Annual Report for Department of Chemical Engineering, NTNU

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Innovation and Creativity

NTNU – Innovation and Creativity
The Norwegian University of Science and Technology (NTNU) in Trondheim represents academic eminence in technology and the natural sciences as well as in other academic disciplines ranging from the social sciences, the arts, medicine, architecture to fine arts. Cross-disciplinary cooperation results in ideas no one else has thought of, and creative solutions that change our daily lives.

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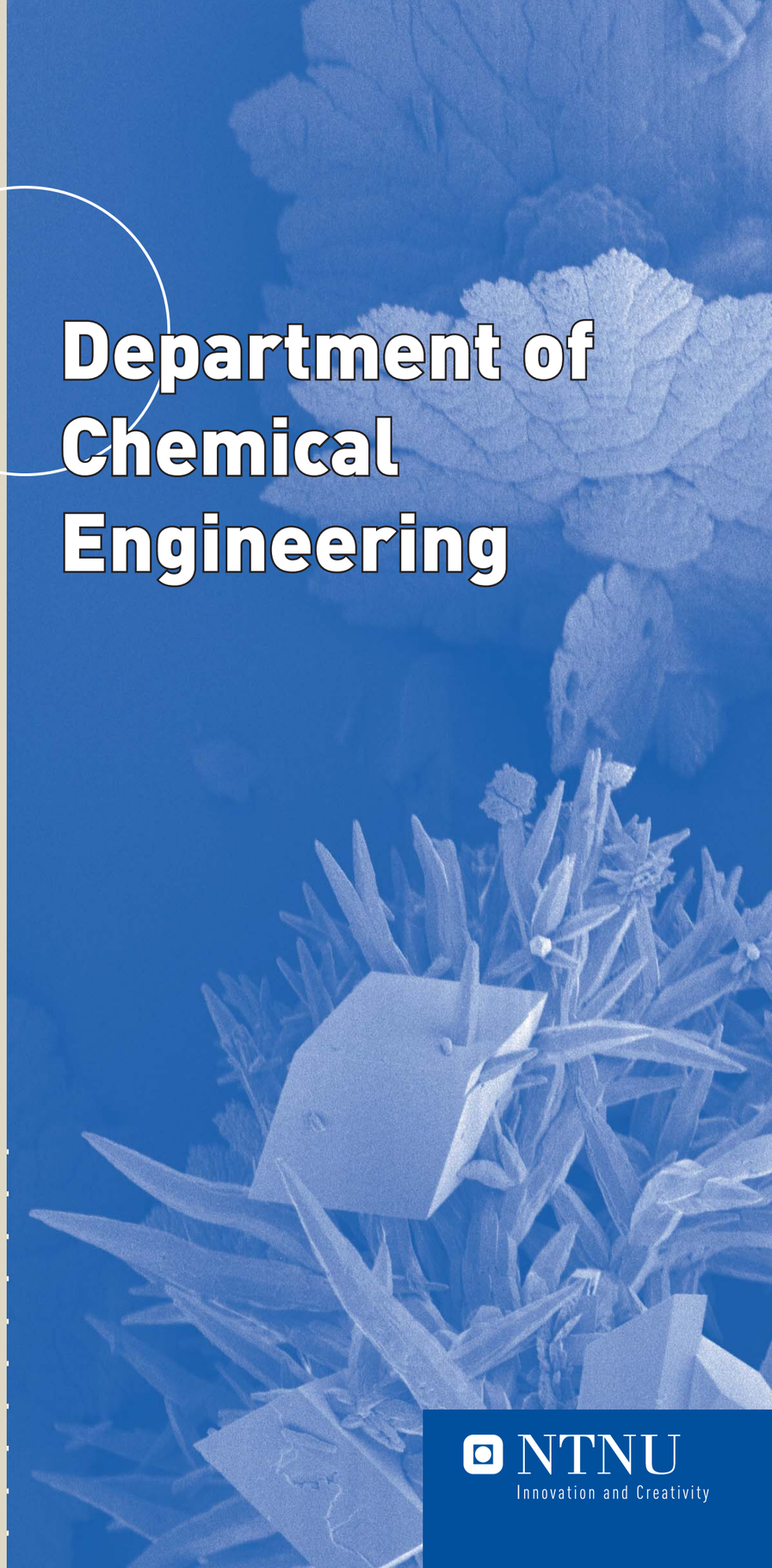
Annual Report 2006

Department of Chemical Engineering



NTNU
Innovation and Creativity

DEPARTMENT OF CHEMICAL ENGINEERING, NTNU

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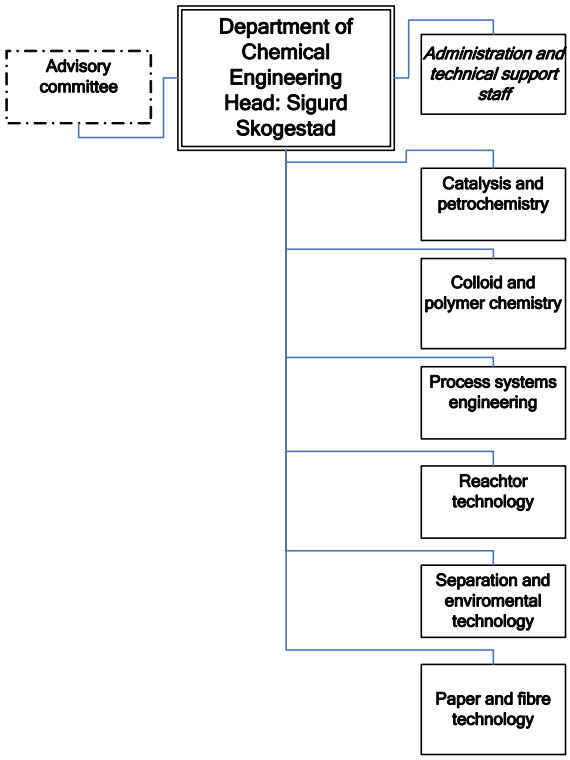
Head of Department:
Professor Sigurd Skogestad
Deputy Head of Department:
Professor Edd A. Blekkan



Department advisory committee

External members:
Chair, Research Director Ole Wærnes, SINTEF
Professor Jon Kleppe, Petroleum Engineering

Internal members:
Professor Heinz Preisig
Professor Hallvard Svendsen
Associate Professor Hilde J. Venvik
Senior Engineer Berit Borthen
Ph.D candidate Anne Silset
Student Marit Kristin Krogstad
Student Gunn Heidi Jentoft

Staff

Academic staff, see the individual research groups

Technical and administrative staff:
Head of Administration Tom Helmersen

Administrative staff:
Senior Executive Officer Torgrim Mathisen
Executive Officer Lisbeth B. Roel
Administrative assistant Synnøve Hestnes
Administrative assistant Tove Barø

Technical staff:
Senior Engineer Berit Borthen
Engineer Harry Brun
Engineer Arne Fossum
Engineer Odd Ivar Hovin
Principal Engineer Signe Håkonsen
Engineer Jan Morten Roel
Principal Engineer Cecilie M. Selsbak
Engineer Frode Sundseth
Senior Engineer Bodhild Øvrevoll
Senior Engineer Asbjørn Øye

COVER-PAGE (photo Ellen Marie Flaten)
Polymorphs of calcium carbonate precipitated in water at 50ºC, showing the complexity of scale studies in oil and gas processing.

DEPARTMENT OF CHEMICAL ENGINEERING, NTNU

http://www.chemeng.ntnu.no

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Printed April 2007
Prepared and edited by Lisbeth Blekkan Roel, Tom Helmersen, Sigurd Skogestad

CHAPTER 1: INTRODUCTION

Introduction to Annual Report 2006

By Sigurd Skogestad (Head of Department)

2006 was another successful year for the Department of Chemical Engineering at NTNU. The research output, as expressed by number of graduated Ph.D. candidates and publications, reached a new all time high. The number of publications in international journals and book chapters, which soared last year from about 50 in 2003 and 2004 to 89 in 2005, increased further in 2006 to 93. Furthermore, 15 Ph.D. graduated in 2006, which is a new record, and the number may increase further in 2007.

The main challenge for the Department is the low student enrolment and output of Master graduates. For more than 15 years, until 2002, the Department graduated on average more than 60 MSc (diploma) graduates 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 5-year program in *Chemistry and Biotechnology*. 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 70, whereas it historically (over the last 30 years) was around 120. It is expected that the significantly improved labour marked will give an increase in the intake in 2007, but these candidates will not be available on the marked until 2012. It is also planned to make some modifications to the program, including changing the name, but this will not take effect until 2008. The Department is planning to enlarge its recruitment base by offering an International Master degree in Chemical Engineering. This was planned to start from 2007, but has been postponed pending final approval from the University. Nevertheless, the department will in the future offer all its courses in the 4th and 5th year in English.

In terms of future plans and faculty recruitment, we follow quite closely the Departments strategic plan from April 2003. The Department has by now almost completed a major replacement of its academic staff, with 12 new fulltime faculty members being hired since 2001.

In April 2006 Dr. Wilhelm R. Glomm was appointed Associate professor (*Førsteamanuensis)* in our Department in the area of nano polymer chemistry. In August 2006 Professor Kim E. Esbensen (Professor at Aalborg University) was called as Adjunct professor (*Professor II*) in the area of Applied Chemometrics. Finally, in February 2007, Dr. Magne Hillestad started as Professor in Process Design. A position (førsteamanuensis / professor) in systems biology was announced in December 2006, and is expected to be filled during 2007.
External projects account for about 2/3 of the overall income to the Department, and to strengthen the service in this area, Mr. Torgrim Mathisen was hired as a Senior Executive Officer from April 2006.

