Symposium on Catalyst Deactivation; 2009-10-25 - 2009-10-28

144. **Wang, Hongmin; Dam, Anh Hoang; Blaylock, Wayne; Ggura, Tappei; Zhu, Yian; Holmen, Anders; Greeen, William H..**
Kinetic study of methane steam reforming over hydrotalcite-based Ni catalyst modified by different metals. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

145. **Wang, Hongmin; Holmen, Anders; Chen, De.**
Optimum design and operation of a hydrogen generation by natural gas autothermal reforming system. 1st Trondheim Gas Technology Conference; 2009-10-21 - 2009-10-22

146. **Wang, Yuefa; Chao, Zhongxi; Jakobsen, Hugo Atle.**
SE-SMR Process Performance in CFB Reactors: Simulation of the CO_2 Adsorption/Desorption Process with CaO Based Sorbents. The 5th Trondheim Conference on CO_2 Capture, Transport and Storage; 2009-06-16 - 2009-06-17

147. **Wang, Yuefa; Chao, Zhongxi; Jakobsen, Hugo Atle.**
3D Simulation of Bubbling Fluidized Bed Reactors for Sorption Enhanced Steam Methane Reforming Process. 1st Trondheim Gas Technology Conference; 2009-10-21 - 2009-10-22

148. **Wangen, Espen Standal; Malik, Azhar; Pagels, Joakim; Lindskog, Magnus; Sanati, Mehri; Blekkan, Edd Anders.**
On the steam reforming of producer gas for the production of clean bio-syngas. Norwegian Symposium on Catalysis; 2009-11-30

149. **Wangen, Espen Standal; Trehjørningen, Kristin Rem; He, Li; Chen, De; Blekkan, Edd Anders.**
Reforming raw synthesis gas from wood gasification. 21st North American Catalysis Society Meeting; 2009-06-07 - 2009-06-12

150. **Watterud, Geir; Seiersten, M.; Andreassen, Jens-Petter.**
Iron Carbonate in MEG/Water mixtures. Solubility, thermodynamic and kinetic measurements. The 20th international Oil Field Chemistry Symposium; 2009-03-22 - 2009-03-25

151. Xie, Minli; Olderøy, Magnus Østgård; Strand, Berit Løkensgard; Andreassen, Jens-Petter; Sikorski, Pawel.
Alginate/CaCO3 Composite Biomaterials. Nanolab Usermeeting 2009; 2009-05-12 - 2009-05-14

152. **Xie, Minli; Olderøy, Magnus Østgård; Strand, Berit Løkensgard; Andreassen, Jens-Petter; Sikorski, Pawel.**
Alginate/CaCO3 Composite Biomaterials. NANOMAT conference 2009; 2009-06-16 - 2009-06-17

153. **Yang, Jia; Tveten, Erik Zakarias; Borg, Øyvind; Rytter, Erling; Holmen, Anders.**
Effect of Support on the Intrinsic Activity and Selectivity for Co-based Fischer-Tropsch Catalysts. EuropaCat IX : Catalysis for a Sustainable World; 2009-08-30 - 2009-09-04

154. **Yu, Qiang.**
Ceramic Tube Supported Carbon Membranes Designed for the Separation CO_2 from Pre-combustion Gases. Network Young Membranes (NYM2009); 2009-09-03 - 2009-09-04

155. **Zakeri, Ali; Øi, Lars Erik; Einbu, Aslak; Svendsen, Hallvard Fjøsne.**
Validation of CO2 capture (VOOC project), experiments in a 0.5 m diameter absorption column. Trondheim CCS Conference; 2009-06-16 - 2009-06-17

156. **Zhao, Tiejun; Boullosa, Eiras Sara; Yu, Yingda; Yu, Xiaofeng; Raaen, Steinar; Rønning, Magnus; Chen, De; Holmen, Anders.**
Synthesis and catalytic performance of high-temperature stable nanocomposites by a versatile nanoparticle-mediated Pechini method. Europcat IX; 2009-08-30 - 2009-09-04

157. **Zhao, Tiejun; Yu, Yingda; Chen, De; Rønning, Magnus.**
Carbon nanofiber/carbon felt supported Cu-CeO2 catalyst: a promising structured catalyst for preferantial oxidation of CO in H2-rich gases. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

158. **Zhao, Tiejun; Yu, Yingda; Yu, Xiaofeng; Raaen, Steinar; Chen, De; Rønning, Magnus.**
Preferential oxidation of CO in H2-rich gases over the Pechini-method- derived Cu-CeO_2 nanocomposite and monolith catalysts. China-North America Workshop on Fuel Cell Science and Technology; 2009-08-13 - 2009-08-15

159. **Zhu, Jun; Rønning, Magnus; Holmen, Anders.**
Platinum nanoparticle shape effect on propane dehydrogenation. Norwegian Catalysis Symposium 2009; 2009-11-30 - 2009-12-01

160. **Zobel, Nico; Anca Couce, Andrés; Behrendt, Frank; Jakobsen, Hugo Atle.**
Multiscale Modelling of Fixed Bed Reactors : The Representative Particle Approach. The Chemical Reaction Engineering Annual Meeting; 2009-06-08 - 2009-06-10

161. **Zobel, Nico; Anca Couce, Andrés; Behrendt, Frank; Jakobsen, Hugo Atle.**
Multiscale-Modeling of Smoldering in Piles of Solid Fuel Particles. the 24th German Flame Day; 2009-09-16 - 2009-09-17

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 and Process Design. In the fourth year the students select further specializations for the remaining of the studies. The students choose between 5 specializations: Petrochemistry and Catalysis, Colloid and Polymer Chemistry, Environmental Engineering and Reactor Technology, Process Systems Engineering and Biorefining 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 2009:

Course code	Course title	Credits	Year	Registered	Passed
TKP4100	Fluid Flow and Heat Transfer	7.5	2	90	67
TKP4105	Separation Technology	7.5	3	75	59
TKP4110	Chemical Reaction Engineering	7.5	3	95	80
TKP4115	Surface and Colloid Chemistry	7.5	3	72	67
TKP4120	Process Engineering	7.5	2	108	102
TKP4130	Polymer Chemistry	7.5	4	29	26
TKP4135	Chemical Process Dynamics and Optimization	7.5	4	9	7
TKP4140	Process Control	7.5	4	46	46
TKP4145	Reactor Technology	7.5	4	3	3
TKP4150	Petrochemistry and Oil Refining	7.5	4	30	25
TKP4155	Reaction Kinetics and Catalysis	7.5	4	50	45
TKP4160	Transport Phenomena	7.5	4	15	12
TKP4165	Process Design	7.5	4	23	23
TKP4170	Process Design, Project (autumn)	7.5	4	32	32
TKP4171	Process Design, Project (spring)	7.5	4	7	7
TKP4175	Thermodynamic Methods	7.5	3	37	24
TKP4180	Bioenergy and Fiber Technology	7.5	4	14	11
TKP4185	Nuclear Power, Introduction	7.5	4	13	11
TKP4510	Catalysis and Petrochemistry, Specialization Project	15	5	3	3
TKP4511	Catalysis and Petrochemistry, Specialization Project	7.5	5	-	-
TKP4515	Catalysis and Petrochemistry, Specialization Course	7.5	5	8	8
TKP4520	Colloid and Polymer Chemistry, Specialization Project	15	5	4	4
TKP4521	Colloid and Polymer Chemistry, Specialization Project	7,5	5	-	-
TKP4515	Colloid and Polymer Chemistry, Specialization Course	7.5	5	5	5
TKP4530	Reactor Technology, Specialization Project	15	5	13	13
TKP4531	Reactor Technology, Specialization Project	7,5		1	1
TKP4535	Reactor Technology, Specialization Course	7,5	5	14	4
TKP4550	Process Systems Engineering, Specialization Project	15	5	7	7
TKP4551	Process Systems Engineering, Specialization Project	7.5	5	1	1
TKP4555	Process Systems Engineering, Specialization Course	7.5	5	8	8
TKP4560	Paper and Fibertechnology, Specialization Project	15	5	1	1
TKP4561	Paper and Fibertechnology, Specialization Project	7.5	5	-	-
TKP4565	Paper and Fibertechnology, Specialization Course	7.5	5	1	1
TKP4850	Experts in Team, Interdisciplinary Project	7.5	4	18	18
TKP4500	Final Year Design, for Spanish students	60	5	-	-
TKP4900	Chemical Process Technology, Master Thesis	30	5	35	35

Master theses 2009 total 35, 24 female and 11 male

Aulie, Håkon Martin
Characterization of SiC and SiO2 in PEG suspensions
Supervisor: Johan Sjöblom

Bergstedt, Elin Maria
Scale formation and bulk precipitation of calium carbonate in the presence of scale inhibitor
Supervisor: Jens-Petter Andreassen

Biørn, Inger Lise
Characterization of products from conversion of heavy oils
Supervisor: Edd Anders Blekkan

Bjartnes, Kirsti
Design and operation of a subsea process system
Supervisor: May-Britt Hägg

Enaasen, Nina
Membrane Separation of Natural Gas at Tjeldbergodden
Supervisor: May-Britt Hägg

Gran, Håvard Foss
Aquous solubility of ARN acids and the effect of Ph and counter ion valency - methodology and experimental results
Supervisor: Johan Sjöblom

Heskestad, Rita
Stability of spherulite crystals in crystallization processes, consequence of crystallization parameters on morphology and filtration properties
Supervisor: Dick Malthe-Sørenssen

Holsæter, Hege Christine
Absorption kinetics and crystallisation during capture of CO_2 in ammonium solutions
Supervisor: Jens-Petter Andreassen

Høyen, Ragnhild
Characterization of alumina supported cobalt based catalysts through temperature programmed surface reaction
Supervisor: Anders Holmen

Haaversen, Linn Christine Loe
Amine reclaiming technologies
Supervisor: Hallvard Svendsen

Johansen, Hege Døvle
Fouling and cleaning of membranes suitable for osmotic power
Supervisor: May-Britt Hägg

Jonassen, Øystein
VLE equilibria in absorbent systems
Supervisor: Hallvard Svendsne

Kalstad, Tone
Fluid Conditioning System for Subsea Wellstream Compression
Supervisor: May-Britt Hägg

Karlsen, Cathrine Hval
Optimization of Polymeric Hollow Fibre - Membranes for Pyrolysis to Carbon Fibres
Supervisor: May-Britt Hägg

Kolås, Kjersti Blytt-Tøsdal
Absorption kinetics and solids crystallization during capture of CO2 in ammonium solutions
Supervisor: Jens-Petter Andreassen

Lin, Yi
A simulation study of droplet-droplet collision under high pressures
Supervisor: Hallvard Svendsen

Løvold, Ane Dyb
Separation of oxygen from gas by carbon membranes
Supervisor: May-Britt Hägg

Mæhle, Inger Roksvåg
Deactivation modeling and verification of model for methanol synthesis catalyst
Supervisor: Magne Hillestad

Nenningsland, Andreas Lyng
Extraction and characterization of bases present in crude oil
Supervisor: Johan Sjöblom

Perzs Aguilera, Luber Carlui
Optimal operation of a LNG (Liquefied Natural Gas) process
Supervisor: Sigurd Skogestad

Røsting, Kristine
Subsea process systems for gas-liquid separation
Supervisor: May-Britt Hägg

Sjulstad, Johanne Schjellungen
Characterisation of fractionated lignosulfonate from wheat straw
Supervisor: Størker Moe

Solsvik, Jannike
Numerical analysis of multicomponent mass diffusion in catalyst pellets for combustion with and without CO_2 capture
Supervisor: Hugo A. Jakobsen

Storsæter, Kathrine
Optimization of the polymerization process at the Mongstad refinery
Supervisor: Anders Holmen

Subinyá Albrich, Mireia
Modelling of absorption of CO_2 in aqueous solutions of alkanolamines
Supervisor: Hallvard Svendsen

Trehjørningen, Kristin Rem
Biomass gasification
Supervisor: Edd A. Blekkan

Tuvnes, Henrik
Production Optimization of Contrast Agent Substance
Supervisor: Sigurd Skogestad

Eirik Fatnes Tørneng
Stabilization of two-phase flow with parallel branches
Supervisor: Sigurd Skogestad

Vaktdal, Hanne Margrethe
Modeling and optimization of a gas-to-liquid plant.
Supervisor: Magne Hillestad

Vattekar, Petter Tangen
Production of Torlon based carbon membranes
Supervisor: May-Britt Hägg|

Vera Lozada, Rafael
Characterization of crude oils according to corrosivity using the Fe POWDER test and TAN
Supervisor: Edd A. Blekkan

Vik, Camilla Berge
Computing - Status Report and a Course Suggestion for NTNU's Chemical Engineering Department
Supervisor: Heinz Preisig

Winstad, Elisabeth Ottestad Nissen
Advanced characterization of Fischer-Tropsch catalysts
Supervisor: Magnus Rønning

Zhang, Xi
Design, synthesis and characterization of bimetallic catalysts
Supervisor: De Chen

