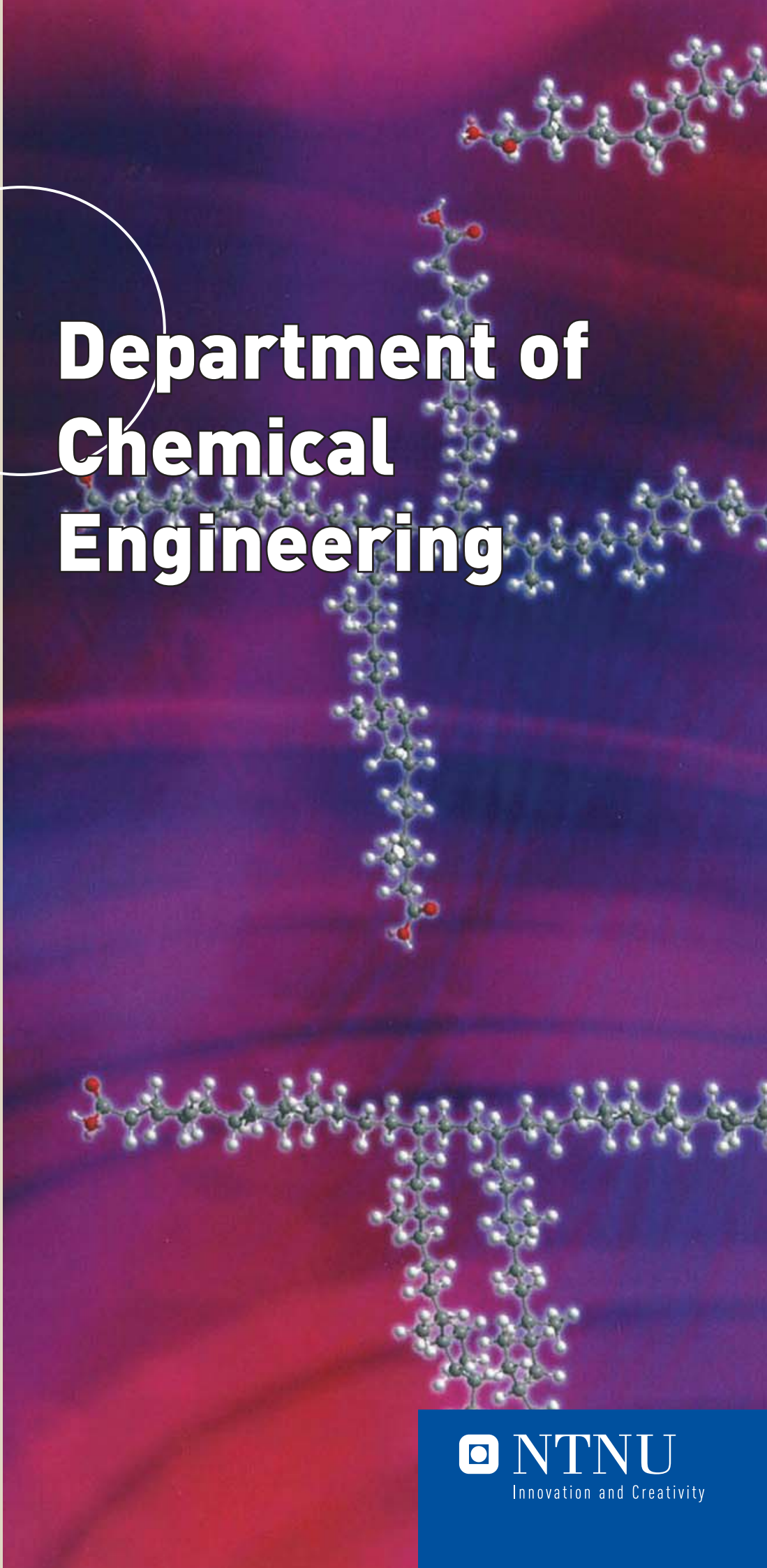
# Department of Chemical Engineering

Annual Report 2005



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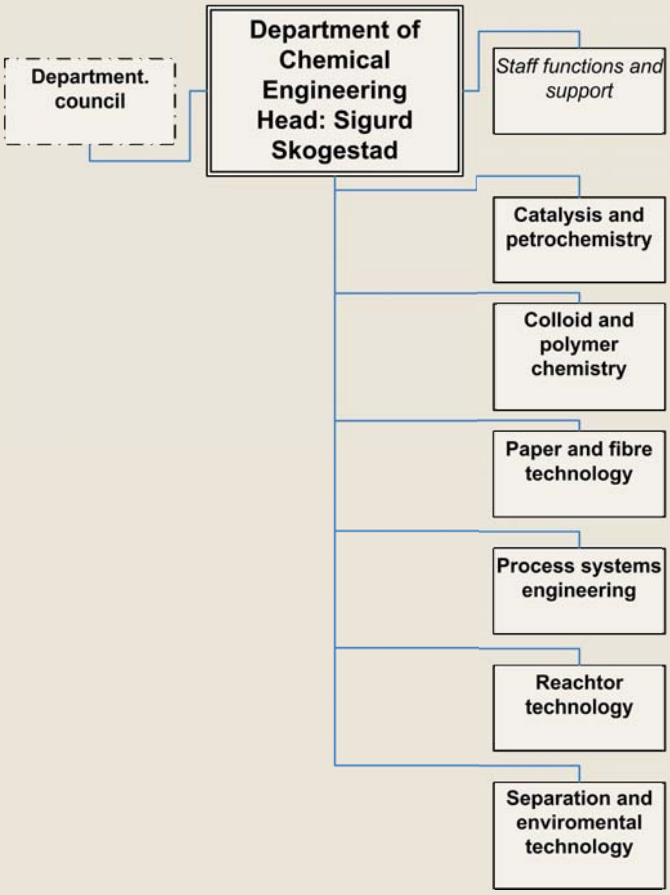


**Staff**
Academic staff, see the individual research groups:

**Technical and administrative staff:**
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Engineer Harry Brun
Principal Engineer Hung-Hsun Lee
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Engineer Arne Fossum
Engineer Jan Morten Roel
Principal Engineer Bodhild Øvrevoll

COVER PAGE
Archeal $C_{80}$ isoprenoid tetraacids responsible for naphthenate deposition in crude oil processing.

# DEPARTMENT OF CHEMICAL ENGINEERING, NTNU

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Printed March 2006
Prepared and edited by Lisbeth Blekkan Roel, Tom Helmersen, Sigurd Skogestad

# CHAPTER 1: INTRODUCTION

## Introduction to Annual Report 2005

2005 was another successful year for the Department of Chemical Engineering at NTNU. In particular, the research output, for example, as expressed by number of graduated Ph.D. candidates and publications, has increased to a new all time high. The number of publications in international journals soared from about 50 in 2003 and 2004 to about 80 in 2005. 13 Ph.D. graduated in 2005 and this number is expected to increase in 2006 and 2007.

In January 2005 *Førsteamanensis* Dr. Gisle Øye was welcomed as a new permanent member of our faculty in the area of colloid chemistry with emphasis on multifunctional nano structures. In September 2005 Dr. Egil Guldbrandsen (IFE Kjeller) was hired in a temporary Professor II (Adjunct professor) in the area of corrosion inhibitors physical chemistry.

In terms of future plans, we follow quite closely the Departments strategic plan from April 2003, which is available on the Departments home page. The Department has by now almost completed a major change in its academic staff, with 10 new fulltime faculty members being hired since 2001. A position (*førsteamanuensis*) in polymer chemistry / nanotechnology was announced in 2005, and a decision has been made to offer the position to Dr. Wilhelm Glomm, who will start in April 2006. At present, we are announcing a position (*førsteamanuensis / professor*) in process design, which is expected to be filled during 2006. At the end of 2006, we plan to announce a position (førsteamanuensis / professor) in systems biology.

Some important events for the Department in 2005. Dr. Zhixin Yu, who obtained his Ph.D. degree with Professor Anders Holmen as his advisor, was awarded the price for the best Ph.D. thesis for 2004-05 in the Faculty of Natural Sciences and Technology. Dr. Katrine Hilmen at ABB in Oslo, who got her doctoral degree in our Department in 2000, was announced by MIT to be one of the 35 most important innovators under 35 years in the world. Two books were published in their second edition in 2005. Johan Sjöblom (editor) published "Emulsions and emulsion stability" on Taylor and Francis, and Sigurd Skogestad and Ian Postlethwaite published "Multivariable feedback control" on Wiley.

A little about our building facilities. The Department is housed mainly in Chemistry building 5 *(kjemiblokk 5)*, and in addition has about half of Chemistry building 4, two floors in the PFI building, and two large experimental labs in "building 6" where SINTEF is located. Building 5 was recently renovated externally, and we are presently remodelling the labs on the third floor. The cost for this is about 4 million NOK, of which it at present seems that the Department must pay 50% from its own funds. In the mean time, most of the lab activity for the Ugelstad laboratory has been moved to the PFI building. There are almost two floors of empty space in building 4, as the Department of Materials Science has just moved out, but we are awaiting a decision from the Faculty on their future use. A problem in building 4 seems to be the lab ventilation. The mechanics in the Department (Roel, Hovin) moved in December 2005 into a new M*onteringshall* in the premises where the Faculty workshop used to be.