Some good news for the Department: At the Technoport Awards in October 2006, Professor Johan Sjöblom was awarded the Statoil Research Award for his work on crude oil emulsions. In June 2006 the Norwegian research Council announced that two groups got funding to participate in Centers for research-based innovation (SFI): These are the Colloid and Polymer Group (Prof. Sjöblom, Ugelstad Laboratory) in "Multiphase flow insurance innovation center" (FACE) with IFE as the coordinator, and the Catalysis Group (professor Holmen) in "Innovative natural gas processes and products" (INGAP) with the University of Oslo as the coordinator. The Norwegian research Council also announced that two groups from our Department (out of only four groups from the whole university) were finalists as Centers for Research Excellence (SFF). These were the Catalysis Group (Prof. Holmen) and the CO_2 removal Group (Prof. Svendsen). In spite of excellent reviews, neither of the two were selected in the end, but it is still an achievement to get this far.

Finally, a little about our facilities: A complete renovation of the main lab in the 3rd floor in Chemistry building 5 (K5) is just being completed. The cost is about 6 million NOK, and we were hoping that the university would cover most of the costs. Unfortunately, the Department has ended up paying about 2/3, which has almost exhausted our savings. The next major project is the renovation of the top two floors in Chemistry building 4 (K4), which have been empty since the Department of Materials Science moved out at the end of 2005. The project is high up on the priority list for the University. The plan is that the activity on CO_2 removal, including SINTEF, will move over from K5 to K4. The freed space in K5 may then be made available for parts of the colloid and polymer group who are presently renting space in the PFI building.

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 all areas in Norway that awards engineering degrees.

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.

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 (*treforedlingskjem*i, 1946), chemical engineering (*kjemiteknikk*, 1949) and industrial chemistry (*industriell kjemi*, 1950). These merged in 1999 to the present Department of chemical engineering (*kjemisk 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 such that it recruits the best candidates, including academic faculty, PhD students and undergraduate students. The social environment shall be very good such that everyone feels welcome.

The permanent staff in 2006 includes

- 13 technical/administrative
- 21 academic, incl.14 Professors and 7 Associate Professors (*Førsteamanuensis*)

The non-permanent staff in 2006 includes

- 3 technical
- 9 Adjunct Professors (*Professor II*) (20% position)
- 59 PhD students
- 22 Post.docs and researchers

The Department also houses 7 Professors emeritus and 4 visitors, in addition to a large SINTEF group.

Student production

Year	MSc	PhD
1994	60	11
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

(*) Transition from 4.5 to 5 year program.

MSc students 2006/07

5th year	30
4th year	34
3rd year	24

New PhD students

2003	20
2004	10
2005	9
2006	18

CHAPTER 2: RESEARCH

CATALYSIS AND PETROCHEMISTRY GROUP

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

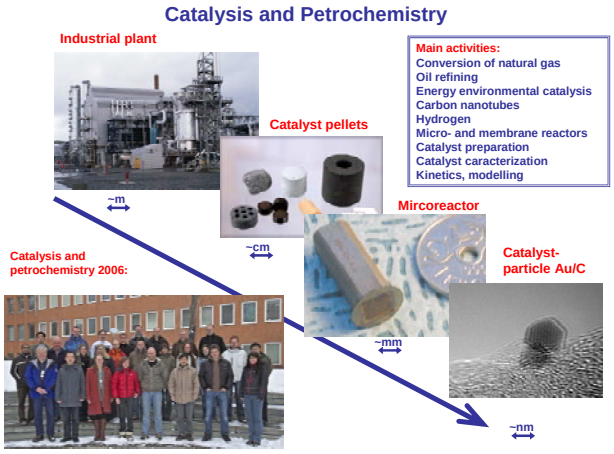
Post.docs.
Jan-Lasse Eilertsen
Santhosh Kumar Matam (from 08.03.06)
Jianmin Xiong
Zhixin Yu (until 17.04.06)
Tiejun Zhao

PhD. candidates
Øyvind Borg
Hamidreza Bakhtiary (from 04.08.06)
Sara Boullosa Eiras (from 01.10.06)
Svatopluk Chytil
Li He (started 19.09.06)
Hoang Anh Dam (from 30.11.06)
Hilde Dyrbeck
Bjørn Christian Enger
Vidar Frøseth (until 14.07.06)
Nina Hammer
Florian Huber (until 31.08.06)
Silje Fosse Håkonsen
Ingvar Kvande
Astrid Lervik Mejdell (from 01.04.06)
Hilde Meland
Esther Ochoa Fernandez
Xuyen Kim Phan (from 30.11.06)
Espen Standal Wangen

Researchers
Lars Erik Fareid (until 21.12.06)
Geir Haugen

Guests
Karen de Lathouder (PhD student from Delft, Netherlands)
Sara Lögdberg (PhD student from KTH, Sweden)
Magnus Ryden (PhD student from Chalmers, Sweden)
Shuihua Tang (PhD student from Dalian Univ. China)
Dewi Tristantini (PhD student from Chalmers, Sweden)
Jun Zhu (PhD student from East China Univ. of Sci. China)

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 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 (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.

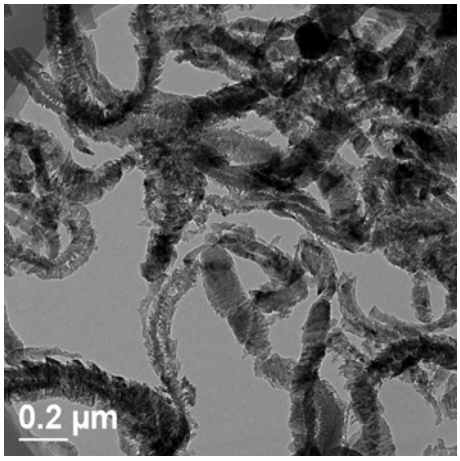
The projects
A description of the Group as well as further details of all the projects are given in our Annual Report.

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 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. 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. 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



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.

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.

COLLOID- AND POLYMER CHEMISTRY GROUP (UGELSTAD LABORATORY)

Academic staff
Professor Johan Sjöblom
Professor Preben C. Mørk
Associate professor Wilhelm R. Glomm (01.04.06)
Associate professor Gisle Øye
Adjunct professor Jan Genzer
Adjunct professor John Daniel Friedemann
Adjunct professor Egil Gulbrandsen
Adjunct professor Michael Stöcker
Adjunct professor Per Stenius
Professor emeritus Arvid Berge

Scientists
Pål V. Hemmingsen (until 31.05.06)
Heléne K. Magnusson
Sebastien Simon

Post.docs.
David Arla (from 07.08.06)
Øystein Brandal (until 14.05.06)
Cedric M. Lesaint (from 01.04.06)
Kristofer Paso (from 17.07.06)
Torbjørn Vrålstad (until 31.08.06)

Phd candidates
Martin Andresen
Shukun Chen (until 31.10.06)
Dorota Dudásová
Martin Smestad Foss
Martin Fossen
Ann-Mari Dahl Hanneseth
Andreas Hannisdal (until 30.06.06)
Ingvild Andersen Johnsen
Marta Lopez Garcia (from 01.01.06)
Erland Nordgård (from 25.09.06)
Anne Silset
Bjørn Thomassen
Sondre Volden

Guests
Iva Králová, (PhD from Brno University, Czech Rep.)
Weijun Zen (Xinjiang University, China)

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 2006 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/

Synthesis and characterization of ordered mesoporous Al-materials for Fischer-Tropsch catalysis 2006-2008
In this VISTA-financed project, the main objectives are:
* Synthesis of new mesoporous alumina materials
* Functionalization by incipient wetness impregnation
* Testing for activity in Fischer-Tropsch catalysis

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. The work on treatment strategies will 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.

Dendritic nanoporous materials with multifunctionality 2004-2006
The main objective of this project is the design and tailoring of porous materials for optical and bioengineering applications using dendritic polymers as structure-directing agents. Dendrimers comprise a relatively new and interesting class of polymers which is characterized by their globular, monodisperse structure, where properties such as size, core entity, surface groups and overall flexibility are completely tunable. Under certain conditions, dendrimers may be considered as soft colloidal particles whose properties are controlled by surface interactions, mainly dependent on particle size and surface structure.
This project is a collaborative effort between the Ugelstad laboratory, Dept. of Physics, NTNU, and the Department of Fibre and Polymer Technology, KTH (Stockholm).

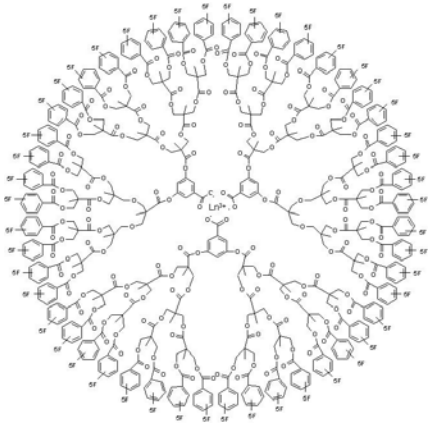


Figure 1: Structural rendition of a generation four (G4) Lanthanide-cored fluorinated dendrimer

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 results 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.

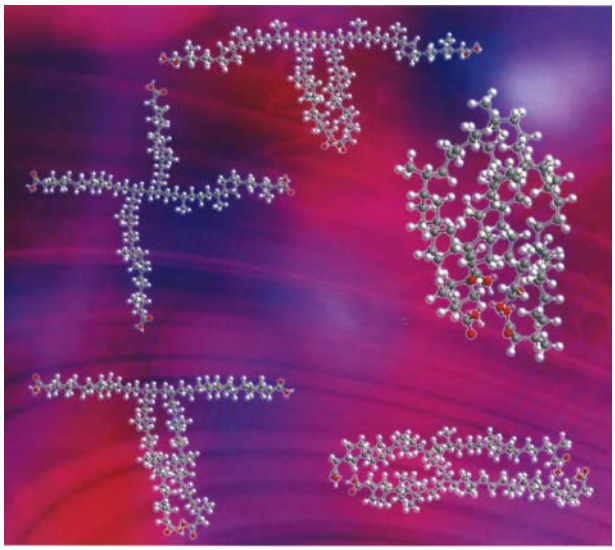


Figure 2: Archeal C_{80} isoprenoid tetraacids responsible for naphthenate deposition in crude oil processing.