Aaserud, Jo
Alternative systems for wood preservation
Supervisor: Wilhelm Glomm

Firs row: Tone Kalstad, Kristine Røsting, Kirsti Bjarnes, Linn Christine Loe Haaversen, Inger Lise Biørn, Jannike Solsvik, Camilla Berge Vik
Second row: Hege Holsæter, Hege Døvle Johansen, Ragnhild Høyen, Elisabeth Windstad, Nina Enaasen, Johanne Schellungen Sjulstad, Elin Bergstedt, Kjersti Blytt-Tøsdal Kolås, Kristin Rem Trehjørningen
Third row: Petter Tangen Vattekar, Eirik Fatnes Tørneng, Martin Håkon Aulie, Andreas Lyng Nenningsland, Henrik J. Tuvnes, Håvard Foss Gran

5th year students 2009/2010
Total 26, 12 female and 14 male

Arthur, Theophilus
Asif, Naveed
Badina, Aderonke
Eklund, Pål
Gao, Bicheng
Gondal, Shahla
Haider, Shamim
Helberg, Ragne Marie Lilleby
Helgestad, Dag-Erik
Hesstvedt, Camilla
Hyllestad, Elisabeth Lovise R.
Jacobsen, Julie Berild
Jensen, Martin Buus
Lillebø, Andreas Helland
Mba, Emmanuel
Munkebye, Knut-Arne Rademacher
Munkejord, June
Nergård, Liv-Turid
Osatiashtiani, Amin
Ringstad, Renate G.
Roel, Carl Marius
Roset, Stine Thysnes
Røed, Anders Haukvik
Skjeldestad, Kjetil
Widarena, Trimaharika
Østbye, Helene

4th year students 2009/2010
Total 27, 13 female and 14 male

Almeland, Silje Kreken
Bøhn, Kristian
Evenrud, Vegar
Graff, Vidar
Greene, Jonathan Ashley
Grimholt, Chriss Tony Robert
Haglund, Ola Kjølberg
Hareide, Henning
Heggvoll, Børge
Helgesen, Anette Hoel
Håseth, Jenny Kristin
Jens, Christian Morten
Karlsen, Aina Elin
Karlsen, Stine
Kjos-Hanssen, Øyvind Jacob
Krossholm, Charlotte
Kvam, Torunn
Leithe, Anna Elise
Lien Bjørnstad, Ida
Meland, Knut Åge
Nergaard, Margrethe
Osmani, Kimete
Plünnecke, Katrine S. Biesterfeld
Roll, Sebastian
Shadman, Amir
Viatkin, Dimitri
Williams, Rebecca Sian

3rd year students 2009/2010
Total 24, 13 female and 11 male

Asphaug, Sindre
Barland, Astrid Odland
Berstad, Eivind
Bersås, Anita
Børtveit, Sølvi
Carlsen, Christina
Dolgov, Iakov
Glas, Sophie Anne Amelie
Hareide, Henning
Heggebø, Ada Cecilie
Hildenes, Knut Arne Wuttudal
Johannessen, Petra-Kristine
Johansen, Stine
Johansson, Emma Matilda
Kjos-Hanssen, Øyvind Jacob
Krossholm, Charlotte
Lefsaker, Martine
Midttveit, Anette
Nesje, Ivar
Nogva, Stig-Erik
Nordvåg, Ole kristian
Pylilo, Alexei
Stavnes, Signe Marie Nielsen
Sørheim, Anders

International master students autumn 2009, Total 11, 1 female and 10 male

Name	Nationality
Alam, Mahmud	Bangladesh
Esmaelpour, Ayob	Iran
Hussain, Waqas	Pakistan
Idrees, Muhammad Usman	Pakistan
Khanam, Ambari	India
Nababan, Ardianty	Indonesia
Nazir, Ahsin	Pakistan
Rahman, Mohammad Mashukur	Bangladesh
Saeed, Muhammad	Pakistan
Saleem, Fahad	Pakistan
Zaidy, Syed Amjad Hussain	Pakistan

Student exchange 2009

32 exchange students visited our Department (15 females and 17 males)

Amadio, Lorenzo	University of Padova, Italy	Colloid- and Polymer Group
Azpeleta, Cristina	University of Valladolid, Spain	Catalysis Group
Benedito Piera, Rocio	Universidad Politecnica De Valencia, Spain	Environmental Egineering and Reactor Tehnology Group
Bouvier, Nicolas	Institut National Polytechnique de Lorraine, France	Environmental Egineering and Reactor Tehnology Group
Chikhi, Benjamin	RWTH Aachen, Germany	Environmental Egineering and Reactor Tehnology Group
Chirnside, Morfula Pamela	RWTH Aachen, Germany	
Class, Caleb	Purdue University, Indianapolis, USA	Process System Engineering Group
Dobos, Laszlo	University of Pannonia, Hungary	Process System Engineering Group
Dreillard, Mattheu	Institut National Polytechnique de Lorraine, France	Environmental Egineering and Reactor Tehnology Group
Estellés, Maria Del Mar	Universidad Politecnica de Valencia, Spain	Process System Engineering Group
Garcia Borreguero, Jaime Hortelano	Universidad Autónoma de Madrid, Spain	Environmental Egineering and Reactor Tehnology Group
Kleinhohl, Nils	Universiät Stuttgart, Germany	Environmental Egineering and Reactor Tehnology Group
Kolomijeca, Anna	Riga Technical University, Latvia	Catalysis Group
Kui, Jie Ren	National University of Singapore, Singapore	
Lefranc, Adeline	ENSIACET, France	Environmental Egineering and Reactor Tehnology Group
Montazaud, Thomas	Ecole Centrale de Lille, France	
Moreno Colomer, Susana	University of Cadiz, Spain	
Pan, Xi	University of Technology Hamburg, Germany	Environmental Egineering and Reactor Tehnology Group
Paradza, Nobert	University of Cape Town (UCT), South Africa	Environmental Egineering and Reactor Tehnology Group
Patte, Céline	ENSIACET, France	Process System Engineering Group
Perez Aguilera, Luber C.	Simon Bolivar University, Venezuela	Process System Engineering Group
Perret, Matthieu	Université de Franche-Comté, France	Colloid- and Polymer Group
Pierrard, Xavier	Université Paul Sabatier, France	Colloid- and Polymer Group
Puschke, Jennifer	RWTH Aachen, Germany	
Romero, Daniel Serena	Universidad Autónoma de Madrid, Spain	Environmental Egineering and Reactor Tehnology Group
Shun Hua, Ong	National University of Singapore, Singapore	
Soh, Cecily	National University of Singapore, Singapore	Environmental Egineering and Reactor Tehnology Group
Subinyà Albrich, Mireia	Polytechnic University of Catalonia, Spain	Environmental Egineering and Reactor Tehnology Group
Tavera Valero, Nuria	Universidat de Granada, Spain	Environmental Egineering and Reactor Tehnology Group
Teo, Swee Gee Constance	National University of Singapore, Singapore	
Ton, Xuan-Anh	ESPCI Paris Tech, France	Colloid- and Polymer Group
Vera Lozada, Rafael	Simon Bolivar University, Venezuela	Catalysis and Petrochemistry Group