The main problem area for the Department is the low student enrolment and output of Master students. For more than 15 years, until 2002, the Department graduated on average more than 60 MS (diploma) students per year, but since 2004 it has dropped to about 30, and it is expected to remain at this low level at least until 2010. Our Department does not have a separate intake and our main recruitment base is the students entering the first year the 5-year program in *kjemi- og bioteknologi*. About 50% of these students choose our Department for their specialization after the second year. This fraction has remained almost constant over the last 30 years. The main reason for our low student numbers is therefore a drop in the intake to the first year, which is presently at about 60, whereas it historically (over the last 30 years) was around 120. In order to rectify this situation, the Department already in 2000 initiated the formation of *Samarbeidsforum* which deals with student recruitment and is funded by industry. In spite of this significant effort, the numbers have remained low. It is expected that the significantly improved labour marked will give an increase in the intake in 2006, but these candidates will not be available on the marked until 2011. The Department is planning to enlarge its recruitment base by offering an International Master degree in Chemical Engineering starting from 2007.

March 2006

Sigurd Skogestad
Head of Department

# CHAPTER 2: RESEARCH

## CATALYSIS AND PETROCHEMISTRY GROUP

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Adjunct professor Erling Rytter
Associate professor emeritus Egil Haanæs

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Tiejun Zhao

**Scientist**
Geir Haugen

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Hilde Dyrbeck
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Silje Fosse Håkonsen
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Hilde Meland
Esther Ochoa Fernandez
Sølvi Storsæter
Espen Standal Wangen
Ingrid Aartun

**Guests**
Sara Lögdberg (PhD from KTH, Sweden)
Dewi Tristantini (PhD from Chalmers, Sweden)
Antti Tynys (PhD from HUIT, Finland)

**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 the university (NTNU, former NTH) and the research company (SINTEF, a large polytechnic research organisation) cooperate and 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 cooperates closely with a number of universities and research groups inside and outside the EU.

**The group and the laboratories**
At present the group comprises about 40 people: 5 professors, about 10 fulltime research scientists holding Ph.D's, 4 Post.doc's and about 16 Ph.D students. The laboratories and equipment include a large number of micro reactors 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 (surface science), the other groups in 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 KINCAT group**

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

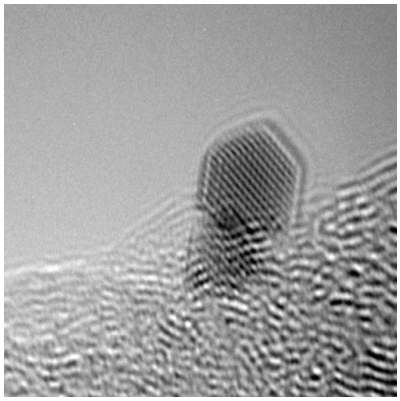
**Natural Gas Conversion**
Natural gas is an abundant hydrocarbon fuel and chemical feedstock, and utilizing this resource with minimum environmental impact is a major challenge to catalysis. It is the main goal of the present programme

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.

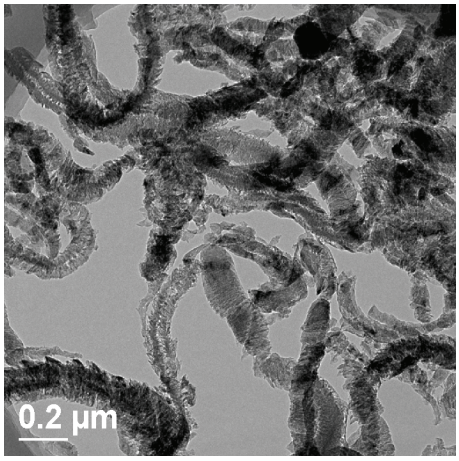
**Hydrogen Technology**
Particular attention is directed towards hydrogen technology: Catalysis is important in the production of hydrogen from hydrocarbons. Natural gas in an important source of hydrogen, and research is thus linked to syngas issues. In addition, the conversion of "transportable" hydrogen 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.

**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. New hybrid materials are also being synthesized where the active metal is included in the support during production. 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

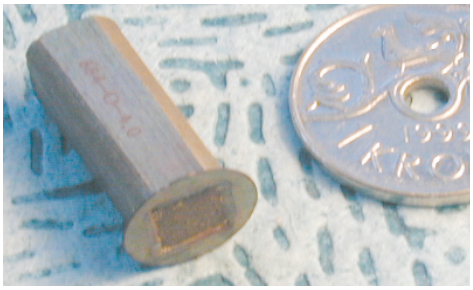


***Au/CNF (Carbon Nanofiber. TEM image)***




***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, Norsk Hydro and Statoil is directed towards the use of high-temperature proton-conducting membranes in hydrogen production with $CO_2$ capture.



***Microstructured reactor for hydrogen production – a collaboration with Forschungszentrum Karlsruhe.***

**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.

**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.

***Examples of industrial catalysts***

# COLLOID- AND POLYMER CHEMISTRY GROUP (UGELSTAD LABORATORY)

**Academic staff**
Professor Johan Sjöblom
Professor Preben C. Mørk
Associate professor Gisle Øye
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Adjunct professor John Daniel Friedemann
Adjunct professor Michael Stöcker
Adjunct professor Per Stenius
Professor emeritus Arvid Berge

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Martin Smestad Foss
Martin Fossen
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Andreas Hannisdal
Ingvild Andersen Johnsen
Magne K. Knag
Anne Silset
Bjørn Thomassen
Sondre Volden
Torbjørn Vrålstad

**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.

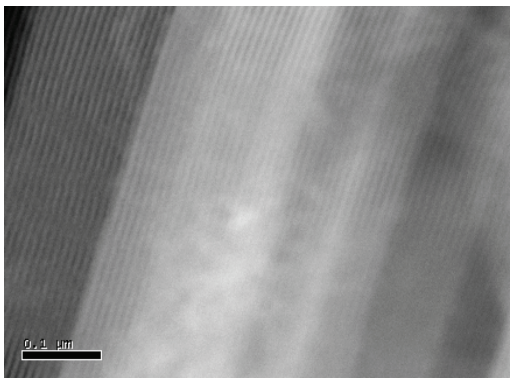
Diploma and Ph.D. studies are offered within these topics, often in close collaboration with industrial companies. The aim is to educate highly qualified candidates for industrial positions. In order to attract the best and most motivated students and researchers, the laboratory has invested in new and 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 2005 are briefly described. For a complete description of the research activities at the Ugelstad Laboratory, please visit our web page: http://www.chemeng.ntnu.no/research/polymer/ugelstadlab/

**Scientific Design and Preparation of New Catalysts and Supports, 2002 - 2005**
This Strategic University Program started during 2002 and the main objective is to gain fundamental insight into preparation techniques of inorganic oxides for use as catalysts and catalyst supports. Properties such as particle size, porosity, pore size and so on will be systematically investigated with respect to functionalisation and catalytic performance.

The project is in collaboration with the Catalysis and Petrochemistry group at NTNU (Department of Chemical Engineering) and SINTEF Applied Chemistry (Oslo), and is fully financed by the Research Council of Norway (NFR).



***STEM image showing the hexagonal ordering of SBA-15.***

**Strategic Reorganization Plan (SRP) 2003-2006**
Sponsored by The Research Council of Norway (NFR) and the Ugelstad Board members, this strategic reorganization plan aims at establishing the Ugelstad Laboratory as a nationally and internationally recognized laboratory within the field of colloid- and polymer chemistry with an expanded research profile based on the following research themes:
* Colloid chemistry within crude oil technology
* Colloid chemistry within nanotechnology and materials science
* Colloid chemistry within polymer science

This strategy came about as a result of an evaluation of Norwegian scientific research groups done by The Research Council of Norway (NFR).

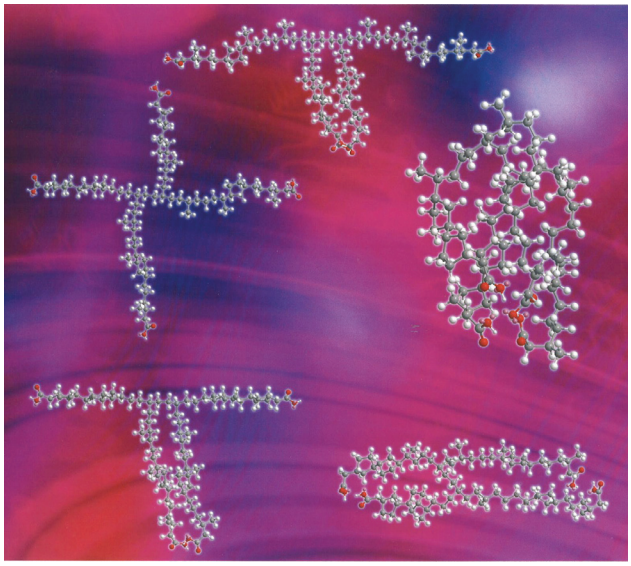
**Particle-stabilized emulsions/Heavy crude oils, 2003 - 2006**
The project aims at a better understanding of stabilizing and destabilizing mechanisms of water-in-crude oil emulsions based on heavy and particle-rich crude oils for improved separation and transport. The main technological goals to achieve will be to improve the water/oil/gas separation and sub-sea transport of multiphase systems. Separation: mechanisms of stabilization / destabilization / electrocoalescence / water and oil quality. Transport: energy input / emulsion stability / rheological models.