PROCESS SYSTEMS ENGINEERING GROUP

Academic staff
Professor Sigurd Skogestad
Professor Terje Hertzberg
Professor Heinz A. Preisig
Associate professor Tore Haug-Warberg
Adjunct professor Kim H. Esbensen (from 01.08.06)

Post.docs.
Stefan de Graaf (Cybernetica)
Eduardo Shigueo Hori
Sridharakumar Narasimhan (from 27.06.06)

PhD candidates
Antonio Carlos Brandao Araújo
Elvira Marie B. Aske
Olaf Trygve Berglihn
Håkon Dahl-Olsen (from 01.06.06)
Ivan Dones (from 09.01.06)
Fatemeh Hayer
Jørgen Bauck Jensen
Tore Lid (Statoil Mongstad)
Andreas Linhart
Bjørn Tore Løvfall
Henrik Manum (from 14.08.06)
Heidi Sivertsen
Jens Petter Strandberg
Federico Zenith
Zhengjie Zhu

Guests
Michela Mulas (09.10. – 19.12.06)
Veerayut Lersbamrungsuk (04.05. – 28.09.06)
Tshepo Modise (08.09 – 01.12.06)
Junping Cai (01.02. – 30.06.06)

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 peoples in addition, 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, and a faculty position in this area has been announced.

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: Heinz, Sridhar, Håkon, Sigurd, Ivan, Olaf, Heidi and Eduardo
Second row: Bjørn Tore, Magnus, Henrik, Stefan, Jens and Andreas

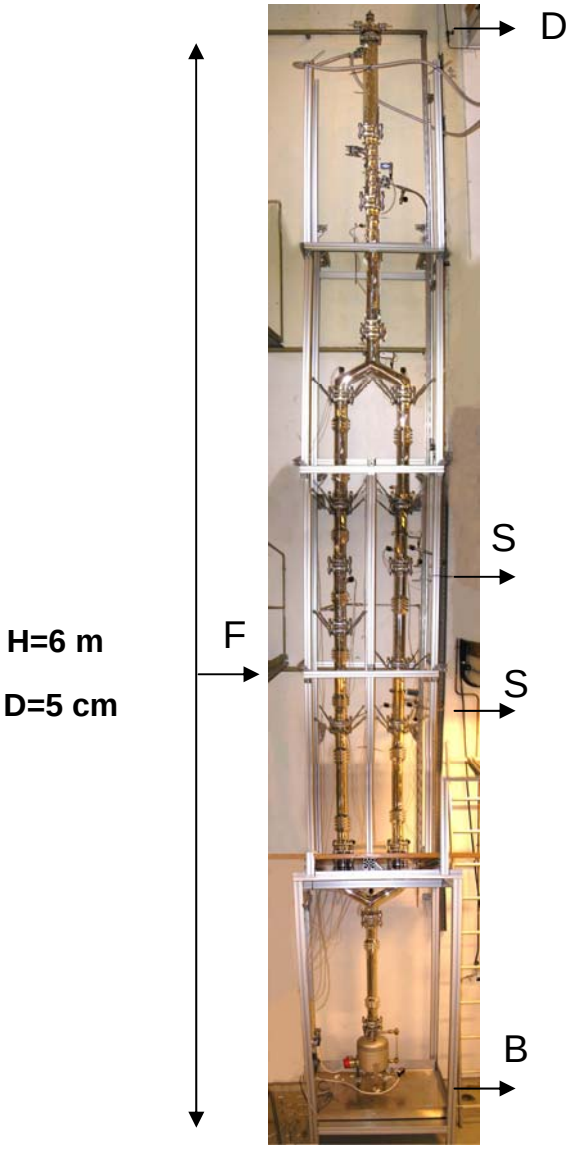
significance). Up to now, the design of the overall "plant-wide" control structure has been based on engineering experience and intuition, whilst the aim has been to develop rigorous techniques. The concept of "self-optimizing control" provides a basis for linking economic optimization and control (Skogestad). 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 build 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 August 2006 professor Kim Esbensen joined the group as professor II in the area of process chemiometrics.

Funding 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

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Post.docs
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Eirik Fack da Silva (from 01.08.06)

PhD candidates
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Rune Engeskaug
Ardi Hartono
Thomas Helsør (until 30.09.06)
Erik Troøien Hessen
Cecilie Gotaas Johnsen (until 31.08.06)
Inna Kim
Håvard Lindborg
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Eddie Setekleiv (from01.10.06)
Andrew Tobiesen (until 15.11.06)
Margrete H. Wesenberg (until 12.06.06)

Guests
Kurt Schmid (PhD student from Univ. of Bergen)

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

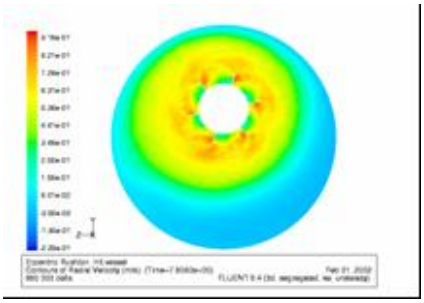
the National scientific competence in our field of research through PhD studies.

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.

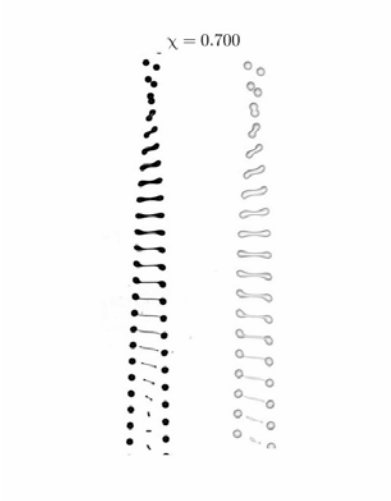
We are also investigating the performance of chemical reactive systems like fluidized beds, fixed bed reactors and agitated tanks. At present we are working with the design of suitable reactors for sorption enhanced reaction processes (SERP) like steam reforming with absorbents for CO_2.



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 half the energy requirement in the process. This work involves al 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

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Adjunct professor Didrik Malthe-Sørenssen
Professor emeritus Olav Erga
Professor emeritus Jørgen Løvland
Professor emeritus Gunnar Thorsen

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Taek-Joong Kim

Post.docs.
Salim Deshmukh (IFE, Kjeller)
Jon Arvid Lie
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Edel M. Sheridan (from 01.11.06)

PhD. candidates
Ralf Beck (from 09.01.06)
Tone Borge
Tom Dagstad
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David R. Grainger
Marius Sandru
Lei Shao
Willy Thelin

Guests
Antti Tynys (PhD student from HUT, Finland)

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

1. Membranes for gas separation

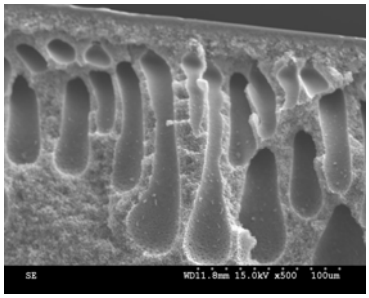
The group of Memfo, http://www.chemeng.ntnu.no/memfo currently counts 11 members (5 PhD-students, 3 post docs, 2 senior researcher, and the head of the group, professor M-B Hägg, in addition there are 2 associated members).

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 the research, and very promising results have been documented. The project continues for 2 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 2006, 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 1 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. In late 2006 the focus on process development was initiated. Project partners are NFR, Statoil and Alstom where the focus is CO_2 capture from flue gas as well as IGCC. There has also been interest from industry on other applications where CO_2 is present in the gas stream (natural gas sweetening, CO_2 removal from anaestethic gas.)



***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.

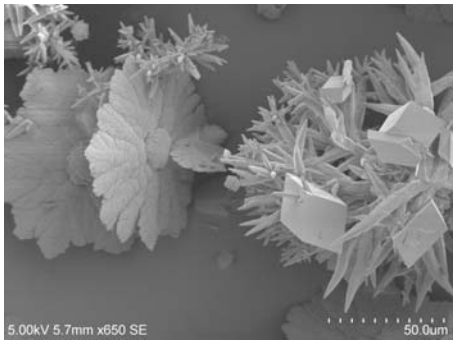
d) Development of hybrid membrane for chlorine purification
Memfo is one of very few groups in the world doing research on membranes for the purification of chlorine gas. This is probably for security and safety reasons, and the challenge of handling this poisonous gas. The project is extremely challenging, 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 2006, and one post doc is currently on the project. There is a major interest from industry in this project.

e) Various
The group of Memfo works very much as a team rather than as 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 although there is not any large ongoing project on this. Carbon membranes has proved to be suitable for upgrading of biogas; documented by experiments and discussed in publications.
Application for a project within the 6th FWP, EU, was granted in December 2005, and had kick-off in November 2006. The project is focusing on "Nanomaterials against Global Warming" (**NanoGloWa**). Memfo is a major partner in the project, task leader for two work packages, and focus on development of both carbon membranes and polymeric materials, including spinning of hollow fibres. The project had a very active start-up in late 2006 when a post doc was attached to it – the expectations are high. 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

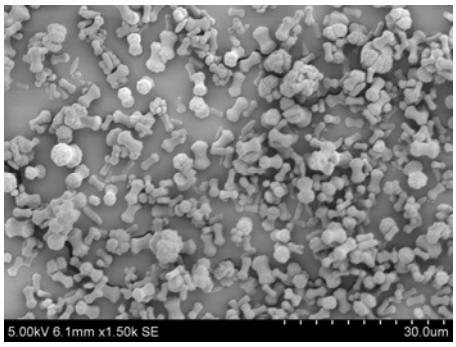
2. Crystallization
The research within crystallization is focused at kinetics of nucleation, crystal growth, and agglomeration in order to predict and control the particle size distribution and shape of crystalline particulate products for scale prevention and effects on down-stream processes like solid-liquid separation and powder characteristics. The crystallization group also investigates fundamental mechanisms in the early formation of solid particles which are of particular interest in the wet synthesis of nano-particles. Work to rebuild the crystallization laboratory was started in 2006 and will be completed during the spring of 2007. The group bought a focused beam reflectance measurement (FBRM) instrument for particle size (i.e. cord length) measurements in 2006, which will be used for particle size analysis in dense suspensions. Here we present two projects and some of the new results obtained in 2006.