6 students from our Department (5 females and 1 male) on exchange

Name	**To Institution**	**Programme**	**Period**
Helgestad, Dag-Erik	University of Berkley, California, USA	Bilateral	21.08.08 – 21.05.09
Hesstvedt, Camilla	Curtin Univ. of Technology, Perth, Australia	Individ	01.07.08 – 01.07.09
Hyllestad, Elisabeth L.	University of Berkley, California, USA	Bilateral	15.01.09 – 31.05.09
Jacobsen, Julie Berild	University of California, Santa Barbara, USA	Individ	22.09.08 – 30.06.09
Munkejord, June	University of California, Santa Barbara, USA	Individ	01.09.08 – 30.06.09
Nergård, Liv-Turid	Technische Hochschule Zürich, Switzerland	Bilateral	01.02.09 – 30.07.09

PhD in Chemical Engineering

PhD courses given at Department of Chemical Engineering:

Cours code	Course title	Credits	Registered	Passed	Semester
KP8100	Advanced Process Simulation	7.5			
KP8102	Wood Chemistry in Pulping and Paper Making	7.5	3	3	Fall 09
KP8104	Industrial Crystallization and Precipitation	9.0	1	1	Fall 09
KP8105	Methematical Modelling and Model Fitting	7.5	13	13	Fall 09
KP8106	Gas Cleaning with Chemical Solvents	9.0			Fall 11
KP8107	Advanced Course in Membrane Separation Process	9.0	12	11	Fall 09
KP8108	Advanced Thermodynamics: With applications to Phase and Reaction Equilibria	9.0			Fall 10
KP8110	Membrane Gas Purification	9.0			Spring 10
KP8115	Advanced Process Control	7.5			Fall 10
KP8117	Paper Physics and Paper Chemistry	9.0			Spring 10
KP8118	Advanced Reactor Modelling	12.0	2	2	Spring 09
KP8120	Colloid Chemistry and Functional Materials	9.0	9	9	Spring 09
KP8123	Colloid Chemistry for Process Industry	9.0			
KP8124	Modelling of Catalytic Reactions	6.0	12	12	Spring 09
KP8125	Design and Preparation of Catalytic Materials	6.0	20	20	Spring 09
KP8130	Systembiology, Modelling and Analysis	7.5	2	2	Fall 09
KP8132	Applied Heterogeneous Catalysis	7.5	13	13	Fall 09
K)8134	Surfactants and Polymers in Aquous Soutions	7.5	4	3	Fall 09
KP8135	Surface, Colloid and Polymer Chemistry Special Topics	7.5	1	1	Fall 09
KP8901	Chemical Process System Engieering	7.5			Fall 08
KP8902	Reactor Technology	7.5	2	2	Spring 09
KP8903	Reaction Kinetics and Catalysis	7.5	1	1	Fall 09
KP8904	Transport Phenomena	7.5	2	2	Fall 09

PhD-Thesis 2009 Total 14, 6 female and 8 male

Aske, Elvira Marie B.
Design of plantwide control systems with focus on maximizing throughput.
Supervisor: Sigurd Skogestad

Beck, Ralf
Crystal Growth Pehnomena and filtration: Morphology and Size Effects for Selected Industrial Compounds.
Supervisor: Jens-Petter Andreassen

Deng, Liyuan
Development of Novel PVAm/PVA Blend FSC Membrane for CO_2 Capture.
Supervisor: May-Britt Hägg

Foss, Martin Smedstad
The Effect of Oil on Carbon Dioxide Corrosion Inhibition on Carbon Steel - Potential for Improved Corrosion Protection
Supervisor: Johan Sjöblom

Hanneseth, Ann-Mari Dahl
An Experimental Study of Tetrameric Naphthenic Acid at w/o Interfaces. Reactivity, inhibition and Emulsion Formation
Supervisor: Johan Sjöblom

Hartono, Ardi
Characterization of diethylenetriamine (DETA) as absorbent for Carbon Dioxide.
Supervisor: Hallvard Svendsen

Kim, Inna
Heat of reaction and VLE of post combustion CO_2 absorbents.
Supervisor: Hallvard Svendsen

Knuutila, Hanna
Carbon dioxide capture with carbonate systems
Supervisor: Hallvard Svendsen

Linhart, Andreas
An aggregation model reduction method for one-dimensional distributed systems.
Supervisor: Sigurd Skogestad

Mejdell, Astrid Lervik
Properties and application of 1-5 µm Pd/Ag23wt.% membranes for hydrogen separation.
Supervisor: Hilde J. Venvik

Nordgård, Erland
Model Compounds for Heavy Crude Oil Components and Tetrameric Acid.
Supervisor: Johan Sjöblom

Nordhagen, Håkon Ottar
Development of Fracture Mechanics to Study End Use of Paper Webs.
Supervisor: Øyvind Gregersen

Sandru, Marius
Development of a FSC membrane for selective CO_2 capture.
Supervisor: May-Britt Hägg

Zhu, Zhengjie
The Least-Squares Spectral Element Method Solution of the Gas-Liquid Multi-fluid Model Coupled with the Population Balance Equation.
Supervisor: Hugo A. Jakobsen

7 PhD exchange students visited our Department in 2009 (3 female and 4 male)

Name	University/Country	Group located
Abbas, Ronald	Univ. Witswaterrand, Johannesburg, South Africa	Process Systems Engineering Group
Balonek, Christina	University of Minesota, USA	Catalysis Group
Bimbela, Fernando	Universidad de Zaragoza, Spain	Catalysis Group
Blaylock, Wayne	University of Minesota, USA	Catalysis Group
Lögdberg, Sara	KTH, Stockholm, Sweden	Catalysis Group
Qin, Feng	Tsinghua University, Beijing, China	Environmental Engineering and Reactor Technology Group
Qiu, Weiwei	Petroleum University of China, Beijing, China	Process Systems Engineering Group

4 PhD students from our Department visited Universities abroad in 2009

Name	University/Country	Period
Deng, Liyuan	University of Colorado at Boulder, USA	27.01. – 14.03.2009
Flaten, Ellen Marie	University of Patras, Greece	27.04. – 07.07.2009
Manum, Henrik	ETH Zürich, Swiss Federal Institute of Technology Zurich, Switzerland	04.01. – 15.07.2009
Paunonon, Sara	Innventia, Stockholm, Sweden	24.08. – 18.12.2009

Seminars, Conferences and meetings organized by the Department in 2009

Seminars:

Technical Seminar on Natural Gas Processing (The Sleipner Field Case)
Dr. Even Solbraa, Statoil, R&D, Trondheim
"Acid Gas Removal: Problem description and experiences from the Sleiper field", 28.04.2009

KinCat seminars in Heterogeneous Catalysis:

Kolbjørn Zahlsen, SINTEF Biotechnology
"*Mass spectrometry in chemical engineering? Possibilities and cooperation", 20.02.2009*

PhD student Jia Yang
"An introduction of Steady-State Isotopic Transient Kinetic Analysis", 06.03.2009

Researcher Tiejun Zhao, Department of Chemical Engineering, NTNU
"Preferential Oxidation of CO in H2-rich gases over Cu-CeO_2 catalysts: Prospects and Progress",
20.03.2009

Postdoctor Espen Standal Wangen
On the Thermochemical Conversion of Biomass to Syngas: Prospects and Progress, 27.03.2009

Dr. Olaf Köhler, Chemspeed Technologies AG
High-output experimentation - automation as an invaluable tool in the development of heterogeneous catalysts, 17.04.2009

PhD Wayne Blaylock, University of Minesota, USA
"Density Functional Theory (DFT) calculations - principles, practice and results", 11.09.2009

Professor Manis Mavrikakis, University of Wisconsin-Madison, USA
"First-Principles approaches to Heterogeneous Catalysis: From reaction mechanisms to new catalytic materials", 24.09.2009

Researcher Rune Myrstad, SINTEF
"Fischer-Tropsch synthesis in a microstructured reactor" 25.09.2009

PhD Christine Balone, University of Minesota, USA
"Millisecond Catalytic Reforming of Solid Polymers: Polystyrene Monoaromatic Representatives over Noble Metals", 09.10.2009

PhD student Miroslav Surma, Department of Chemical Engineering, NTNU
"Algorithmization of some microkinetic issues"
23.10.2009

PhD student Daham Gunawardana, Department of Chemical Engineering, NTNU/Kyungpook National University, South Korea:
"Copper-ceria catalysts for water gas shift and (oxidative) steam reforming of methanol"
06.11.2009

PhD student Oana Mihai, Department of Chemical Engineering, NTNU
"The volatility properties of reformulated gasolines with alcohols", 20.11.2009

Guest lectures:

Professor Geir Dullerud, University of Illinois Urbana-Champaign, USA
"Multi-agent control with multi-resolution sensing over networks", 08.10.2009

Professor Vladimir Tepliakov, Topchiev Institute of Ptrochemical synthesis, Russian Academy of Sciences, Moscow, Russia
*"Membrane contactors in biogas and biogas pgrading",*13.10.2009

Dr.ing. Peter Pfeifer, Karlsruhe Institute of Technology, Germany
"Considerations of mass and heat transfer for scale-up of microreactors"
04.11.2009

Conferences:

4th Advanced Membrane Conference
Membranes for Clean and Sustainable Processes
Orginsed by ECI Technical Liaison and May-Britt Hägg, NTNU-MemfoACT AS
07.06. – 12.06.2009

The 5th Trondheim Conference on CO_2 Capture, Transport and Storage
Orginised by Gas Technology Centre, NTNU-SINTEF
16.06. – 17.06.2009

1st. Trondheim Gas Technology Conference
Orginised by Gas Technology Centre, NTNU-SINTEF
21.10 – 22.10.2009

"Norsk katalysesymposium", Trondheim 30.11 and 17.12. 2009, 74 participants

Nordic Wood Processing Symposium
08. – 09.2009, 80 participants

Awards in 2009

Associated Professor Wilhelm Robert Glomm, was awardet with Akzo Nobels Nordiska Forskarpris i Yt- och Kolloidkemi (Akzo Nobel Nordic Researcher Award in Surface and Colloid Chemistry) for 2009

Post Doc.tor Jon Arvid Lie and Professor May-Britt Hägg received the firstprice on "Innovator 2009" for the new established company MemfoACT AS

MemfoACT also received a fellowship from Adolf Ferdinand Øien's fond, NOK 500 000 in 2009

Adjunct professor Kjell Moljord, received the price for best education on behalf of himself and Professor Edd A. Blekkan

Senior Engineer Berit Borthen, HMS coordinator, received NTNUs work environmental price for her work with students and employees about safety and security in laboratories

CHAPTER 5: ORGANIZATION - ECONOMY

Organization (also see cover page)

In 2009 the Department board was reintroduced at the Department. It consist of 2 external members with and members form scientific staff, administrative staff, Ph.D's ande Students. The board is elected for 4 years. The Head of department is chair of the board. We also elected a new Head of Department in 2009. Professor Øyvind Gregersen 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 Ph.D's, the students and technical staff. The management team meets every second week and discusses running matters.

In addition to the scientific staff the department has 18 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)	Professor Edd Anders Blekkan, deputy: Associate Professor Jens-Petter Andreassen
Faculty Research Committee (Department representatives)	Professor Hallvard Fjøsne Svendsen, deputy: Professor Hugo Atle Jakobsen
Study Program Chemical Engineering and Biotechnology (Industriell kjemi og bioteknologi) (Department representatives)	Associate Professor Jens-Petter Andreassen
Exchange of Norgwegian 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 Senior Excecutive Officer Jørn Olav Løkken

Department Economy

The department has three main sources of income: regular funds from the University, strategic funding from the University and external projects. In terms of external funds, including contributions from the research Council and industry, the situation is very good. The gross regular funds from the University were about 39 million NOK in 2009. These funds are mainly used to pay salaries to the permanent staff. The big increase from 2007-2008 is due to a new practice of charging overhead from and to the external projects. Furthermore several strategic funds have been moved to the regular funds over the last years so what appears as a substantial growth actually just is a new way of distributing funds.
More details are shown in Table 1.