Technical collaboration: Ugelstad Laboratory, Sintef Energy, Statoil ASA and Vetco.
**Treatment of Produced Water: Characterization and New Treatment Strategies.**
**Petromaks program (NFR).**
The research tasks in this proposal will contribute to the development of new and improved technology for a more efficient and cost effective treatment of produced water from offshore installations. A fundamental necessity of developing and designing any treatment scheme is the knowledge and understanding of the fluid to be treated. Determining characteristics of the major substances in the produced water will therefore be of high priority. The work on treatment strategies will then focus on two areas: treatment of suspended constituents and of dissolved/soluble constituents. A major factor in achieving a zero harmful discharge to sea is the removal of suspended solids and dispersed oil from produced water. Particle separation is a fundamental process in any treatment process for the production of high quality effluent from an aqueous stream. The removal of dissolved constituents in produced water is necessary within the zero harmful discharge network. One of the research tasks in this proposal is to investigate the applicability of biological degradation of specific target compounds.

**Development of new bio based materials using nanotechnology.**
The main objective of this project, which is a collaboration with SINTEF and PFI is to create new functional biofibre-based materials with industrially attractive properties. Functionalized nano-sized cellulose microfibrils (MFC) will be developed by modification of never-dried MFC using tailored chemical coupling reactions.

**Structure, behaviour and reactivity of tetrameric naphthenic acids (ARN) in bulk and at w/o interfaces 2005-2008**
The naphthenate R&D group at Statoil has done very systematic work during the past years to identify the structure of the naphthenic acid being the most active in forming metalnaphthenate deposits, which is a severe obstacle in processing of acid crudes. The results from the Statoil research in this field are pioneering, and have lead to the discovery of the so-called ARN naphthenic acid, which represents an acid family of C80 tetramers. The reults from the Statoil discovery have recently been published, and one can foresee a heavy international scientific follow-up in this area in the years to come.

The objective of this programme is to focus on combining the efforts of the Statoil Naphthenate R&D Group and from our recently completed VISTA project. In the new VISTA programme, we are going to undertake a fundamental study of the ARN family of naphthenic acids with regard to clarify the structure(s), the physico-chemical properties, the interfacial activity and reactivity, selectivity in reaction patterns with multivalent cations, filmforming properties, etc.
* Structure and chemistry of ARN
* Physico-chemical properties
* Interfacial activity
* Reactivity
* Selectivity in reaction patterns with multivalent cations
* Film forming properties



***Archeal $C_{80}$ isoprenoid tetraacids responsible for naphthenate deposition in crude oil processing.***

## PROCESS SYSTEMS ENGINEERING GROUP

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Professor Heinz A. Preisig
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Jens Petter Strandberg
Federico Zenith
Zhengjie Zhu

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 presently consists of about 20 people being housed by the Department of Chemical Engineering. 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 spear-point center" both by NTNU and SINTEF.

At present, the main activities in the group are within process control and process modelling including efficient thermodynamic calculations. There are plans to start an activity in systems biology.

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 (Skogestad, Preisig), the objective of the research is to develop simple yet rigorous tools to solve problems significant to industrial applications (of engineering

***First row: Heidi, Stathis, Vinay, Eduardo, Zhengjie***
***Second row: Jens, Heinz, Sigurd, Andreas, Antonio***
***Last row: Terje, Olaf, Jens, Federico, Bjørn Tore, Tore.***

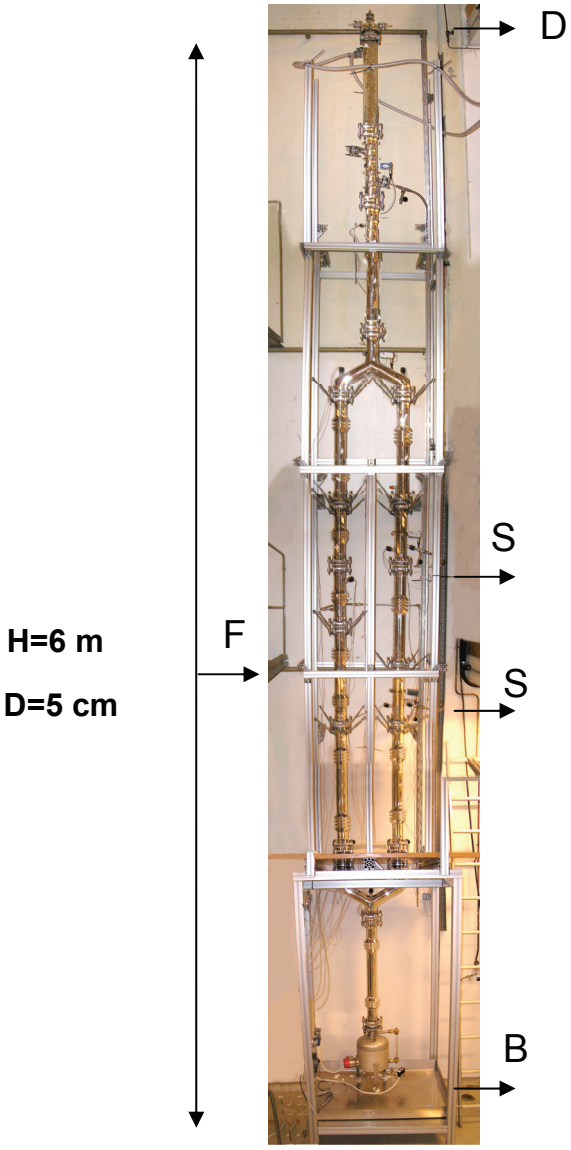
significance). Up to now, the design of the overall "plant-wide" control structure has been based on engineering experience and intuition, whilst the aim has been to develop rigorous techniques. The concept of "self-optimizing control" provides a basis for linking economic optimization and control (Skogestad). 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. 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. The group also has an automatic drink mixer, which is used for demonstration purposes and to study sequence control based on automata theory (Preisig).

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 mechanism. The equations are then generated and assembled automatically taking the applicable equations from a data base that has been built applying mechanistic descriptions where ever applicable. 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. 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. The fourth generation of a high-level modelling tool is presently being developed (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 differentation capabilities and serves as the basis of several industrial strength simulations (YASIM, CADAS) and energy accounting tools (HERE) in co-operation with Norsk Hydro and Yara.

The model generally needs to be fitted to experimental data, and the group has always has a strong focus on statistical methods and experimental design (Hertzberg). In 2006 professor Kim Esbensen will join the group as professor II in the area of process chemiometrics.

Financing comes from the Norwegian Research Council, the Gas Technology Center at NTNU and SINTEF, from industry (Statoil, Gassco, Hydro) and from the EU (Promatch program).




***Kaibel distillation column.***

# REACTOR TECHNOLOGY GROUP

**Academic staff**
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Jana Poplsteinova Jakobsen

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Rune Engeskaug
Ardi Hartono
Thomas Helsør
Erik Troøien Hessen
Cecilie Gotaas Johnsen
Inna Kim
Håvard Lindborg
Kurt Schmid
Sholeh Ma'mun
Hans Kristian Rusten
Eirik Fack da Silva
Andrew Tobiesen
Margrete H. Wesenberg

The Reactor Technology group has concentrated its activities 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.
- Experimental analyses of fluid flow and heat transfer phenomena in chemical reactors.
- Multiphase flow modeling.
- Experimental validation of numerical models.
- Environmental technology (e.g., gas cleaning of $CO_2$).

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 and have experience with most of the important toolboxes.

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

However, the computationally demanding models are implemented in FORTRAN 90 and c++. Application areas are special chemicals reactors, polymer production, synthesis gas and methanol synthesis, membrane reactors, and reactive absorption of acid gases (e.g. $CO_2$) including membrane contactors.

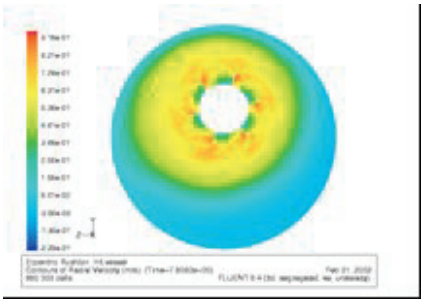
Educationally the main objective of our group is to educate MSc for the Norwegian industry and to raise the National scientific competence in our field of research through PhD studies.

**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/).

***Bubble column used for studies on solid particle concentration, bubble size and void fraction.***

**Modeling of multi-phase reactors**
We have for more than 15 years been developing in-house CFD codes for simulating multiphase flows in chemical reactors. We also license the commercial CFD code FLUENT. 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 methods designed for this particular purpose. See the CARPET project, http://www.CARPET.ntnu.no.

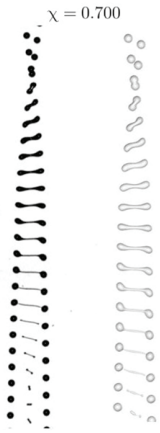
We are also investigating the performance of chemical reactive systems like fluidized beds, fixed bed reactors and agitated tanks. At present we are working with the design of suitable reactors for sorption enhanced reaction processes (SERP) like steam reforming with absorbents for $CO_2$.