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 2006 have shown that the MEG significantly affects the induction time for precipitation, the particle size, and the polymorphic compostion of calcium carbonate. This will impact on the design of glycol loops and it also emphasises the need to update exisiting thermodynamic calculation packages to include these variations in the solid phase.



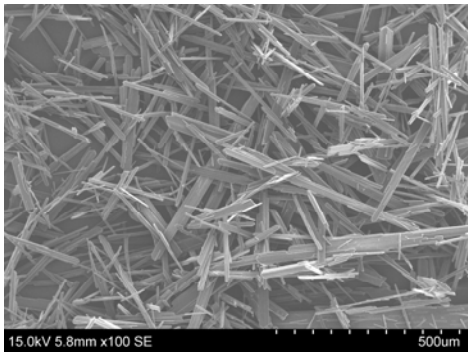
The polymorphic compostion of calcium carbonate at 50 ºC in water.



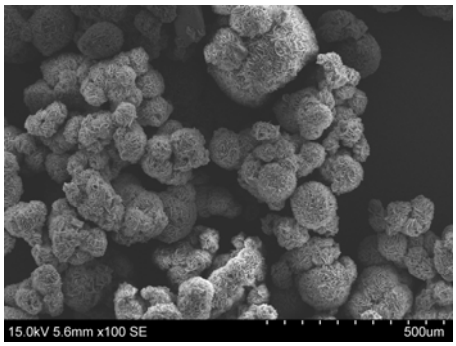
The effect adding ethylene glycol to the precipitation of calcium carbonate at 50 ºC at comparable supersaturation.

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.

In 2006 we have investigated the effect of supersaturation and temperature on the particle design of pharmaceutical compounds. We have identified a possible general mechanism of crystal growth switching whereby particle shape is dramatically altered. This is illustrated for the precipitation of sodium glutamate by swithing from the well-known needle crystals of β-blutamate to spherical particles of the same polymorph. The effect of these changes on filtration rates and powder flow will be investigated in 2007.



Conventional needle-shaped crystals of sodium glutamate.



Switching from needles to spherical crystals of sodium glutamate.

3. Membrane separation of liquids:
In 2006 Professor Norvald Nesse went on retirement, but the work within separation of liquids with membranes which was his main research field, are continued in the group of Memfo; partly by involvement in the sample project mentioned below but also on production of biofuels and purification processes using membranes.

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. These problems have been investigated in two doctoral projects. 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 run continuously for several months. Verifying experiments for comparison are performed 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.

PAPER AND FIBRE TECHNOLOGY GROUP

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Marianne Lenes
Hilde Lyngstad (until 28.02.2006)
Tommy Nesbakk
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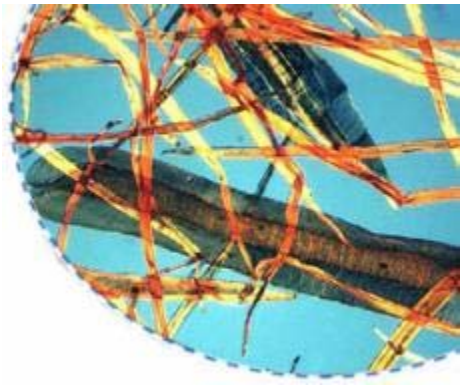
David Vaaler



The size distributions of fibres and fines are essential for the papermaking properties of a pulp.

Teaching

The Paper 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. During 2006 3 MSc and 4 PhD candidates graduated from our group. We also gave two industry courses in Pulp and Paper technology and a course in pulp and paper technology at The Norwegian University of Life Sciences (UMB).

Partners

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.

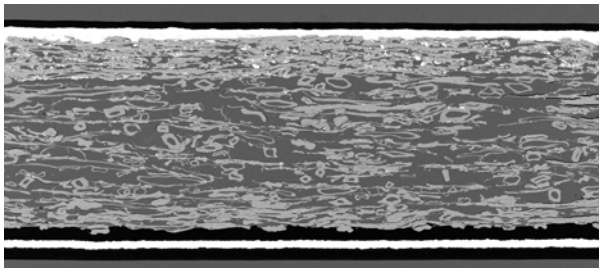
Research

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

- 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.
- Reduced print through defect in newsprint by optimized sheet structure
- Better strength and surface properties of wood-containing paper by use of micro-fibrillar cellulose as an additive.
- The influence of paper structure on mechanical, optical and surface properties of paper.

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 bio-fuel production have also started. The goal is cost effective production of bio-diesel 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.

CHAPTER 3: PUBICATIONS

PUBLICATIONS IN REFEREED JOURNALS.

1. **Adam, Judit; Antonakou, Eleni; Lappas, Angelos; Støcker, Michael Wilhelm; Nilsen, Merete Hellner; Bouzga, Aud; Hustad, Johan Einar; Øye, Gisle**. In situ catalytic upgrading of biomass derived fast pyrolysis vapours in a fixed bed reactor using mesoporous materials. *Microporous and Mesoporous Materials* 2006;96:93-101

2. **Andresen, Martin; Johansson, Leena-Sisko; Tanem, Bjørn Steinar; Stenius, Per**. Properties and characterizaton of hydrophobized microfibrillated cellulose. *Cellulose (London)* 2006;13:665-677

3. **Araujo, Antonio Carlos Brandao; Skogestad, Sigurd**. Limit Cycles with Imperfect Valves: Implications for Controllability of Processes with Large Gains. *Industrial & Engineering Chemistry Research* 2006;45:9024-9032

4. **Arstad, Bjørnar; Venvik, Hilde Johnsen; Klette, Hallgeir; Walmsley, John; Tucho, Wakshum Mekonnen; Holmestad, Randi; Holmen, Anders; Bredesen, Rune**. Studies of self-supported 1,6 µm Pd/23 wt.% Ag membranes during and after hydrogen production in a catalytic membrane reactor. *Catalysis Today* 2006;118:63-72

5. **Berge, Arvid Trygve; Mejdell, Thor**. Melamine formaldehyde compounds. The active species in acid catalyzed eactions. *Polymer* 2006;47:3249-3256

6. **Bergem, Håkon; Vollebekk, Elisabeth; Rizki, Abdelhakim; Blekkan, Edd Anders**. Inhibition Effects of Organic Nitrogen Compounds on Hydrodesulfurization Reactions. *Preprints - American Chemical Society. Division of Petroleum Chemistry* 2006;51(2):384-385

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8. **Borg, Øyvind; Storsæter, Sølvi; Eri, Sigrid; Wigum, Hanne; Rytter, Erling; Holmen, Anders**. The effect of water on the activity and selectivity for gamma-alumina supported cobalt Fischer-Tropsch catalysts with different pore sizes. *Catalysis Letters* 2006;107:95-102

9. **Brandal, Øystein; Hanneseth, Ann-Mari Dahl; Hemmingsen, Pål Viggo; Sjöblom, Johan; Kim, Sunghwan; Rodgers, Ryan P.; Marshall, Alan G.**. Isolation and characterization of naphthenic acids from a metal naphthenate deposit: Molecular properties at oil-water and air-water interfaces. *Journal of Dispersion Science and Technology* 2006;27:295-305

10. **Chiesa, Matteo; Ingebrigtsen, Stian; Melheim, Jens Andreas; Hemmingsen, Pål Viggo; Hansen, Erik Bjørklund; Hestad, Øystein**. Investigation of the role of viscosity on electrocoalescence of water droplets in oil. *Separation and Purification Technology* 2006;50:267-277

11. **Christensen, Kjerst Omdahl; Chen, De; Lødeng, Rune; Holmen, Anders**. Effect of supports and Ni crystal size on carbon formation and sintering during steam methane reforming. *Applied Catalysis A: General* 2006;314:9-22

12. **Chytil, Svatopluk; Glomm, Wilhelm; Kvande, Ingvar; Zhao, Tiejun; Blekkan, Edd Anders**. Platinum nanoparticles incorporated in mesoporous silica SBA-15 by the deposition-precipitation method. *Studies in Surface Science and Catalysis* 2006;162:513-520

13. **Deng, Liyuan; Kim, Taek Joong; Hagg, May-Britt**. PVA/PVAm blend FSC membrane for CO2-capture. *Desalination* 2006;199:523-524

14. **Dorao, Carlos Alberto; Jakobsen, Hugo Atle**. A least squares method for the solution of population balance problems. *Computers and Chemical Engineering* 2006;30:535-547

15. **Dorao, Carlos Alberto; Jakobsen, Hugo Atle**. Application of the least-squares method for solving population balance problems in Rd+1. *Chemical Engineering Science* 2006;61:5070-5081

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125. **Zhu, Zhengjie; Preisig, Heinz A.; Haug-Warberg, Tore**. Conceptual Approaches to Computer-Aided Process Modeling [Vitenskapelig foredrag]. CAPE Forum 2006; 11.02.2006 - 12.02.2006

126. **Øye, Gisle**. Synthesis of Cobalt Containing Mesoporous Catalysts [Vitenskapelig foredrag]. The Second KIFEE Symposium, Kyoto International Forum for Environment and Energy; 06.09.2006 - 08.09.2006

127. **Øye, Gisle**. Synthesis of Cobalt Containing Mesoporous Model Catalysts [Vitenskapelig foredrag]. ZMPC 2006 (International Symposium on Zeolites and Microporous Crystals); 30.07.2006 - 02.08.2006

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 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

Master courses given in 2006:

Number	Course title	Year	Registered	Passed
TKP4100	Fluid Flow and Heat Transfer	2	77	65
TKP4105	Separation Technology	3	75	55
TKP4110	Chemical Reaction Engineering	3	89	77
TKP4115	Surface and Colloid Chemistry	3	43	35
TKP4120	Process Engineering	2	115	94
TKP4125	Paper and Fiber Technology	4	6	6
TKP4130	Polymer Chemistry	4	23	21
TKP4135	Chemical Process Dynamics and Optimization	4	6	5
TKP4140	Process Control	4	21	20
TKP4145	Reactor Technology	4	12	8
TKP4150	Petrochemistry and Oil Refining	4	21	17
TKP4155	Reaction Kinetics and Catalysis	4	42	30
TKP4160	Transport Phenomena	4	25	21
TKP4165	Process Design	4	27	25
TKP4170	Process Design, Project	4	24	24
TKP4171	Process Design, Project	4	3	3
TKP4700	Catalysis and Petrochemistry, Specialization	5	11	11
TKP4710	Colloid and Polymer Chemistry, Specialization	5	5	5
TKP4720	Process Systems Engineering, Specialization	5	2	2
TKP4730	Reactor Technology, Specialization	5	6	6
TKP4740	Separation and Environmental Technology, Specialization	5	4	2
TKP4750	Paper and Fibertechnology, Specialization	5	1	1
TKP4850	Experts in Team, Interdisciplinary Project	4	17	17
TKP4500	Final Year Design, for Spanish students	5	2	2

Master theses 2006

Ahmed, Noman
The influence of Energy Input on Crystallisation of substituted aromatic amine compounds
Supervisor: Dick Malthe-Sørenssen

Faksvåg, Kari
CO Hydrogenation in Monolith Reactors
Supervisor: Anders Holmen

Fareid, Lars Erik
Carbon Nanofibers as Catalysts Support
Supervisor: De Chen

Guldbjørnsen, Johan
The effect of paper machine webstrain on runnability and strength properties
Supervisor: Øyvind Gregersen

Haugen, Fredrik Nygård
Numerical investigation of integrated reactor-separator designs for precombustion with carbondioxide capture
Supervisor: Hugo Jakobsen

Høie, Anne Næss
Chemicals-based solutions (Scavengers) for oil/condensate fractions with a high content of mevcaptans
Supervisor: Edd A. Blekkan

Johannesen, Erik
Fiber quality; The effect of late wood and fiber dimensions
Supervisor: Øyvind Gregersen

Karlsen, Eirik Kultom
Study of relation between surfaces properties and friction between surface and pulp
Supervisor: Øyvind Gregersen

Lacalle Vilá, Claudia
Hydrogen Production by Sorption Enhanced Methane Reforming
Supervisor: De Chen

Manum, Henrik
Analysis of techniques for automatic detection and quantification of stiction in control
loops
Supervisor: Sigurd Skogestad

Nilsen, Siljee
Characterization of products from the conversion of heavy oils
Supervisor: Edd A. Blekkan

Næsland, Kathrine
Interpretation of Emulsion Separation Data
Supervisor: Johan Sjöblom

Olsen, Alice
Mongstad refinery. A Model for analysing the Ecology of the Overall Process
Supervisor: Heinz Preisig

5th year students 2006/2007

Berntsen Helene
Bjørn Christian Melby
Ekerbakke Hilde
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
Kompalla Thomas
Kordahl Sina
Krogstad Marit Kristin
Mellbye, Andrea S.
Munkebye, Knut-Arne Rademacker
Noreng Lars Erik
Pettersen Martin Vignes
Riseggen Henning
Schønning Magnus
Sletengen Kine
Smith, Marie Bragdø
Solberg Anette
Tandstad Ingfrid
Tjosevik Marie
Tomter Anne
Østli Kristian

Dahl-Olsen, Håkon
Anti-Slug control and Topside Measurements for Pipeline-Riser Systems
Supervisor: Sigurd Skogestad

Qian, Jin
Catalytic Partial Oxidation of Methane at Moderate Temperatures
Supervisor: Anders Holmen

Smith, Marie Bragdø
Correlation between crystallization, filtration and washing of a model substance of x-ray agents
Supervisor: Dick Malthe-Sørenssen

Wendelbo, Helene
Fischer-Tropsch-Catalysts
Supervisor: Anders Holmen

Aanonsen, Tomas
Development of carbon molecular sieve membranes for hydrogen recovery
Supervisor: May-Britt Hägg

Aardal, Brynjar Fausk
Membrane reactor for production of hydrogen from methanol
Supervisor: Hilse Venvik

4rd year students 2006/2007

Aulie, Martin Håkon
Beinset Morten
Bekkevold Jan Petter
Bergstedt Elin
Braathen Bjarne
Elde Ingrid Elise
Ellingsen, Christian
Evensen Trond
Fagerbekk Siri Albertsen
Fahadi Jalal
Fjeldstad, Lars Johann
Fostenes Siv Monica
Frøseth Fredrik
Fævelen Erlend Schou
Haukebø, Siv Hustad
Husås Ranveig
Jonassen Øystein
Jøndahl Mari
Karlsen Cathrine Hval
Kleppa Gøril
Knudsen Agnethe
Leonard, Aron
Lie Marianne
Opedal Nils
Pettersen Tone Sejnæs
Skogestad Hanne
Smedsrud, Helge
Solsvik, Jannike
Spets, Øyvind
Theogene, Uwarwema
Tveten Erik Zakarias
Vatneberg Stine V.
Zhu, Ye
Aarhoug Kristin

3rd year students 2006/2007

Bjartnes, Kirsti
Borander, Andreas Høiem
Enaasen, Nina
Helberg, Ragne Marie Lilleby
Holsæter, Hege Christine
Høyen, Ragnhild
Haaversen, Linn christine Loe
Johansen, Hege Døvle
Jonassen, Øystein
Kalstad, Tone
Mæhle, Inger Roksvåg
Nenningsland, Andreas Lyng
Nergård, Liv-Turid
Roll, Sebastian
Røsting, Kristine
Sjulstad, Johanne Schjellungen
Storsæter, Kathrine
Tuvnes, Eirik Fatnes
Tørneng, Eirik Fatnes
Vaktdal, Hanne Margrethe
Vattekar, Petter Tangen
Vik, Camilla Berge
Østbye, Helene
Aaserud, Jo

Student exchange 2006

15 students from our Department (11 females and 4 males).

Name	To Institution	Programme	Period
Beinset, Morten	Universidad de Granada, Spain	Erasmus	01.09.05 - 01.07.06
Bekkevold, Jan Petter	Ecole Nationale Superieure, Paris, France	Erasmus	15.09.05 - 15.07.06
Braathen, Bjarne	Universität Karlsruhe, Germany	Erasmus	01.09.06 – 01.08.07
Fagerbekk, Siri Albertsen	ETH, Zürich, Switzerland	Erasmus	01.09.06 – 01.07.07
Haugbråten, Kristin Sarsten	Royal Melbourne institutt, Australia	Individual	15.08.05 – 15.08.06
Jøndal, Mari	University of California, Berkeley, USA	Erasmus	01.09.06 – 20.12.06
Karlsen, Cathrine	Ecole Nationale Supérior des Ing., France	Erasmus	04.09.06 – 30.06.07
Kordahl, Sina	University of Bath, England	Erasmus	15.09.05 - 15.06.06
Manum, Henrik	University of Pisa, Italy		10.01.06 - 01.08.06
Pettersen, Tone Sejnæs	University of British Colombia,	Bilateral	01.09.06 - 01.06.07
Skogestad, Hanne	University of Texas, Austin, USA	Bilateral	30.08.06 – 01.06.07
Tjosevik, Marie	University of Newcastle upon Tyne, England	Bilateral	15.08.05 - 15.06.06
Tomter, Anne	Vysoká Skola chemicko-technol., Czeck Rep.	Erasmus	15.09.05 - 15.06.06
Tøsdal, Kjersti Blytt	Universität Karlsruhe, Germany	Erasmus	20.10.06 – 20.08.07
Vatneberg, Stine Vemmestad	Technische Universität Berlin, Germany	Erasmus	01.09.06 – 01.08.07

26 exchange students to our Department, (12 females and 14 males)

Name	From Institution	Programme	Period
Ajuria, Olatz	Universidad del Pais Vasco, Spain	Erasmus	05/06
Arnaez, Leire Andres	Basque Country Univsity (UPV), Spain	Erasmus	Spring 06
De Vis, Benjamin	Katholieke Universiteit Leuven, Belgium	Erasmus	05/06
Dominques Castro, Fernando	Universidad de Cádiz, Spain	Erasmus	06/07
Dufour, Céline	Institut National Polytechn. De Toulouse, France	Ensiacet-agreement	06-09.06
Frias, Marcos Dionisio Lobato	Universidad Pablo de Olavide, Sevilla, Spain		
Garcia Aparici, Daniel	Universidad Autonoma de Madrid, Spain	Erasmus	06/07
Gillot, Coralie	Institut National Polytechn. De Toulouse, France	Ensiacet-agreement	06-09.06
Hernaiz Esteban, Joseba	University of the Basque Country, Bilbao, Spain	Erasmus	06/07
Iñigo Arrillaga, Mikel	University of the Basque Country, Bilbao, Spain	Erasmus	06/07
Izquierdo Peinado, Miguel Angel	Universidad de Granada, Spain	Erasmus	05/06
Jaunet, Julie	Institut National Polytechn. de Toulouse, France	Training agreement	06.-09.06
Korak, Julie	University of Colorado, USA	Free mover	06/07
Lacalle Vilá, Claudia	Universitat de Barcelona, Spain	Erasmus	05/06
Manner, Matti Vili-Pekka	Tampereen teknillinen, Finland	Nordplus	05/06
Palacios, Maria Aragon	Universidad de Cádiz, Spain	Erasmus	Autumn 06
Peña Gómez, Yolanda	Universidad de Granada, Spain	Erasmus	05/06
Radstake, Paul	Universiteit Utrecht, The Netherlands	Erasmus	Spring 06
Campllonch Roig, Roger	Universidad Rovira I Virgili, Spain	Erasmus	06/07
Sanchez Melgareio, Jose Enrique	Universidad de Granada, Spain	Erasmus	06/07
Scorl, Anja	Technische Universität Freiberg, Germany	Erasmus	05/06
Segura De La Monja, Paula	Universidad Autónoma de Madrid, Spain	Erasmus	Springr 06