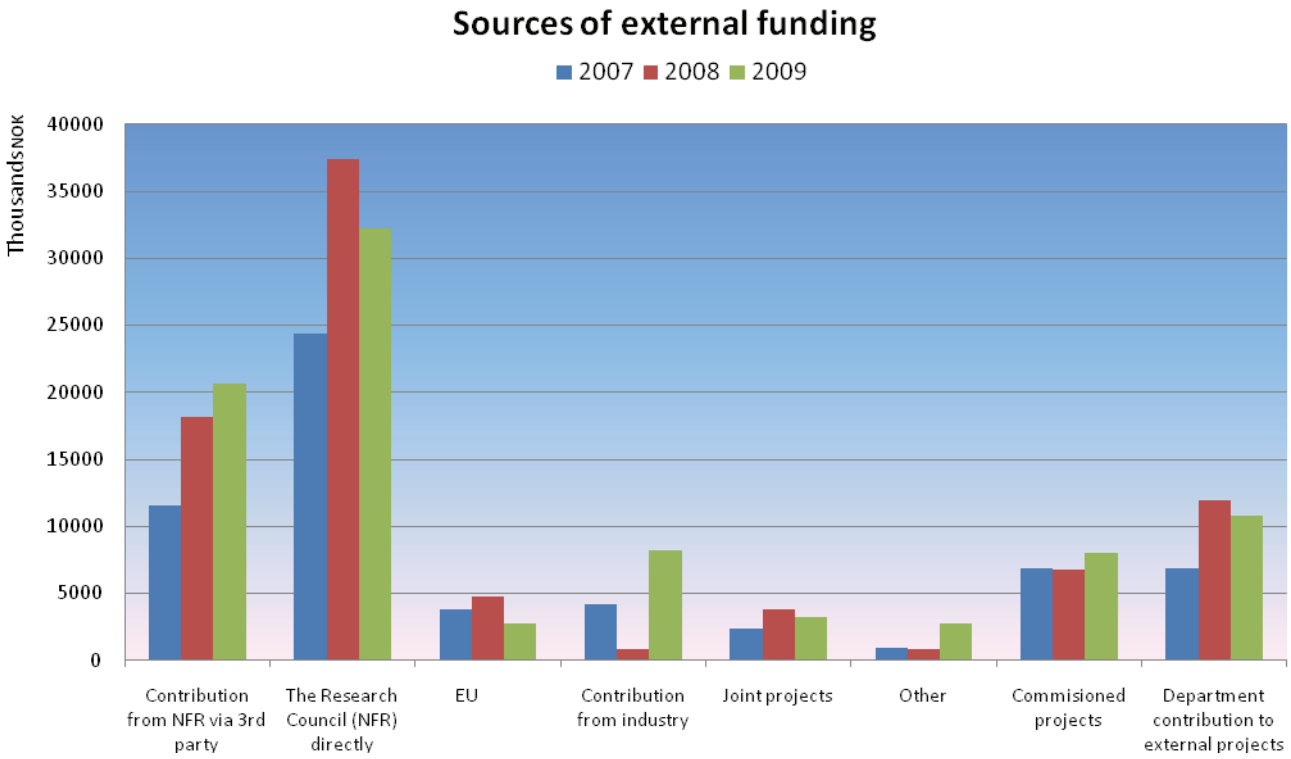
Accounts	2006	2007	2008	2009
Income:				
University funding	24 434 113	26 554 529	33 064 000	39 151 000
Overhead external projects	2 390 000	2 846 260		
Sum income	26 824 113	29 402 796	33 064 000	39 151 000
Expences:				
Wages	22 514 217	21 260 668	21 525 000	24 726 000
Investment		2 546 924	147 000	250 000
Operating expenses	3 818 963	3 472 929	2 778 000	2 684 000
NTNU contribution to ext. projects			9 053 000	9 810 000
Sum expenses	26 333 180	27 280 521	33 504 000	37 470 000
Result	490 933	2 120 268	-439 000	-1 681 000

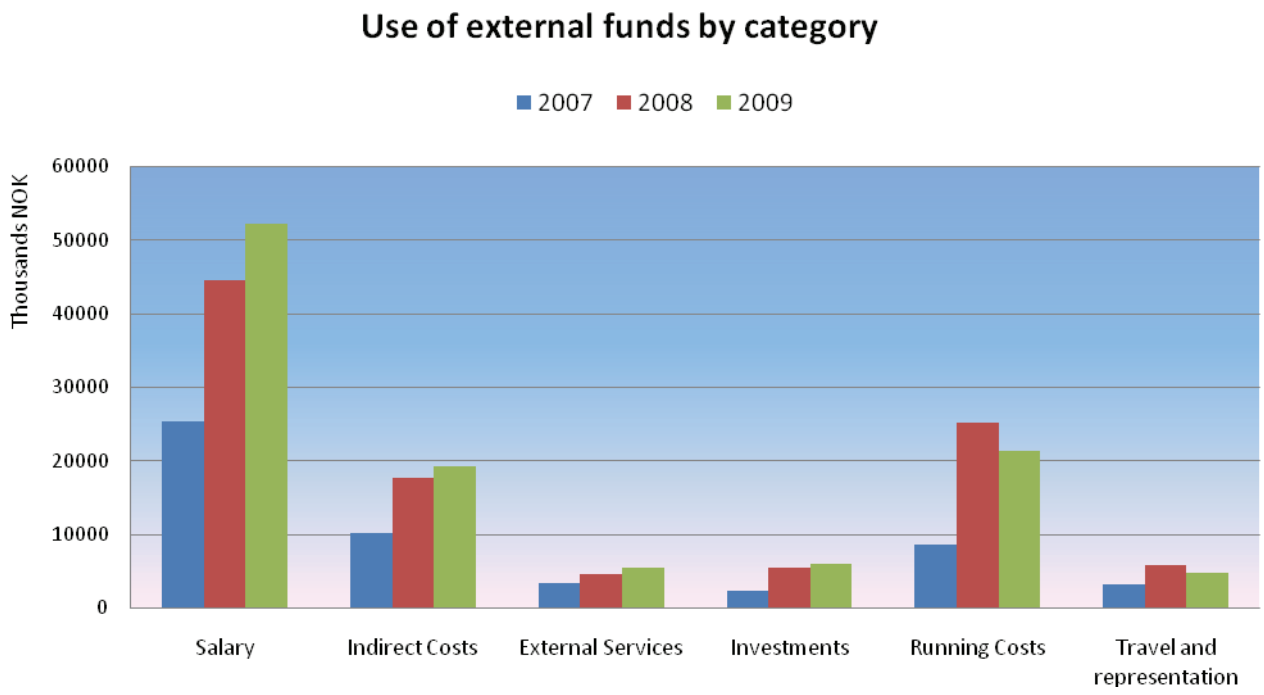
Table 1. Departments income from University and spending.

External funding

In addition to the funding shown in Table 1, the Department has a yearly income from external contributors of approx 80 million NOK. Details are shown in Tables 2 and 3. In the last years we have gotten several big projects that have raised the income substantially. 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 industrial contributions and commissioned research are now stabilized. The EU-funding had a little dip in 2009, but is expected to rise again in 2010. This is important because University focus on EU- funding that gives extra credit and funding from the Ministry. We keep on having focus on EU as a growth area for our research activities. A problem in the past has been to cover the high costs in Norway within the EU framework, so many of these projects have been underfinanced. New support routines from The University will help to balance these projects. As Table 3 shows are most of the costs related to salary for PhD candidates and researchers, and the share it takes of the total funding are rising. We have many joint industrial programmes and the industry partners comes from countries in Europe, North-America, South America and Asia. External funding from commissioned research was approx 10 % in 2009, and the customers comes from the mentioned areas and Africa.