***Simulation of the flow pattern from an off-center turbine impeller.***

The dynamic 2D CFD simulations are normally run on standard PCs whereas the more computationally demanding 3D simulations are run on the national super-computers located at the university.

**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. A project is established for studying the phenomena governing such separations, see http://www.HiPGaS.ntnu.no. In collaboration with six industrial partners separation rigs have been established for both low and high (<150 bar) pressures at NTNU and at Statoil. Results from the high pressure rigs are unique and form a basis for model validation. In addition a laser laboratory is built for the study of droplet/droplet and droplet/surface collisions and for studies on the stability and break-up of liquid surfaces leading to re-entrainment of droplets.




***Droplet collision leading to break-up. Experimental result to the left and model right.***

**$CO_2$ removal from natural – and exhaust gases**
(http://www.ntnu.no/satsingsomraader/energi_miljo/miljogass.htm).
The activity in this area comprises several projects, partly funded by the Research Council, industry and the European Union. We are heavily involved the EU FP6 Integrated Project CASTOR, see http://www.co2castor.com . The work is concentrated along two axes, one studying $CO_2$ capture from off gases from fossil fueled power plant and from the iron and steel-making industry, and the other directed toward the removal of acid gases from natural gas. The aim in CASTOR is to develop new solvents and process equipment that enables us to capture $CO_2$ at a cost of 20-30€/ton $CO_2$ and to halve the energy requirement in the process. This work involves all the steps from theoretical screening by use of computational chemistry, through experimental screening, characterization of equilibria, thermal properties, transport properties and kinetic, to testing in a laboratory pilot plant. In parallel we develop models for mass transfer and for the whole absorption/desorption process. Other projects in this area are EU FP6 ULCOS, and the Research Council financed BIGCO2.

***Laboratory pilot plant for $CO_2$ capture by absorption***

## SEPARATION AND ENVIRONMENTAL TECHNOLOGY GROUP

**Academic staff**
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Adjunct professor Didrik Malthe-Sørenssen
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Professor emeritus Jørgen Løvland
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Lei Shao
Willy Thelin

The research in the group of Separation and Environmental Technology is focused upon the two main areas of membrane separations, i.e. gases and liquids, as well as membrane material development, and separation by crystallization.

**1. Membrane separation of liquids:**
***Sample project:*** **Developing Pressure Retarded Osmosis (PRO) for power production**.
Membrane separations in liquid media are well established in many processes and expected improvement may often be small and incremental, but still there are many open problems.
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.

To make this principle to work economically, the membrane and its function is of very large importance.

One of the problems to eliminate or reduce is the gradually fouling of the membranes by different impurities in the water and also the possibility of bacterial and algae growth on the membranes. This will gradually reduce the water flux through the membrane. In two doctoral projects in our group these problems have been under investigation for the last few years. The studies are performed in experimental membrane rigs, equipped with automatic cleaning cycles and remote data reading.
One set of experiments is performed in small cells which are designed to uncover the types of fouling that may occur on contacting Norwegian river water with sea water from a fjord. Cleaning procedures and frequencies of are tested during the experiments which are run continuously for several months. Verifying experiments for comparison are run in a local laboratory.
Another set of experiments on a larger rig is aiming at optimizing membrane modules of a new construction for use in salinity power plants. Included in this part of the project is also computer modelling of the flow through the modules.
The experiments are done in cooperation with SINTEF and others, and are partly financed by Statkraft.

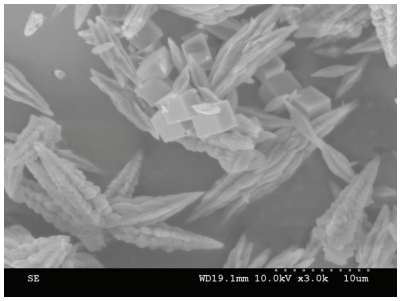
**2. Crystallization**
The research within crystallization is focused at kinetics of nucleation, crystal growth, and agglomeration in order to predict and control the particle size distribution and shape of crystalline particulate products for the effect on down-stream processes like solid-liquid separation and powder characteristics.

In 2005 one researcher has been working in a project directly financed by GE Healthcare to analyse the separation and purification in a bottleneck intermediate crystallization step in their production units at Lindesnes, Norway.

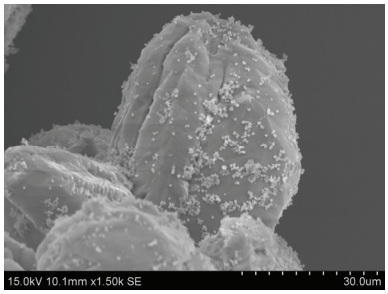
Two joint projects have been started up in 2005 employing 2 PhD candidates and 1 Post Doc for the period 2006-2008/2009.

***Sample Projects:***
**a) 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 crystallization behaviour of salts and scale-forming carbonates in ethylene glycol 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).



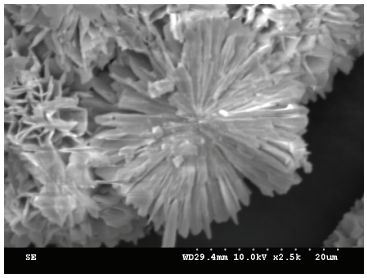

***Different polymorphs of calcium carbonate crystals (2-20 µm) in water-glycol solutions***

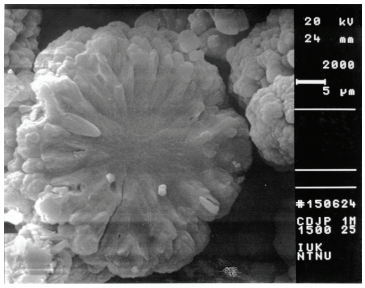



***Precipitation of sub-micron calcium carbonate crystals on larger particles of sodium carbonate***

**b) Industrial Crystallization and Powder Technology**

The goal of this project is to relate filtration and washing characteristics and powder 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 parameter choices 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 SEM-micrographs reveal similar spherulitic growth pattern in 30 micron particles of an aromatic amine (top) and inorganic calcium carbonate (bottom).***

**3. Membranes for gas separation**

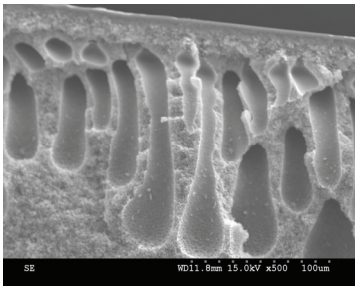
The Memfo group,
http://www.chemeng.ntnu.no/memfo
currently counts 9 members (5 PhD-students, 2 post docs, 1 senior researcher, and the head of the group, professor May-Briitt Hägg)
Two PhD-students received their doctoral degree in 2005; one on carbon membranes for biogas upgrading and one on membrane development for chlorine purification. 7 presentations were held at international conferences and 5 papers submitted to high profile journals (4 are published), and one PCT accepted for patent application.
The group has 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 applications, the research on membranes for chlorine separation continues. The membrane materials in focus are various types of polymers, nanocomposites, 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 projects***

**a) EU-project NaturalHy** http://www.naturalhy.net
The project counts ~40 partners, and the main idea is to investigate the possibility of using the European gas net work 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 (for fuel cells or storage). The task into which Memfo is doing research, is development of suitable membrane(s) for hydrogen recovery. Carbon molecular sieve membranes as well as mixed matrix materials are investigated for this purpose. One PhD-student and one post doc is engaged in this research. Very promising results have been documented. The project continues for 3 more years; project co-ordinator is Gas Unie in the Netherlands

**b) Membrane development for selective $CO_2$ capture**

The membrane material being developed in this project contains a specific "carrier" which makes it selective for $CO_2$ while other gas components are being retained. The material is based on a polymer containing fixed amine groups as carriers. A significant progress was achieved during 2005, 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 now patented, and there are big expectations for the further development. The project runs for 2 more years; then hopefully the membrane is ready for small scale pilot testing. One senior researcher, one PhD, and one "associated PhD" is working on the project. Next step will be focusing on process development. Project partners are NFR, Statoil and Alstom




**SEM-picture showing a cut through a composite membrane. Thickness of Selective layer is~2µm**

**c) Two projects within the Nanomat program / NFR**

in cooperation with Sintef and North Carolina State University. In both projects the material development for hydrogen – $CO_2$ separation are in focus. There are two PhD-students on the US-side; one PhD and one Post doc on the NTNU-side, in addition to one "associated PhD" on the NTNU-side. The materials under development here are nano-composites (so called mixed matrix) and block copolymers – very challenging and very promising. Within this project a NASA award was granted during 2005 for a US patent.

**d) Development of hybrid membrane for chlorine purification**

Memfo is one of very few groups in the world doing research on membranes for the purification of chlorine gas. This is probably for security and safety reasons, and the challenge of handling this poisonous gas. The project is extremely challenging, but if successful, it will be a major step towards simplification of expensive and complicated unit operations for recovery of chlorine from various process streams. Chlorine is one of the major chemicals used in chemical process industry worldwide. The materials in focus are glass and perfluorinated polymers. There is co-operation with Japanese research in this project. Small steps forward have been documented during 2005, and one post doc is currently on the project. There is a major interest from industry in this project.