Theiler, Stefan	RWTH Aachen, Germany	Erasmus	Spring 06
Terra, João	Universidade Técnica de Lisboa, Portugal	Erasmus	06/07
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-Theses 2006

Bjørgum, Erlend
Methane Conversion over Mixed Metal Oxides
Supervisor: Anders Holmen

Chen, Shukun
Rheological Properties of Water in Oil Emulsions and Particulate Suspensions
Supervisor: Johan Sjöblom

Dorao, Carlos Alberto
High Order Methods for the Solution of the Population Balance Equation with Applications to Bubbly Flows
Supervisor: Hugo Jakobsen

Eriksen, Øyvind
The influence of paper structure on ink pigment distribution and printthrough
Supervisor: Øyvind Gregersen

Frøseth, Vidar
A steady-state isotopic transient kinetic study of Co catalysts on different supports
Supervisor: Anders Holmen

Hannisdahl, Andreas
Particle-Stabilized Emulsions and Heavy Crude Oils. Characterization, Stability Mechanisms and Interfacial Properties.
Supervisor: Johan Sjöblom

Haugan, Marianne
Hydrogen peroxide bleaching of mechanical pulp
Supervisor: Øyvind Gregersen

Helsør, Thomas
Experimental Characterizaton of Wire Mesh Demisters
Supervisor: Hallvard Svendsen

Huber Florian
Nanocrystalline copper-based mixed oxide catalysts for water-gas shift
Supervisor: Anders Holmen

Lyngstad, Hilde
Seasonal variations in mechanical pulp quality
Supervisor: Størker Moe

Siepmann, Volker
Process modelling on a canonical basis
Supervisor: Tore Haug-Warberg

Skjetne, Bjørn
Numerical Studies of Brittle-Elastic Fracture
Supervisor: Torbjørn Helle

Tobiesen, Finn Andrew
Modelling and Experimental Study of Carbon Dioxide Absorption and Desorption
Supervisor: Hallvard Svendsen

Volden, Sondre
Preparation and Characteristics of Novel Silica-based Materials and Adsorbed Macromolecules
Supervisor: Johan Sjöblom

Wesenberg, Margrete Hånes
Gas Heated Steam Reformer Modelling
Supervisor: Hallvard Svendsen

PhD students from our Department visited other Universities in 2006

Name	University/Country	Period
Dyrbeck, Hilde	Dipartemento di Chimica, Bologna, Italy	02.10.06 – 28.02.07
Jensen, Jørgen Bauck	Linde Engineering, Pullach, Germany	18.09.05 – 31.12.06
Johnsen, Cecilie G.	University of Stuttgard, Germany	03.10.05 – 31.01.06

12 PhD exchange students visited our Department in 2006, (6 female and 6 male).

Name	University/Country	Group located
Cai, Junping	Aalborg University, Denmark	Process systems and Engineering Group
De Lathouder, Karen	Delft University, The Netherlands	Catalysis and Petrochemistry Group
Králová, Iva	Brno University, Czech Republic	Colloid- and Polymer Group
Lersbamrungsuk, Veerayut	Kasetsart University, Thailand	Process systems and Engineering Group
Lögdberg, Sara	KTH, Sweden	Catalysis and Petrochemistry Group
Modise, Tshepo	University of the Witwatersrand, South-Africa	Process systems and Engineering Group
Ryden, Magnus	KTH, Sweden	Catalysis and Petrochemistry Group
Schmidt, Kurt	University of Bergen	Reactortechnology Group
Tang, Shuihua	Dalian University, China	Catalysis and Petrochemistry Group
Tristantini, Dewi	Chalmers University, Sweden	Catalysis and Petrochemistry Group
Tynys, Antti	HUT, Finland	Catalysis and Petrochemistry Group
Zhu, Jun	East China University of Science, China	Catalysis and Petrochemistry Group

Suplementery education

EEU-course KP6002, Paper technology, 16.01. – 20.01, and 13.-17.02.2006. The course had 18 participants. Those who passed the exam got 6 ECTS. Responsible for the course: Professor Øyvind Gregersen and Associate Professor Størker Moe.

EVU-course KP6001 Offshore processing, 16.01. – 20.01., and 30.01. – 03.02.2006. The course had 9 participants. Those who passed the exam got 6 ECTS. Responsible for the course: Professor May-Britt Hägg, Professor Emeritus Jørgen Løvland, and Adjunct Professor John Daniel Friedemann.

Seminars and meetings organized by the Department in 2006

Symposiums:

12th Nordic Symposium on Catalysis
Energy and Environmental Catalys. Catalysis in Nordic Countries.
Arranged by the Catalysis Group, Department of Chemcal Engineering, NTNU, 28. – 30.05.2006

8th International Conference on Greenhouse Gas Control Technologies.
Arranged by The Gas Technology Center NTNU-SINTEF (May-Britt Hägg). 18.06. – 22.06.2006

10th Nordic Filtration Symposium,
High temperature gas filtration, Membrane gas cleaning, Aerosol separation, Industrial applications
Arranged by The MEMFO group, NTNU/SINTEF (May-Britt Hägg), 03.09 - 05.09.2006

Minisymposium in Colloid Chemistry: Professor Johan Sjöblom, Department of Chemical **Engineering, NTNU.** 14.09. – 15.09.2006

Seminars:

KinCat Seminar in Heterogeneous Catalysis: Denitrification of drinking water. The possibilities of catalysis, **Dr A. Eduardo Palomares, Department of Chemical Engineering, Technical University of Valencia, Spain,** 14.09.2006

Seminar/course in Colloid Chemistry
A Short Course on Fluorescence Measurements, **Professor Mats Almgren, Uppsala Univeristy, Sweden,** 16.10. – 18.10.2006

Seminar in Crystallization and Powder Technology **Didrik Malthe-Sørenssen and Jens-Petter Andreassen,** Oslo 23.11.2006

KinCat Seminar in Heterogeneous Catalysis: Synthesis, Characterization, and Hierarchiacal Ordering of Mesoporous Silica.
Dr. Anna Lind, Åbo Academy, Finland, 06.11.2006.

Guest lectures:

Professor Jiri Cejka, J. Heyrovsky Institute of Physical Chemistry, Academy of Sciences, Czech Republic: *Organized Mesoporous Alumina: State-of-the-Art*, 10.02.2006

Professor Bjørn Kvamme, Department of Physics and Technology, University of Bergen: *Inteffaces: Challenges and possibillities for molecular modelling with special emphasis on application in kinetic modelling of hydrate in porous media*, 09.06.2006

Professor Tor Austad, University of Stavanger: *Seawater as IOR Fluid in Chalk,* 14.06.2006

Professor Mingyuan Li, Beijing Petroleum University, Peoples Republic of China: *The Formation and Characterization of Emulsions in Connection with Alkaline Polymer and Surfactant Flooding in China*, 09.10.2006

Dr. Brian A. Grimes, Johannes Gutenberg Universität Mainz, Mainz, Germany: *Modeling and Simulation of Transport Phenomena in Chromatographic Systems with network and Continuum Models*, 06.11.2006

Dr. E. Hugh Stitt, Johnson Matthey Technical Centre Billingham, UK: *Cat in a Hot Tin Tube,* Norwegian Chemical Society Industry Lecture, 30.05.2006

Dr Hiroki Nanko: *Energy consumption during production of microfibrillated cellulose.* 18.08.2006

CHAPTER 7: ORGANIZATION - ECONOMY

Organization (see cover page):
The Head of department is elected for a four-year period (2005 – 2008). The scientific staff is divided in 6 research groups. Each research group has a representative in the management team. The management team meets every second week and discusses running matters.
In addition the department has 12 persons in a technical and administrative staff to support teaching and research of all the research groups.

Department economy:
The department receives contribution from the University and overhead from external projects of about 27 million NOK.
These funds are mainly used to pay salaries to the permanent staff . More details are shown in Table 1.

Accounts	2003	2004	2005	2006
Income				
University funding	21 309 641	20 556 093	22 129 000	24 434 113
Overhead external projects	1 278 884	2 153 815	2 153 815	2 390 000
Sum income	22 588 525	22 709 908	24 282 815	26 824 113
Expences				
Wages	19 335 309	17 703 181	19 216 318	22 514 217
Operating expenses	3 878 386	3 937 176	3 660 005	3 818 963
Sum expenses	23 213 695	21 640 358	22 876 323	26 333 180
Result	(625 170)	1 069 551	1 406 492	490 933

Table 1. Departments income and spending

External funding
In addition to the funding shown in Table 1, the Department has a yearly income from external contributors of approx 48 million NOK. Details are shown in Tables 2 and 3. Most of the costs are related to salary for PhD candidates. The main contributor to the external research activity is The Norwegian Research Council (NFR). Most of these funds come from projects at the Department, but the second largest external source is NFR projects where we contribute as a third party. Industrial contributions are growing rapidly, mainly due to NFR policy that focus on collaboration between universities and industry. Therefore an increasing number of projects are partly financed by industry and/or research institutes. Funding from commisioned research is also growing. We have several joint industrial programmes with industry partners from countries in Europe, North-America, South America and Asia. The share of external funding from commisioned research was approx 18% in 2006.