Strategic funds from University

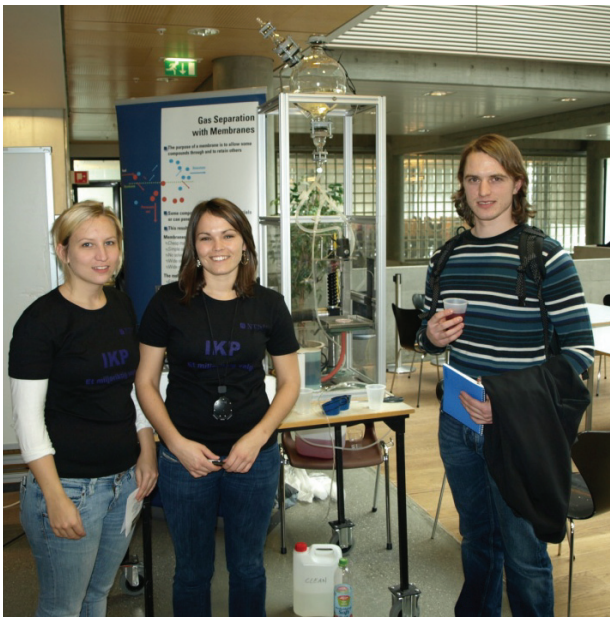
The third source of income is strategic funding from the University to support research and academic profile. These funds are used for investments in research equipment or Ph.D. or Post doc. positions. In 2009 we got only one new strategic project, KNOK 2000 to renewal of experiments in our student laboratories.

Net funding from NTNU

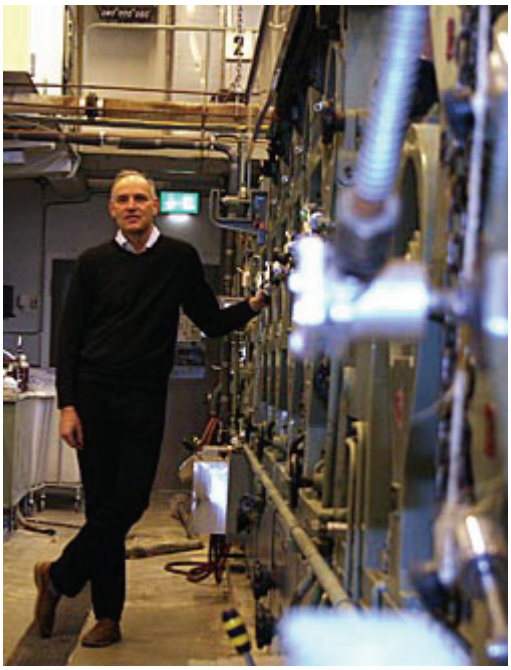
From the numbers in Table 1 it seems like the funding from the University has increased heavily in the last few years. However, the departments contributes overhead on external project to the NT-Faculty, which over the same period has increased from 3633 (2007), 12658 (2008), 15500 (2009) and 19200 (2010). The estimated jump by about 9 millions NOK in 2008 from 2007 to 2008 is because of a recent increase in overhead on salaries (from 15 % to 40 %.) Subtracting the overhead to the NT-Faculty, the net funding from the University to the Department over the last few years is 21764 (2007), 19582 (2008), 20590 (2009) and 22287 (2010). We are then back at the same level of funds from the Faculty as in 2007.

Some pictures of different activities at the Department

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



Hege and Kjersti is promoting our Department



Sigurd Skogestad beside the paper machine before it was removed

From "Monteringshallen". Jan-Morten is helping Washim and Ali

LIST OF TELEPHONE NUMBERS (03.04.2009)