**e) Various**

The Memfo group works very much as a team rather than as individual reseachers. 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 although there is not any large ongoing project on this. Co-operation with Aalborg University, Denmark, is performed through student projects. Carbon membranes has proved to be suitable for upgrading of biogas, and documented by experiments in 2005. Applications for projects with Denmark and Russia (Univ. of St. Petersburg) were filed in 2005 – the co-operation is already active.

Application for a project within the 6$^{th}$ FWP, EU, was filed in early 2005; it obtained a very high score, and was granted in December 2005. The project will focus on "Nanomaterials against Global Warming" (=NanoGloWa). Memfo will be a major partner in this project, with focus on both carbon membranes and polymeric materials.

Memfo is also an active partner in the EU-project ENGAS http://www.ntnu.no/engas - a special project which promotes the laboratory facilities at NTNU/Sintef within energy, and make them available for international co-operation.

Within the EU-project ULCOS (=Ultra Low $CO_2$ emissions from Steel industry) Memfo has, in co-operation with Sintef, investigated the potential for use of selected membranes for $CO_2$-capture

## PAPER AND FIBRE TECHNOLOGY GROUP

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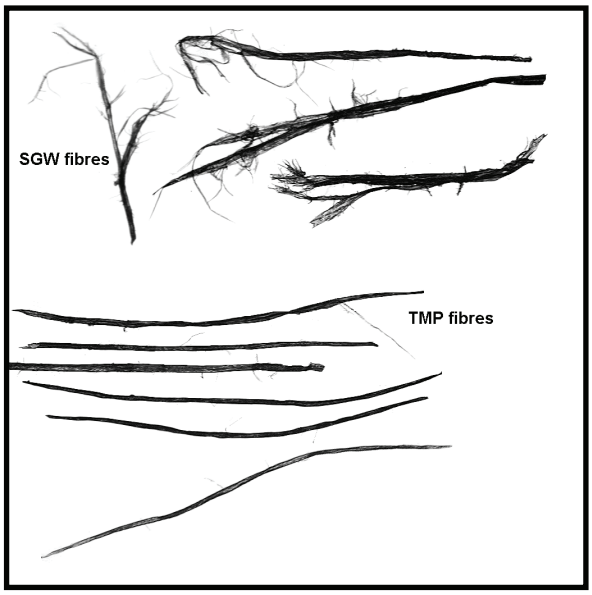
Marianne Lenes
Hilde Lyngstad
Tommy Nesbakk
Håkon Nordhagen
David Vaaler

The Paper and Fibre 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. The Paper and Fibre 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. We also cooperate closely with pulp and paper industry partners such as Norske Skog, Södra Cell, Borregaard, Peterson and Voith.

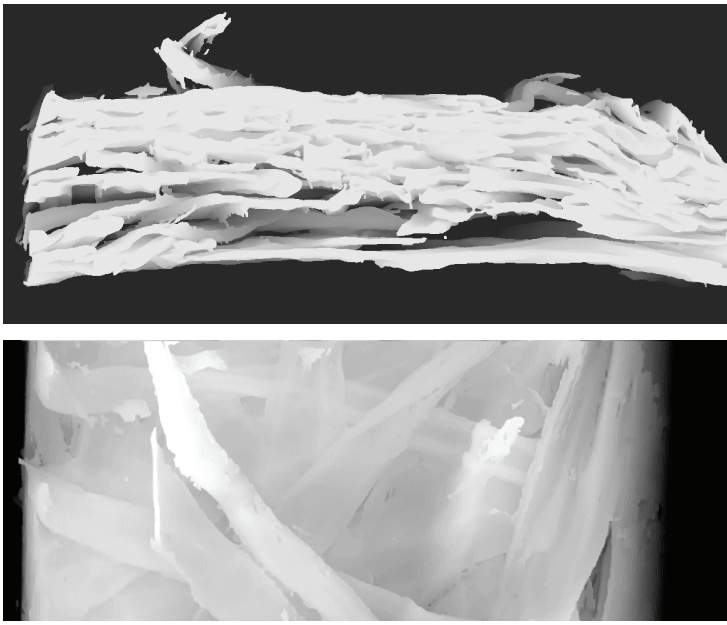
Our research is focused on improvements in the pulp and paper process and on improved end product quality. Examples are:

- Reduced energy consumption and/or better fibre properties of mechanical pulp through high intensity refining, co-refining of different raw materials or pretreatment of wood chips.
- Increased brightness or reduced bleaching chemical consumption through separate bleaching of different particle size fractions of mechanical pulp.
- Reduced print through defect in newsprint by optimized sheet structure

The last years a new activity on use of cellulose based particles in composite materials have also started. Goals here are improved strength, barrier and surface properties.




***Improvement of the fibre production process and fibre quality is one central research topic.***



***Quantification of paper structure and design of the optimal structure for different end use properties of paper is another central research topic***

## CHAPTER 3:

### PUBLICATIONS IN REFEREED JOURNALS.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75. **Silva, Eirik Falck da; Poplsteinova, Jana; Ma'mun, Sholeh; Svendsen, Hallvard Fjøsne**. Characterization of new absorbents for CO2 capture; combination of experimental work, engineering models and computaitonal chemistry [Vitenskapelig foredrag]. The Third Trondheim Conference on CO2 Capture, Transport and Storage; 10.10.2005 - 11.10.2005

76. **Sjöblom, Johan; Hannisdal, Andreas; Ese, Marit-Helen**. Fluid Characterizatuib and Multiphase Flow [Vitenskapelig foredrag]. Norway - North America Petroleum Research Workshop; 31.10.2005 - 03.11.2005

77. **Sjöblom, Johan; Hannisdal, Andreas; Ese, Marit-Helen**. The Influence of Interfaces on Multiphase Flow [Vitenskapelig foredrag]. SPE 2005 Forum Series. "Molecules on move. Physico-Chemical Effects on Multiphase Transport"; 23.10.2005 - 28.10.2005

78. **Stenstad, Per; Tanem, Bjørn Steinar; Nygård, Per; Schult, Tove; Syverud, Kristin; Andresen, Martin; Moe, Størker; Stenius, Per**. Tailor-made films from cellulose microfibrils [Poster]. Birkeland-NANOMAT conference 2005 Norges forskningsråd; 02.06.2005 - 03.06.2005

79. **Storkaas, Espen; Skogestad, Sigurd**. Controllability analysis of an unstable non-minimum phase process [Vitenskapelig foredrag]. 16th IFAC World Congress; 04.07.2005 - 08.07.2005

80. **Storsæter, Sølvi; Borg, Øyvind; Blekkan, Edd Anders; Holmen, Anders**. Effect of water on Co-Supported Fischer-Tropsch Catalysts [Vitenskapelig foredrag]. Norwegian Catalysis Symposium; 20.11.2005 - 21.11.2005

81. **Svendsen, Hallvard Fjøsne**. CO2 capture technologies, an overview and status [Vitenskapelig foredrag]. Guest Lecture, Xiangtan University 2005

82. **Svendsen, Hallvard Fjøsne**. Post Combustion and Absorption Processes [Vitenskapelig foredrag]. US-Norway Summer School 2005

83. **Tobiesen, Finn Andrew; Svendsen, Hallvard Fjøsne**. Innfanging av CO2 med absorpsjon; potensiale for forbedring [Vitenskapelig foredrag]. Gass- og energiteknologi 2005 Tekna; 07.06.2005 - 08.06.2005

84. **Tobiesen, Finn Andrew; Svendsen, Hallvard Fjøsne; Juliussen, Olav**. Experimental validaiton of a model for CO2 post-combustion capture system using monoethanolamine (MEA) [Vitenskapelig foredrag]. 8th International CO2 Capture Network; 03.10.2005 - 04.10.2005

85. **Tobiesen, Finn Andrew; Svendsen, Hallvard Fjøsne; Juliussen, Olav**. Experimental validation of a model for CO2 post-combustion capture using monoethanolamine (MEA) [Vitenskapelig foredrag]. The Third Trondheim Conference on CO2 Capture, Transport and Storage; 10.10.2005 - 11.10.2005

86. **Tobiesen, Finn Andrew; Svendsen, Hallvard Fjøsne; Juliussen, Olav; Dindore, Vishwas Y.**. Experimental Validation of a Rigorous Model for CO2 Post-Combustion Capture Using Monoethanolamine (MEA) [Vitenskapelig foredrag]. The 2005 AICHE Annual Meeting; 01.11.2005 - 03.11.2005

87. **Tristantini, Dewi; Lögdberg, Sara; Gevert, Börje; Borg, Øyvind; Holmen, Anders**. A study of hydrocarbon production via Fischer-Tropsch (FT) synthesis from different model bio-syngases over un-promoted and and rhenium-promoted alumina supported cobalt catalyst [Poster]. SYNBIOS: Second-Generation Automotive Biofuels; 18.05.2005 - 20.05.2005

88. **Tristantini, Dewi; Lögdberg, Sara; Gevert, Börje; Borg, Øyvind; Holmen, Anders**. Effect of water addition on hydrocarbon production via Fischer-Tropsch synthesis from different model bio-syngases over unpromoted and rhenium-promoted alumina-supported cobalt catalysts [Poster]. EuropaCat-VII; 28.08.2005 - 01.09.2005