Table 2. Sources of external funding

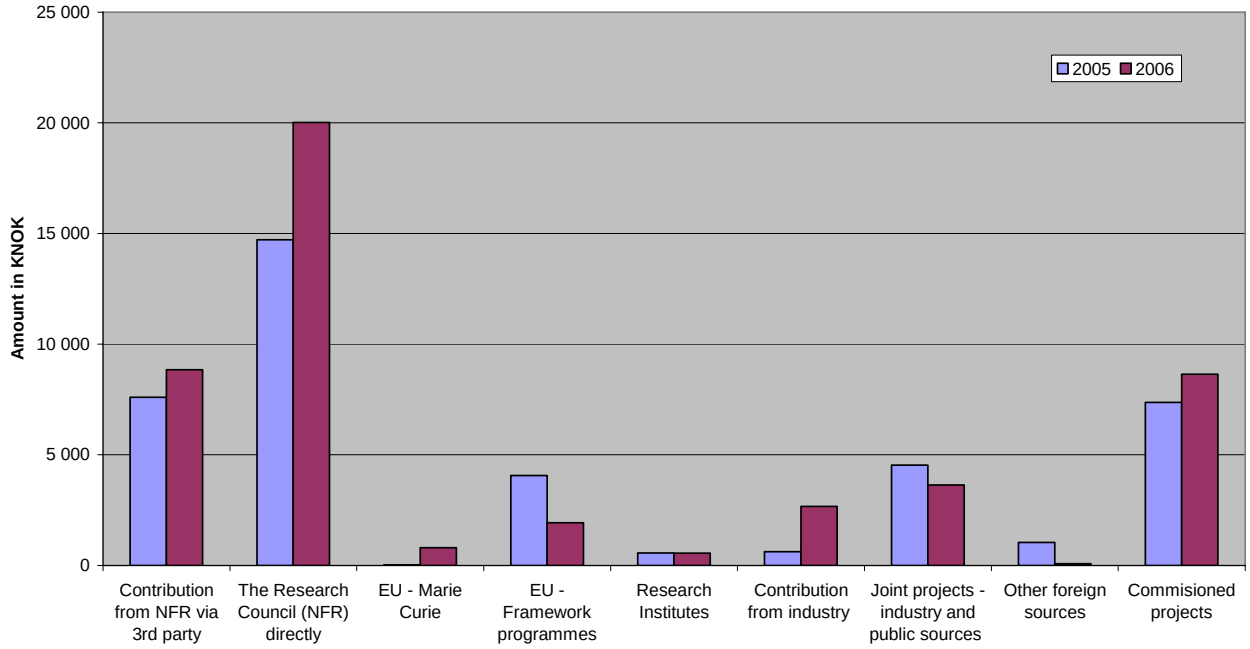
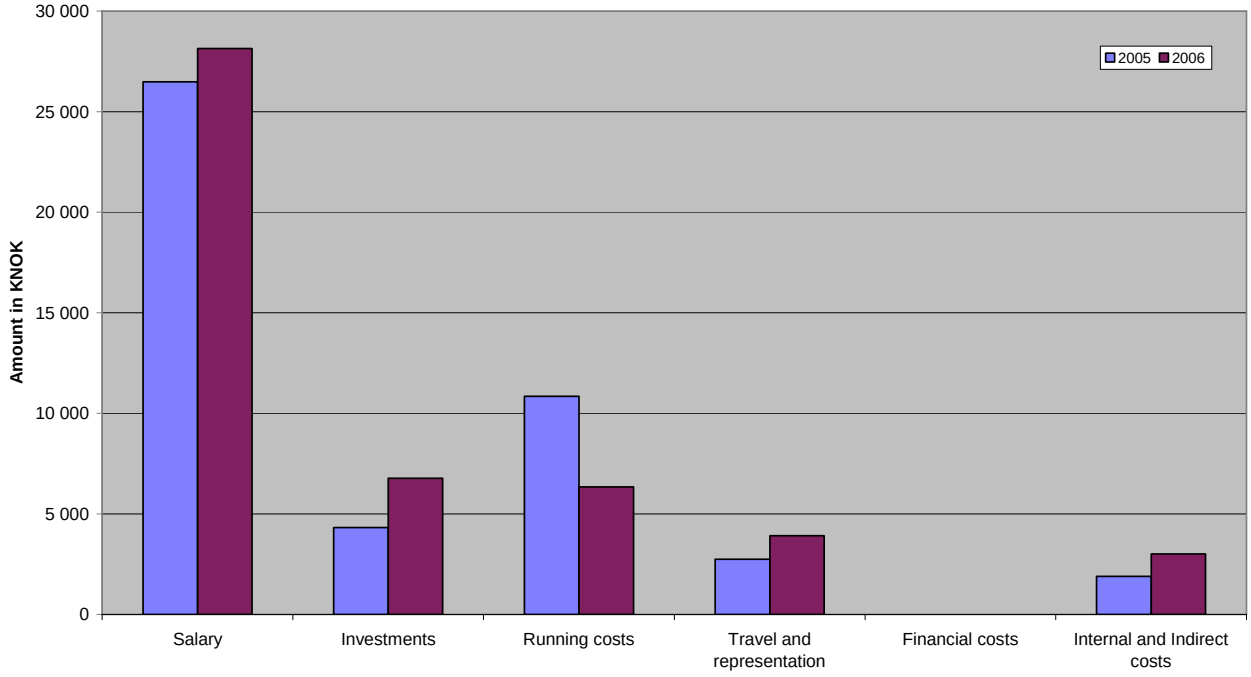


Table 3. Use of external funds by cost category



Some pictures of different activities at the Department

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

Jens-Petter Andreassen and students in the Chrystalisation Laboratory

Heidi Sivertsen shows how to make ice-cream with liquid Nitrogen at "Open day" at NTNU.

Henrik Manum helps making "robot-juice" at "Reachers day" in Trondheim.

Scientific wine tasting during Strategy seminar in Selbu March 2007. In the middle the Head and Deputy Head of Department

Asbjørn Øye, Sigurd Skogestad, Magne Hillestad, Dean of Faculty Bjørn Hafskjold, and student Marit Kristin Krogstad. In the background Norvald Nesse.

From the nearly finished new laboratory in the 3rd floor in building K5.