	Agnihotri, Swarnima, Post doctor	PFI-3209
	Ahmad, Jamil, Ph.D. candidate	K4-213
	Alsvik, Inger Lise, Ph.D. candidate	K4-215
95878	Amiri, Asal, Ph.D. candidate	PFI-3405
94209	Andreassen Jens-Petter, Associate Professor	K4-305
	Aronu, Ugochukwu Edwin, Ph.D. candidate	K4-309
97018	Bakthiary Hamidreza, Ph.D. candidate	K5-M12
50318	Barø Tove, Executive Officer	K5-101
	Beck Ralf, Post doctor	K4-302
50924	Benmekhbi, Mehdi, Ph.D. candidate	PFI-3408
94138	Berge, Arvid, Professor Emeritus	K5-M11
94157	Blekkan Edd Anders, Professor	K5-429
90638	Borka, Zsolt, Ph.D. candidate	K5-225
91664	Borthen Berit, Chief Engineer	K4-167
94141	Boullosa Eiras Sara, Ph.D. candidate	K5-411
	Bruder, Peter, Ph.D. candidate	K4-309
94144	Brun Harry, Engineer	K5-341
94125	Chao, Zhongxi, Ph.D. candidate	K5-145
93149	Chen De, Professor	K5-407
94163	Ciftja, Arlinda, Ph.D. candidate	K4-430
94190	Dagsgård, Camilla, Principal Engineer	K5-304
94312	Dam, Anh Hoang, Ph.D. candidate	Kh-108
94125	Dar, Hassan Jamil, Ph.D. candidate	K5-145
	Deng Liyuan, Post doctor	K4-224
93149	Dragsten, Karin W., Principal Engineer	K5-407
94110	Dupuy Pablo, Ph.D. candidate	K5-244
	Dwivedi, Deeptanshu, Ph.D. candidate	K4-239
	Eide-Haugmo, Ingvild, Ph.D. candidate	K4-430
94120	Erga Olav, Professor Emeritus	K5-237
50339	Farooq, Umer, Ph.D. candidate	K5-340
	Finnøy, Geir, Chief Engineer	K4-421
94143	Fossum Arne, Engineer	K5-019
94017	Gawel, Bartlomiej, Researcher	K5-336
	Ghadrdan, Maryam, Ph.D. candidate	K4-239
94158	Glomm Wilhelm R. Associate Professor	K5-336
98354	Gorelkin, Ilya, Ph.D. candidate	K5-M4
94029	Gregersen Øyvind, Professor	PFI-2109
90338	Grimes Brian, Post doctor	K5-339
94126	Gunawardana, Daham Sanjaya	K5-158
	Gupta, Mayuri, Ph.D. candidate	K4-430
94039	Hammer, Nina, Post doctor	K5-413
	Hartono, Ardi, Researcher	K4-407
94108	Haug-Warberg Tore, Associate Professor	K4-228
94073	Hayer Fatemeh, Ph.D. candidate	K5-M6
92839	He Li, Researcher	K5-421
	He, Xuezhong, Ph.D. candidate	K4-213
94031	Helle Torbjørn, Professor emeritus	PFI-2109
50304	Helmersen Tom, Office Manager	K5-101
94113	Hertzberg Terje, Professor Emeritus	K4-333
	Hessen Erik Troøien, Ph.D. candidate	K4-409
94122	Hillestad Magne, Professor	K5-213
94151	Holmen Anders, Professor	K5-401
94026	Hovin Odd Ivar, Engineer	Kh-155
50540	Håkonsen Signe, Senior Engineer	PFI3404
51128	Huang, Fan, Ph.D. candidate	K5-443
94033	Hägg May-Britt, Professor	K4-339
91673	Iotti, Marco, Post doctor	PFI-3204
	Jahanshahi, Esmaeil, Ph.D. candidate	K4-209
50537	Janga, Kando Kalifa, Ph.D. candidate	PFI-3207
	Jacobsen, Magnus Glosli, Ph.D. candidate	K4-232
94132	Jakobsen Hugo Atle, Professor	K5-209
	Jäschke, Johannes, Ph.D. candidate	K4-207
	Karimi, Mehdi, Ph.D. candidate	K4-411
94145	Kazi, Saima Sultana, Ph.D. candidate	K5-443
94149	Keleşoğlu, Serkan, Ph.D. candidate	K5-308
93138	Kim Taek-Joong, Researcher	K5-251
	Klimantos, Paris	K4-406
91605	Králová, Iva, Chief Engineer	PFI-3403
	Lapaumier, Helene, Post doctor	K4-408
50540	Lesaint Caterina, Senior Engineer	PFI-3404
94105	Lesaint Cédric, Post doctor	K5-324
	Luo, Xiao, Ph.D. candidate	K4-411
94120	Malthe-Sørenssen Dick, Adjunct Professor	K5-238
	Manum Henrik, Ph.D. candidate	K4-207
95498	Marchetti, Jorge Mario, Post doctor	K5-156
94153	Mathisen Torgrim, Higher Executive Officer	K4-166
	Mehdizadeh, Hamid, Ph.D. candidate	K4-411
94073	Mihai, Oana, Ph.D. candidate	K5-M6
94018	Mingot, Andrea, Principal Engineer	K1-309
94032	Moe Størker, Associate Professor	PFI-2108
94147	Moljord, Kjell, Adjunct Professor	K5-M11
94193	Muthuswamy, Navaneethan, Ph.D. candidate	Kh-250
94148	Mørk Preben C., Professor	K5-M11
94022	Nayak, Ameeya Kumar, Post doctor	K5-156
94112	Nilsen Tom-Nils, Senior Researcher	K4-224
50325	Nordgård, Erland, Post doctor	K5-306
94111	Noor, Tayyaba, Ph.D. candidate	Kh-251
50924	Opedal, Nils van der Tuuk, Ph.D. candidate	PFI-3408
	Owrang, Farshid, Researcher	K4-407
	Panahi, Mehdi, Ph.D. candidate	K4-212
94111	Patanou, Eleni, Ph.D. candidate	Kh-251
93147	Paso Kristofer, Post doctor	K5-304
95879	Patruno Luciano, Ph.D. candidate	K5-245
50397	Paunonen, Sara, Ph.D. candidate	PFI-3103
94208	Phan, Xuyen Kim, Ph.D. candidate	K5-M12
92807	Preisig Heinz A, Professor	K4-233
98354	Radstake, Paul, Ph.D. candidate	K5-M4
	Rafiee, Ahmad, Ph.D. candidate	K4-406
94156	Rane, Shreyas P., Ph.D. candidate	K5-158
91686	Rodionova, Galina, Ph.D. candidate	PFI-3209
94139	Roel Jan Morten, Principal Engineer	Kh-155
94150	Roel Lisbeth H B, Executive Officer	K5-101
94125	Rout, Kumar Ranjan, Ph.D. candidate	K5-145
50536	Rusu, Marius, Ph.D. candidate	PFI-3206
94147	Rytter Erling, Adjunct Professor	K5-M11
94121	Rønning Magnus, Associate Professor	K5-408
50318	Samseth, Jon, Adjunct Professor	K4-333
50331	Sánchez, Rafael, Ph.D. candidate	K5-237
	Sandru Marius, Post doctor	K4-224
94073	Setekleiv Eddie, Ph.D. candidate	K5-M6
	Shamsuzzoha, Mohammad, Post doctor	K4-227
91657	Simon, Sebastien, Post doctor	PFI-3406
95505	Sjöblom Johan, Professor	K5-344
	Skancke, Jørgen, Ph.D. candidate	K4-212
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94124	Skjøndal-Bar, Nadav, Associate Professor	K4-227
94154	Skogestad Sigurd, Professor	K4-211
94114	Sporleder, Federico, Ph.D. candidate	K5-247
94106	Sundseth Frode, Engineer	K5-033
94187	Surma, Miroslav, Ph.D. candidate	K5-M9
94100	Svendsen Hallvard, Professor	K4-435
50540	Sætran, May Grete, Senior Engineer	PFI3404
91668	Tanase, Mihaela, Ph.D. candidate	PFI-3205
94119	Thorsen Gunnar, Professor Emeritus	K5-M8
	Trollebø, Anastasia, Ph.D. candidate	K4-308
50322	Tronstad, Ingvild, Ph.D. candidate	Kh-109
94146	Tsakoumis, Nikolaos, Ph.D. candidate	Kh-249
94126	Udani, Charitha, Ph.D. candidate	K5-158
94136	Uddin, Mohammad, Ph.D. candidate	K5-225
94182	Vanhaecke, Estelle, Post doctor	K5-430
92831	Venvik Hilde, Associate Professor	K5-406
	Vevelstad, Solrun, Ph.D. candidate	K4-430
94126	Vicinanza, Nicla, Ph.D. candidate	K5-158
94149	Volden Sondre, Post doctor	K5-308
94189	Voronov, Alexey, Ph.D. candidate	Kh-104
94193	Wang, Hongmin, Post doctor	K h-250

50331	Wang, Lijuan, Ph.D. candidate	K5-237		Yu, Qiang, Post doctor	K4-213
50372	Wang, Yuefa, Post doctor	K5-156		Zakeri, Ali, Ph.D. candidate	K4-308
94078	Wangen, Espen, Post doctor	K5-432	94155	Zhao Tiejun, Post doctor	K5-432
50536	Xhanari, Klodian, Ph.D. candidate	PFI-3206	94126	Zhu, Jun, Post doctor	K5-158
50537	Yamakawa, Asuka, Researcher	PFI-3207	94018	Øye Asbjørn, Chief Engineer	K5-145
93146	Yang, Jia, Ph.D. candidate	K5-411	94135	Øye Gisle, Professor	K5-307
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