89. **Tsypkin, Mikhail; Briskeby, Stein Trygve; Kvande, Ingvar; Børresen, Børre; Chen, De; Tunold, Reidar**. PLATINUM ON CARBON NANOFIBERS AS ELECTROCATALYST FOR HIGH TEMPERATURE POLYMER ELECTROLYTE FUEL CELLS [Poster]. The 56th Annual Meeting of the International Society of Electrochemistry; 25.09.2005 - 30.09.2005

90. **Tsypkin, Mikhail; Johnsen, Sten-Egil; Marshall, Aaron; Rønning, Magnus; Sunde, Svein; Tunold, Reidar**. In-situ X-ray absorption spectroscopy of amorphous iridium oxide [Poster]. The 56th Annual Meeting of the International Society of Electrochemistry, Pusan S.Korea; 25.09.2005 - 30.09.2005

91. **Volden, Sondre; Glomm, Wilhelm; Øye, Gisle; Sjöblom, Johan**. Nanotemplating of Mesoporous Silica from Dendritic Polymers [Poster]. Nordic Polymer Days; 17.09.2005 - 19.09.2005. Publisert i: *Book of abstracts*; 2005

92. **Vrålstad, Torbjørn; Øye, Gisle; Glomm, Wilhelm; Rønning, Magnus; Stöcker, Michael; Sjöblom, Johan**. Characterization of Metal-Containing Mesoporous Materials by EXAFTS Spectroscopy [Vitenskapelig foredrag]. 3rd Norwegian User Meeting - Application of Synchrotoron Radiation; 10.03.2005 - 11.03.2005

93. **Vrålstad, Torbjørn; Øye, Gisle; Stöcker, Michael; Sjöblom, Johan**. Synthesis of Cobalt-Containing Mesoporous Model Catalysts [Poster]. 3rd FEZA Conference; 23.08.2005 - 26.08.2005. Publisert i: *Book of abstracts*; 2005

94. **Wesenberg, Margrete H.; Olsvik, Ola; Ströhle, Jochen; Svendsen, Hallvard Fjøsne**. Gas heated steam reformer: two-dimensional finite difference model with heater side discrete ordinates radiation scheme [Vitenskapelig foredrag]. 7th World Congress of Chemical Engineering; 10.07.2005 - 14.07.2005

95. **Yu, Zhixin; Borg, Øyvind; Chen, De; Frøseth, Vidar; Enger, Bjørn Christian; Rytter, Erling; Moljord, Kjell; Holmen, Anders**. Carbon nanofiber supported Co catalysts for Fischer-Tropsch synthesis with high activity and selectivity [Vitenskapelig foredrag]. 2nd NTNU Seminar Synthesis and Applications of CarbonNanofibers/Nanotubes 2005

96. **Zenith, Federico; Skogestad, Sigurd**. Control of a Fuel-Cell Powered DC Electric Vehicle Motor [Vitenskapelig foredrag]. Annual Meeting 2005 of the American Institute of Chemical Engineers; 30.10.2005 - 04.11.2005. Publisert i: *Conference Proceedings of AIChE 2005 Annual Meeting (CDROM), artikkel 398c*; 2005

97. **Zenith, Federico; Skogestad, Sigurd**. Dynamic Modelling and Control of Polybenzimidazole Fuel Cells [Vitenskapelig foredrag]. ECOS 2005; 20.06.2005 - 22.06.2005. Publisert i: *Proceedings of the ECOS 2005 Conference*; 2005

## CHAPTERS IN BOOKS

1. **Dukhin, Stanislav S.; Sjöblom, Johan; Sæther, Øystein**. An Experimental and Theoretical Approach to the Dynamic Behavior of Emulsions. I: *Emulsions and Emulsion Stability, 2nd edition*. New York: Taylor & Francis Books 2005. ISBN 0-8247-2695-2. s. 1-106

2. **Hemmingsen, Pål Viggo; Auflem, Inge Harald; Sæther, Øystein; Westvik, Arild**. Droplet Size Distribution of Oil-in-Water-Emulsions under High Pressures by Video Microscopy. I: *Emulsions and Emulsion Stability, 2nd edition*. New York: Taylor & Francis Books 2005. ISBN 0-8247-2695-2. s. 631-650

3. **Hemmingsen, Pål Viggo; Auflem, Inge Harald; Sæther, Øystein; Westvik, Arild**. Droplet Size Distributions od Oil-in-Water Emulsions under High Pressures by Video Microscopy. I: *Emulsions and Emulsion Stability, 2nd edition*. New York: Taylor & Francis Books 2005. ISBN 0-8247-2695-2. s. 631-649

4. **Hori, Eduardo Shigueo; Skogestad, Sigurd; Kwong, W.H.**. Use of perfect indirect control to minimize state deviations. I: *European Symposium on Computer Aided Process Engineering - 15*: Elsevier 2005. ISBN 0-444-51987-4. s. 1219-1224

5. **Jakobsen, Jana Poplsteinova; Svendsen, Hallvard Fjøsne; Krane, Jostein**. MODELING VLE FOR CO2-H2O-ALKANOLAMINE SYSTEMS AND NMR STUDY ON THE LIQUID PHASE COMPOSITION. I: *Proceedings of the 7th International Conference on Greenhous Gas Control Technologies, Volume II - Part 2*: Elsevier 2005. ISBN 0-080-44883-6. s. 1869-1872

6. **Jensen, Jørgen Bauck; Skogestad, Sigurd**. Control and optimal operation of simple heat pump cycles. I: *European Symposium on Computer Aided Process Engineering - 15*: Elsevier 2005. ISBN 0-444-51987-4. s. 1429-1434

7. **Ma'mun, Sholeh; Jakobsen, Jana Poplsteinova; Juliussen, Olav; Svendsen, Hallvard Fjøsne**. Modeling of Equilibrium Solubility of Carbon Dioxide in Aqueous 30 Mass % 2-(2-Aminoethyl)-Aminoethanol Solution. I: *Proceedings of The 18th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems*. Trondheim: Tapir Akademisk Forlag 2005. ISBN 82-519-2041-8. s. 741-748

8. **Ma'mun, Sholeh; Svendsen, Hallvard Fjøsne; Hoff, Karl Anders; Juliussen, Olav**. Selection of New Absorbents for Carbon Dioxide Capture. I: *Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies*: Elsevier 2005. ISBN 0-080-44881-X. s. 45-53

9. **Preisig, Heinz A.**. Computer-aided Modelling: A Study on the Dynamic Flash. I: *European Symposium on Computer Aided Process Engineering - 15*: Elsevier 2005. ISBN 0-444-51987-4. s. 271-276

10. **Silva, Eirik Falck da; Svendsen, Hallvard Fjøsne**. THE CHEMISTRY OF CO2 ABSORPTION IN AMINE SOLUTIONS STUDIED BY COMPUTATIONAL CHEMISTRY. I: *Proceedings of the 7th International Conference on Greenhous Gas Control Technologies, Volume II - Part 2*: Elsevier 2005. ISBN 0-080-44883-6. s. 1891-1895

11. **Sivertsen, Heidi; Skogestad, Sigurd**. Anti-slug control experiments on a small-scale two-phase loop. I: *European Symposium on Computer Aided Process Engineering - 15*: Elsevier 2005. ISBN 0-444-51987-4. s. 1021-1026

12. **Sjöblom, Johan; Øye, Gisle; Glomm, Wilhelm; Hannisdal, Andreas; Knag, Magne Kawai; Brandal, Øystein; Ese, Marit-Helen; Hemmingsen, Pål Viggo; Havre, Trond Erik; Oschmann, Hans-Jörg; Kallevik, Harald**. Modern Characterization Techniques for Crude Oils, Their Emulsions and Functionalized Surfaces. I: *Emulsions and Emulsion Stability, 2nd edition*. New York: Taylor & Francis Books 2005. ISBN 0-8247-2695-2. s. 415-476

13. **Tobiesen, Finn Andrew; Svendsen, Hallvard Fjøsne**. Modeling the Regeneration Units for Amine Based CO2 Absorption Plants: Introduction of an Organic Stripping Medium. I: *Proceedings of The 18th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems*. Trondheim: Tapir Akademisk Forlag 2005. ISBN 82-519-2041-8. s. 765-774

## BOOKS

**Sjöblom, Johan**. Emulsions and Emulsion Stability, 2nd edition. New York: Taylor & Francis Books 2005. ISBN 0-8247-2695-2. 670 s.

**Skogestad, Sigurd; Postlethwaite, Ian**. Multivariable Feedback Control. Analysis and Design. England: John Wiley & Sons 2005. ISBN 0-470-01168-8. 574 s.

## JOURNALS

**Johan Sjöblom, Editor-in-Chief:** Journal of Dispersion Science and Technology, Volume 26.
New York: Taylor & Francis Books 2005.
6 issues in 2005.

# CHAPTER 4: EDUCATION

## Chemical Engineering

The specialization in Chemical Engineering starts in the third year through the basic technological courses in Separation Technology, Reaction Engineering, Thermodynamics and Process Design. In the fourth year the students elect further specializations for the remaining of the studies. The students choose between 6 specializations: Petrochemistry and Catalysis, Colloid and Polymer Chemistry, Separation Technology, Reactor Technology, Process Systems Engineering and Pulp and Paper Chemistry.

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 university 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 PhD-studies in Chemical Engineering.