LIST OF TELEPHONE NUMBERS

94209	Andreassen Jens-Petter, Associate Professor	K5-208
50537	Andresen Martin, Ph.D. candidate	PFI-3207
50325	Arla David, Post doctor	K5-306
91559	Aske Elvira Marie B, Ph.D. candidate	K4-206
97018	Bakthiary Hamidreza, Ph.D. candidate	K5-M12
50318	Barø Tove, Administrative assistant	K5-101
92837	Beck Ralf, Ph.D. candidate	K5-146
94138	Berge, Arvid, Professor Emeritus	K4-116
93692	Berglihn Olaf Trygve, Ph.D. candidate	K4-218
94157	Blekkan Edd Anders, Professor	K5-429
93146	Borg Øyvind, Ph.D. candidate	K5-411
90638	Borge Tone, Ph.D. candidate	K5-225
91664	Borthen Berit, Chief Engineer	PFI-2101
94141	Boullosa Eiras Sara, Ph.D. candidate	K5-411
94144	Brun Harry, Engineer	K5-341
93149	Chen De, Professor	K5-407
94182	Chytil Svatopluk, Ph.D. candidate	Kh-104
94312	Dam, Anh Hoang, Ph.D. candidate	Kh-108
93691	Dahl-Olsen Håkon, Ph.D. candidate	K4-225B
95867	Deng Liyuan, Ph.D. candidate	K4-210
93942	Dones Ivan, Ph.D. candidate	K4-212
90338	Dudásová Dorota, Ph.D. candidate	K5-339
94110	Dupuy Pablo, Ph.D. candidate	K5-244
94146	Dyrbeck Hilde, Ph.D. candidate	Kh-107
94187	Enger Bjørn Christian, Ph.D. candidate	K5-M09
94120	Erga Olav, Professor Emeritus	K5-237
50537	Eriksen Øyvind, Post doctor	PFI-3207
94124	Esbensen Kim H., Adjunct Professor	K4-116
92837	Flaten Ellen Marie, Ph.D. candidate	K5-146
	Foss Martin Smestad, Ph.D. candidate	
94149	Fossen Martin, Ph.D. candidate	K5-308
94143	Fossum Arne, Engineer	K5-019
94017	Friedemann John Daniel, Adjunct Professor	K5-338
94158	Glomm Wilhelm R. Associate Professor	K5-336
93138	Grainger David, Ph.D. candidate	K5-251
94029	Gregersen Øyvind, Professor	PFI-2109
90338	Grimes Brian, Post doctor	K5-339
94017	Gulbrandsen Egil, Adjunct Professor	K5-338
98354	Hammer Nina, Ph.D. candidate	K5-M5
94159	Hanneseth Ann-Mari Dahl, Ph.D. candidate	PFI-3407
94125	Hartono Ardi, Ph.D. candidate	K5-145
94161	Haugen Geir, Researcher	K5-430
94108	Haug-Warberg Tore, Associate Professor	K4-231
95714	Hayer Fatemeh, Ph.D. candidate	K4-225B
92839	He Li, Ph.D. candidate	K5-421
94031	Helle Torbjørn, Professor emeritus	PFI-2109
50304	Helmersen Tom, Office Manager	K5-101
94113	Hertzberg Terje, Professor	K4-234
94110	Hessen Erik Troøien, Ph.D. candidate	K5-244
94122	Hillestad Magne, Professor	K5-213
94151	Holmen Anders, Professor	K5-401
94039	Hori Eduardo Shigueo, Post doctor	K4-214
94026	Hovin Odd Ivar, Engineer	Kh-155
94033	Hägg May-Britt, Professor	K5-204
98354	Håkonsen Silje Fosse, Ph.D. candidate	Kh-M5
50540	Håkonsen Signe, Senior Engineer	PFI3404
94132	Jakobsen Hugo Atle, Professor	K5-209
50331	Jensen Jørgen B. , Ph.D. candidate	K4-225 D
50372	Kim Inna, Ph.D. candidate	Kh-156
95867	Kim Taek-Joong, Researcher	K4-208
94125	Knuutila Hanna, Ph.D. candidate	K5-145
51128	Kvande Ingvar, Ph.D. candidate	K5-443
50540	Lesaint Caterina, Senior Engineer	PFI-3404
94253	Lesaint Cédric, Post doctor	K5-335
50924	Less Simone, Ph.D. candidate	PFI-3408
94114	Lie Jon Arvid, Post doctor	K5-247
94114	Lindborg Håvard, Ph.D. candidate	K5-247
93138	Lindbråthen Arne, Post doctor	K5-223
39691	Linhart Andreas, Ph.D. candidate	K4-225B
94189	López Garciá Marta, Ph.D. candidate	PFI-3401
50331	Løvfall Bjørn Tore, Ph.D. candidate	K4-225D
94124	Løvland Jørgen, Professor Emeritus	K4-116
94105	Magnusson Heléne K., Researcher	K5-324
94120	Malthe-Sørenssen Didrik, Adjunct Professor	K5-238
94136	Manum Henrik, Ph.D. candidate	K4-216
94155	Matam Santhosh Kumar, Post doctor	K5-432
94153	Mathisen Torgrim, Higher Executive Officer	K5-101c
50322	Mejdell Astrid Lervik, Ph.D. candidate	Kh-109
94187	Meland Hilde, Ph.D. candidate	K5-M09
94032	Moe Størker, Associate Professor	PFI-2108
94147	Moljord Kjell, Adjunct Professor	K5-M11
94148	Mørk Preben C., Professor	K5-301
94163	Narasimhan Sridharakumar, Post doctor	K4-229B
91668	Nesbakk Tommy, Ph.D. candidate	PFI-1405
94133	Nesse Norvald, Professor Emeritus	K4-312
94112	Nilsen Tom-Nils, Senior Researcher	K4-204
50537	Nordhagen Håkon, Ph.D. candidate	PFI-3207
94145	Ochoa Fernandez Esther, Ph.D. candidate	K5-443
93147	Paso Kristofer, Post doctor	K5-304
95879	Patruno Lucioano, Ph.D. candidate	K5-245
94208	Phan Xuyen Kim, Ph.D. candidate	K5-M12
92807	Preisig Heinz A, Professor	K4-221
90638	Sheridan, Edel, Post doctor	K5-225
94139	Roel Jan Morten, Engineer	Kh-155
94150	Roel Lisbeth H B, Executive Officer	K5-101
50359	Rusten Hans Kristian, Ph.D. candidate	K5-156
94147	Rytter Erling, Adjunct Professor	K5-M11
94121	Rønning Magnus, Associate Professor	K5-408
94136	Sandru Marius, Ph.D. candidate	K4-216
91605	Selsbak Cecilie Mørk, Senior Engineer	PFI-3402
94073	Setekleiv Eddie, Ph.D. candidate	K5-M6
50331	Shao Lei, Ph.D. candidate	K4-225B
94159	Silset Anne, Ph.D. candidate	PFI-3407
94125	Silva Eirik Falck da, Post doctor	K5-145
91657	Simon Sebastien, Post doctor	PFI-3406
95714	Sivertsen Heidi, Ph.D. candidate	K4-225B
95505	Sjöblom Johan, Professor	K5-344
50339	Skjetne Ragnhild, Ph.D. candidate	K5-340
94154	Skogestad Sigurd, Professor	K4-232
50344	Steineke Fredrik, coordinator	K-IV 221 B
94017	Stenius Per, Adjunct Professor	K5-338
93692	Strandberg Jens Petter, Ph.D. candidate	K4-218
94017	Stöcker Michael, Adjunct Professor	K5-338
94106	Sundseth Frode, Engineer	K5-033
94100	Svendsen Hallvard, Professor	K5-237
94119	Thorsen Gunnar, Professor Emeritus	K5-M8
94193	Tynys Antti, Senior Researcher	Kh-250
92831	Venvik Hilde , Associate Professor	K5-406
94149	Volden Sondre, Post doctor	K5-308
93145	Wangen Espen Standal, Ph.D. candidate	Kh-106
94156	Xiong Jianmin, Post doctor	Kh-105
93942	Zenith Federico, Ph.D. candidate	K4-212
94155	Zhao Tiejun, Post doctor	K5-432
95728	Zhu Zhengjie, Ph.D. candidate	K4-220
50342	Øvrevoll Bodhild, Senior Engineer	PFI-3403
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Associate professor Hilde J. Venvik
Senior engineer Berit Borthen
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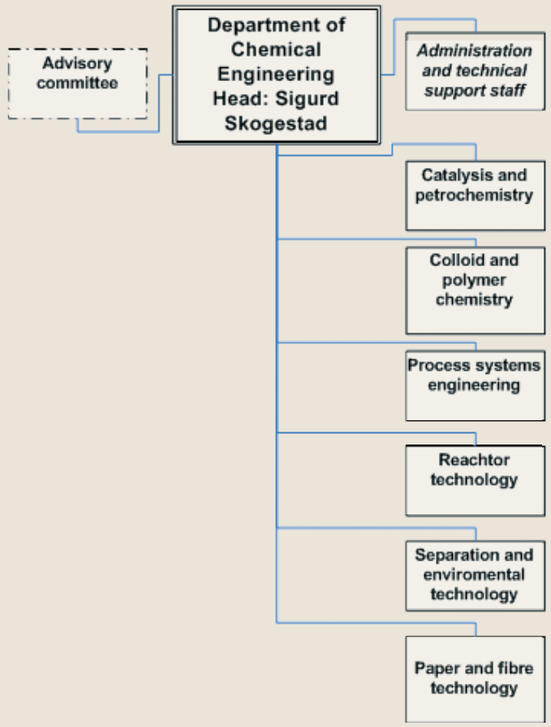
Student Marit Kristin Krogstad
Student Gunn Heidi Jentoft



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Academic staff, see the individual research groups:

Technical and administrative staff:
Head of Administration Tom Helmersen

Administrative staff:
Senior Executive Officer Torgrim Mathisen
Executive Officer Lisbeth B. Roel
Administrative assistant Synnøve Hestnes
Administrative assistant Tove Barø

Technical staff:
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Engineer Harry Brun
Engineer Arne Fossum
Engineer Odd Ivar Hovin
Principal Engineer Signe Håkonsen
Engineer Jan Morten Roel
Principal Engineer Cecilie M. Selsbak
Engineer Frode Sundseth
Senior Engineer Bodhild Øvrevoll
Senior Engineer Asbjørn Øye

COVER PAGE (photo Ellen Marie Flaten)
Polymorphs of calcium carbonate precipitated in water at 50°C, showing the complexity of scale studies in oil and gas processing.

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50537	Andresen Martin, Ph.D. candidate	PFI-3207
50325	Arla David, Post doctor	K5-306
91559	Aske Elvira Marie B, Ph.D. candidate	K4-206
97018	Bakthiary Hamidreza, Ph.D. candidate	K5-M12
50318	Barø Tove, Administrative assistant	K5-101
92837	Beck Ralf, Ph.D. candidate	K5-146
94138	Berge, Arvid, Professor Emeritus	K4-116
93692	Berglihn Olaf Trygve, Ph.D. candidate	K4-218
94157	Blekkan Edd Anders, Professor	K5-429
93146	Borg Øyvind, Ph.D. candidate	K5-411
90638	Borge Tone, Ph.D. candidate	K5-225
91664	Borthen Berit, Chief Engineer	PFI-2101
94141	Boullosa Eiras Sara, Ph.D. candidate	K5-411
94144	Brun Harry, Engineer	K5-341
93149	Chen De, Professor	K5-407
94182	Chytil Svatopluk, Ph.D. candidate	Kh-104
94312	Dam, Anh Hoang, Ph.D. candidate	Kh-108
93691	Dahl-Olsen Håkon, Ph.D. candidate	K4-225B
95867	Deng Liyuan, Ph.D. candidate	K4-210
93942	Dones Ivan, Ph.D. candidate	K4-212
90338	Dudásová Dorota, Ph.D. candidate	K5-339
94110	Dupuy Pablo, Ph.D. candidate	K5-244
94146	Dyrbeck Hilde, Ph.D. candidate	Kh-107
94187	Enger Bjørn Christian, Ph.D. candidate	K5-M09
94120	Erga Olav, Professor Emeritus	K5-237
50537	Eriksen Øyvind, Post doctor	PFI-3207
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92837	Flaten Ellen Marie, Ph.D. candidate	K5-146
94149	Fossen Martin, Ph.D. candidate	K5-308
94143	Fossum Arne, Engineer	K5-019
94017	Friedemann John Daniel, Adjunct Professor	K5-338
94158	Glomm Wilhelm R. Associate Professor	K5-336
93138	Grainger David, Ph.D. candidate	K5-251
94029	Gregersen Øyvind, Professor	PFI-2109
90338	Grimes Brian, Post doctor	K5-339
94017	Gulbrandsen Egil, Adjunct Professor	K5-338
98354	Hammer Nina, Ph.D. candidate	K5-M5
94159	Hanneseth Ann-Mari Dahl, Ph.D. candidate	PFI-3407
94125	Hartono Ardi, Ph.D. candidate	K5-145
94161	Haugen Geir, Researcher	K5-430
94108	Haug-Warberg Tore, Associate Professor	K4-231
95714	Hayer Fatemeh, Ph.D. candidate	K4-225B
92839	He Li, Ph.D. candidate	K5-421
94031	Helle Torbjørn, Professor emeritus	PFI-2109
50304	Helmersen Tom, Office Manager	K5-101
94113	Hertzberg Terje, Professor	K4-234
94110	Hessen Erik Trøien, Ph.D. candidate	K5-244
94122	Hillestad Magne, Professor	K5-213
94151	Holmen Anders, Professor	K5-401
94039	Hori Eduardo Shigueo, Post doctor	K4-214
94026	Hovin Odd Ivar, Engineer	Kh-155
94033	Hägg May-Britt, Professor	K5-204
98354	Håkonsen Silje Fosse, Ph.D. candidate	Kh-M5
50540	Håkonsen Signe, Senior Engineer	PFI3404
94132	Jakobsen Hugo Atle, Professor	K5-209
50331	Jensen Jørgen B. , Ph.D. candidate	K4-225 D
50372	Kim Inna, Ph.D. candidate	Kh-156
95867	Kim Taek-Joong, Researcher	K4-208
94125	Knuutila Hanna, Ph.D. candidate	K5-145
51128	Kvande Ingvar, Ph.D. candidate	K5-443
50540	Lesaint Caterina, Senior Engineer	PFI-3404
94253	Lesaint Cédric, Post doctor	K5-335
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