## Master courses given:

| Number | Course title | Year | Registered | Passed |
|---|---|---|---|---|
| TKP4100 | Fluid Flow and Heat Transfer | 2 | 83 | 54 |
| TKP4105 | Separation Technology | 3 | 73 | 44 |
| TKP4110 | Chemical Reaction Engineering | 3 | 81 | 59 |
| TKP4115 | Surface and Colloid Chemistry | 3 | 48 | 33 |
| TKP4120 | Process Engineering | 2 | 120 | 99 |
| TKP4125 | Paper and Fibre Technology | 4 | 3 | 3 |
| TKP4130 | Polymer Chemistry | 4 | 8 | 8 |
| TKP4135 | Chemical Process Dynamics and Optimization | 4 | 13 | 7 |
| TKP4140 | Process Control | 4 | 11 | 8 |
| TKP4145 | Reactor Technology | 4 | 10 | 10 |
| TKP4150 | Petrochemistry and Oil Refining | 4 | 12 | 9 |
| TKP4155 | Reaction Kinetics and Catalysis | 4 | 32 | 23 |
| TKP4160 | Transport Phenomena | 4 | 24 | 20 |
| TKP4165 | Process Design | 4 | 25 | 20 |
| TKP4170 | Process Design, Project | 4 | 24 | 24 |
| TKP4171 | Process Design, Project | 4 | 4 | 4 |
| TKP4700 | Catalysis and Petrochemistry, Specialization | 5 | 9 | 9 |
| TKP4710 | Colloid and Polymer Chemistry, Specialization | 5 | 0 | 0 |
| TKP4720 | Process Systems Engineering, Specialization | 5 | 4 | 4 |
| TKP4730 | Reactor Technology, Specialization | 5 | 1 | 1 |
| TKP4740 | Separation and Environmental Technology, Specialization | 5 | 5 | 5 |
| TKP4750 | Paper and Fibertechnology, Specialization | 5 | 4 | 4 |
| TKP4850 | Experts in Team, Interdisciplinary Project | 4 | 21 | 21 |
| TKP4500 | Final Year Design, for Spanish students | 5 | 2 | 2 |
| | | 2 | 2 | |

## Master students

### Master thesis 2005

*Bakksjø, Trine-Lise*
Characterization of heavy oils
Supervisor: Edd A. Blekkan

*Berget, Kjetil*
Modelling of fixed Bed Reactor
Supervisor: Hugo A. Jakobsen

*Bysheim, Bjørn Arild*
Preparation of nano-particular crystals of barium- and leadtitanate
Supervisor: Jens-Petter Andreassen

*Elholm, Gunnar*
Dynamic simulation in HYSYS
Supervisor: Terje Hertzberg

*Enger, Bjørn Christian*
Fischer-Tropsch Catalysts on Different Modified Alumina Supports
Supervisor: Anders Holmen

*Eriksen, Elise Nordberg*
Drying parameters in atmospheric freeze drying
Supervisor: Norvald Nesse

*Halsen, Siri Line*
Oxidative Dehydrogenation of Ethane
Supervisor: Anders Holmen

*Haugen, Geir*
An evaluation of numerical algorithms for the solution of the population balance equation.
Supervisor: Hugo A. Jakobsen

*Haugros, Ingeborg*
A study of catalyst for methanol synthesis
Supervisor: Anders Holmen

*Hegdal, Jeanette*
Separation of heavy oils in SARA-fractions
Supervisor: Edd A. Blekkan

*Hellesøy, Steinar*
Viscosity measurements and correlations of mictures relevant to the processing of reservoir fluids
Supervisor: Hallvard Svendsen

*Hersi, Ahmed*
Treatment of Produced Water
Supervisor: Johan Sjöblom

*Hessen, Erik Troøien*
A Numerical Analysis of Fixed Bed Reactors for SERP Steam Reforming
Supervisor: Hugo A. Jakobsen

*Jonassen, Cecilie*
Absorption properties of gravure printing inks into SC-paper containing Calcium Carbonate
Supervisor: Øyvind W. Gregersen

*Kristensen, Linda Kahtrin*
Membrane dewatering of fish-silage
Supervisor: Norvald Nesse

*Lundberg, Camilla Elisabeth*
Effect of adsorption of various lignosulphonates on the viscosity of concrete paste
Supervisor: Preben C. Mørk

*Mathisen, Guro Malene*
Cleaning of process- and wastewater from industry, by combination of evaporation and oxidation
Supervisor: Norvald Nesse

*Motta, Serena*
Heat transfer experimental studies in stirred tank at different rheologies
Supervisor: Norvald Nesse

*Overgård, Ramona Jeanette*
Development of Cold Flow simulator
Supervisor: Hallvard Svendsen

*Patel, Bijal*
Carbon dioxide absorption: Equilibrium measurements
Supervisor: Hallvard Svendsen

*Pettersen, Hanne E.*
Transport of gas hydrates in oil, effect of polar crude oil fraction
Supervisor: Johan Sjöblom

*Ingela Reppe*
Controll of continuous distillation column for training purposes
Supervisor*:* Sigurd Skogestad

*Rødsten, Marit*
Drying parameters in atmospheric freeze drying
Supervisor: Norvald Nesse

*Valvatne, Vivian Meyer*
Carbondioxide-absorption; modeling of absorber and pilot validation
Supervisor: Hallvard Svendsen

*Vollebekk, Elisabeth*
Catalytic hydrotreatment: model studies
Supervisor: Edd A. Blekkan

## 4th year students in our department

Beinset Morten
Bekkevold Jan Petter
Berntsen Helene
Bjørn Christian Melby
Ekerbakke Hilde
Fjeldstad Lars Johann
Fossan Åse-Lill
Hasanbegovic Nedim
Haugbråten Kristin
Haugen Petter Hande
Haugland Lise
Haukebø Siv Hustad
Huynh Dao Bich Thi
Jacobsen Magnus G
Jensen Kristian Holm
Jentoft Gunn Heidi
Jørgensen Vegard
Karlsen Mats-Gøran
Kompalla Thomas
Kordahl Sina
Krogstad Marit Kristin
Noreng Lars Erik
Pettersen Martin Vignes
Riseggen Henning
Schønning Magnus
Sletengen Kine
Solberg Anette
Tandstad Ingfrid
Tjosevik Marie
Tomter Anne
Østli Kristian

## 3rd year students in our department

Bergstedt Elin
Braathen Bjarne
Elde Ingrid Elise
Ellingsen, Christian
Evensen Trond
Fagerbekk Siri Albertsen
Fahadi Jalal
Fostenes Siv Monica
Frøseth Fredrik
Fævelen Erlend Schou
Husås Ranveig
Jonassen Øystein
Jøndahl Mari
Karlsen Cathrine Hval
Kleppa Gøril
Knudsen Agnethe
Lie Marianne
Opedal Nils
Pettersen Tone Sejnæs
Skogestad Hanne
Tveten Erik Zakarias
Vatneberg Stine V.
Aarhoug Kristin

## Student exchange

During 2005, 12 students from our department (7 females and 5 males) studied in different universities all over the world.

| Name | To Institution | Programme | Semester |
|---|---|---|---|
| Beinset, Morten | Universidad de Granada, Spain | Erasmus | 05/06 |
| Bekkevold, Jan Petter | Ecole Nationale Superieure, Paris, France | Erasmus | 05/06 |
| Haugbråten, Kristin Sarsten | Royal Melbourne institute, Australia | Individual | 05/06 |
| Haugen, Petter Hande | Rheinisch-Westfälische Univ. Aachen, Germany | Erasmus | 04/05 |
| Jensen, Kristian Holm | Rheinisch-Westfälische Univ. Aachen, Germany | Erasmus | 04/05 |
| Kordahl, Sina | University of Bath, England | Erasmus | 05/06 |
| Mellbye, Andrea S | Technische Universität Berlin, Germany | Erasmus | 04/05 |
| Nilsen, Silje | Curtin University of Techn. Perth, Australia | Individ | 04/04 |
| Næsland, Kathrine | Politecnico di Milano, Italy | Erasmus | 04/05 |
| Olsen, Håkon n | Technische Universität Berlin, Germany | Erasmus | 04/05 |
| Tjosevik, Marie | University of Newcastle upon Tyne, England | Bilateral | 05/06 |
| Tomter, Anne | Vysoká Skola Chemicko, Prague, Czech Republ | Erasmus | 05/05 |

During 2005, 20 exchange students (12 females and 8 males) visited our department on different exchange programs.

| Name | From Institution | Programme | Semester |
|---|---|---|---|
| Ajuria, Olatz | Universidad del Pais Vasco, Spain | Erasmus | 05/06 |
| De Vis, Benjamin | Katholieke Universiteit Leuven, Belgium | Erasmus | 05/06 |
| Fernandez D'Arlas Bidegain, Borja | Universidad del Pais Vasco, Spain | Erasmus | 04/05 |
| Garcia, José Angel Alcantud | Universidad Granada, Spain | Erasmus | 04/05 |
| Hilliard, Marcus | Univ. of Texas, Austin, USA | Bilateral | Spring 05 |
| Indacoechea Vega, Irune | Univeridad deValladolid, Spain | Erasmus | 04/05 |
| Izquierdo Peinado, Miguel Angel | Universidad de Granada, Spain | Erasmus | 05/06 |
| Jäschke, Johannes | Rheinisch-Westfälische Univ. Aachen, Germany | Erasmus | 04/05 |
| Jurova, Eva | Vysoká Skola Chemicko, Prague, Czech Republ | Marie Curie | 04/05 |
| Knuutila, Hanna | Tampereen Teknillinen, Finland | Marie Curie | 05/06 |
| Lacalle Vilá, Claudia | Universitat de Barcelona, Spain | Erasmus | 05/06 |
| Manner, Matti Vili-Pekka | Tampereen teknillinen, Finland | Nordplus | 05/06 |
| Motta, Serena | Politecnico di Milano, Italy | Erasmus | 04/05 |
| Pellegrinelli, Morgane | ENSIACET, France | Erasmus | Autumn 05 |
| Peña Gómez, Yolanda | Universidad de Granada, Spain | Erasmus | 05/06 |
| Peyrelongue, Maylis | ENSIACET, France | Erasmus | Autumn 05 |
| Rojas, Vanesa | Univeridad deValladolid, Spain | Erasmus | 04/05 |
| Scorl, Anja | Technische Universität Freiberg, Germany | Erasmus | 05/06 |
| Votrubec, Martin | Vysoká Skola Chemicko, Prague, Czech Republ | Erasmus | 05/06 |
| Zarubova, Sarka | Vysoká Skola Chemicko, Prague, Czech Republ | Erasmus | 05/06 |

## PhD courses given:

KP8100 Advanced Process Simulation
KP8102 Wood Chemistry in Pulping and Paper Making
KP8104 Industrial Crystallization and Precipitation
KP8105 Methematical Modelling and Model Fitting
KP8106 Gas Cleaning with Chemical Solvents
KP8107 Advanced Course in Membrane Separation Process
KP8108 Advanced Thermodynamics: With applications to Phase and Reaction Equilibria
KP8109 Environmental Catalysis
KP8110 Membrane Gas Purification
KP8111 Catalytic Conversion of Hydrocarbons
KP8112 Applied Heterogeneous Catalysis
KP8113 Characterizaton of Heterogeneous Catalysts
KP8115 Advanced Process Control
KP8116 Colloid Chemistry for Process Industry
KP8117 Paper Physics and Paper Chemistry
KP8118 Advanced Reactor Modelling
KP8119 Surfactants and Polymers in Aquous Soutions
KP8120 Colloid Chemistry and Functional Materials

## PhD-Thesis 2005

*Yu, Zhixin*
Synthesis of Carbon Nanofibers and Carbon Nanotubes
Supervisor: Anders Holmen

*Lindbråthen, Arne*
Development and modification of glass membranes for aggressive gas separations
Supervisor: May-Britt Hägg

*Christensen, Kjersti O.*
Steam Reforming of Methane on Different Nickel Catalysts
Supervisor: Anders Holmen

*Storkaas, Espen*
Control solutions to avoid slug flow in piperline-riser system
Supervisor: Sigurd Skogestad

*Alstad, Vidar*
Studies on Selection of Controlled Variables
Supervisor: Sigurd Skogestad

*Aartun, Ingrid*
Microstructured reactors for hydrogen production
Supervisor: Anders Holmen

*Storsæter, Sølvi*
Fischer-Tropsch synthesis over cobalt supported catalysts
Supervisor: Anders Holmen

*Knag, Magne K.*
Surfactan Aggregation in Solution and on Metal Surfaces and the Impact on Corrosion Rate Supervisor: Johan Sjöblom

*Brandal, Øystein*
Interfacial (o/w) Properties of Naphthenic Acids and Metal Naphthenates, Naphthenic Acid Characterization and Metal Naphthenate Inhibition
Supervisor: Johan Sjöblom

*Da Silva, Eirik Falck*
Computational Chemistry Study of Solvents for Carbon Dioxide Absorption
Supervisor: Hallvard Svendsen

*Lie, Jon Arvid*
Synthesis, performance and regereration of carbon membranes for biogas upgrading – a future energy carrier
Supervisor: May-Britt Hägg

*Ma'mun, Sholeh*
Selection and Characterization of New Absorbents for Carbon Dioxide Capture
Supervisor: Hallvard Svendsen

*Vrålstad, Torbjørn*
Synthesis and characterization of cobalt-containing mesoporous model catalysts
Supervisor: Johan Sjöblom

5 PhD exchange students visited our department in 2005, (2 female and 4 male).

| **Name** | **University/Coutnry** | **Group located** |
|---|---|---|
| Nitzche, Jörg | Freiberg University, Germany | Catalysis and Petrochemistry Group |
| Saarinen, Tapio | | Colloid and polymer Group |
| Lögdberg, Sara | KTH, Sweden | Catalysis and Petrochemistry Group |
| Tristantini, Dewi | Chalmers University, Sweden | Catalysis and Petrochemistry Group |
| Tynys, Antti | HUIT, Finland | Colloid and polymer Group |
| Schmidt, Kurt | UiB | Reactortechnology Group |

# CHAPTER 6: ORGANIZATION - ECONOMY

**Organization (see cover page):**
The Head of Department is elected for a four-year period, and has an advisory committee for consultation. The scientific staff is divided in to 6 research groups by scope of research. Each group has a representative in the management team. The team that has meetings every second week and discusses running matters. In addition, the Department has 12 persons in technical and administrative staff to support teaching and research of all the research groups.

The department receives contribution from the Government and from external contributors. Our area of research are mainly in applied sciences, and we are getting approx 2/3 of our yearly income of KNOK 72 000 from external sources.

The Governmental funding and overhead from external projects are mainly used to pay salaries to the permanent staff of scientific, technical and administrative personnel. The last year's spendings are shown in the table below:

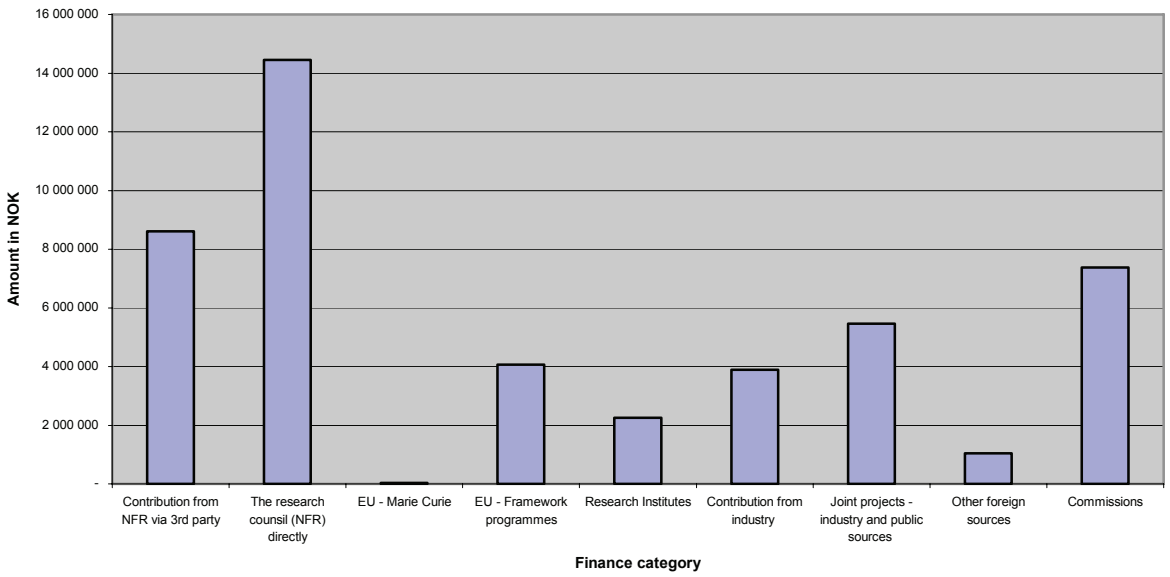
**Economy:**

| Accounts | 2003 | 2004 | 2005 |
|---|---|---|---|
| **Income** | | | |
| **Public funding** | 21 309 641 | 20 556 093 | 22 129 000 |
| **Overhead external projects** | 1 278 884 | 2 153 815 | 2 153 815 |
| **Sum income** | 22 588 525 | 22 709 908 | 24 282 815 |
| **Expenses** | | | |
| **Wages** | 19 335 309 | 17 703 181 | 19 216 318 |
| **Operating expenses** | 3 878 386 | 3 937 176 | 3 660 005 |
| **Sum expenses** | 23 213 695 | 21 640 358 | 22 876 323 |
| **Result** | (625 170) | 1 069 551 | 1 406 492 |

**External funding**
The Department has a yearly income from external contributors of approx KNOK 47 000. Main contributor to the research activity is The Research Counsil of Norway (NFR). Most of these funds come from The Departmensts own projects, but the second largest external source are NFR-projects where we contribute as a third party. The industrial contributions are growing rapidly, mainly due to NFR policy of more focus on collaboration between universities and industry. Therefore a growing portion of projects are partly financed by industry and/or research institutes.

We also have projects solely fundend from international industry. We have several ongoing Joint Industrial Programmes (JIP's) with industry partners from countries in Europe, North-America, South-America and Asia. Commissions from national and foreign companies were in 2005 approx 16% of the total external funding.

**EXTERNAL FUNDING**



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