NTNU NanoLab

Annual Report 2007

NTNU
Norwegian University of Science and Technology

NTNU NanoLab

Faculty of Natural Sciences and Technology
Realfagbygget
N-7491 Trondheim
NORWAY

Phone: (+47) 73 59 45 44
E-mail: nanolab@nt.ntnu.no

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COVER PAGE (Photo: Anne Støre)
NTNU NanoLab's clean roomarea for chemical methods.
Editor: Hanna Gautun

NTNU NanoLab

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Introduction

During 2007, NTNU NanoLab has continued the mission as coordinator and promoter of nanotechnological research at NTNU. A substantial part of this effort has been devoted to the establishment of new clean room facilities on the campus of Gløshaugen. The first milestone on this road was the official opening of the clean room area dedicated to chemical methods by Pro Rector Research and Innovation, NTNU, professor Astrid Lægreid, in March. When completed, this area will constitute an integrated part of the total 700 m^2 clean room designed for interdisciplinary research. Part of the teaching and training of MSc students will also be supported by the facilities within the clean room area. The plans for the remaining areas of the laboratory have been finalized during the autumn of 2007 and the construction of a new building for this purpose will start in January 2008.

Efficient and stable operation of such advanced facilities requires highly qualified technical assistance, as well as well designed working routines. Thus, the first member of NTNU NanoLab's technical staff was hired at the beginning of the year. NTNU NanoLab has a high awareness about the existing HES challenges related to exposure of various nanomaterials. A compulsory user course focusing on HES issues related to nanotechnological research and good laboratory practice in a clean room has therefore been established.

At the same time as the establishment of the new clean room facilities moves forward, research within nanoscience and nanotechnology at NTNU is pursued by numerous staff members at various departments. Around 117 scientific papers related to this field were published in 2007, which is twice the number registered in 2006. The increase in the research activity within the field is also demonstrated by the good participation at the 2nd NTNU NanoLab User Meeting and at the NANOMAT conference in Bergen. In the latter meeting, NTNU was represented by 7 lectures and 21 poster presentations within nanotechnology. On an international level, a group of 19 researchers from NTNU and SINTEF met with 15 delegates from AIST in Japan on a one-day seminar for scientific discussions aimed at establishing a bilateral research cooperation. The initiative was supported by the Research Council of Norway.

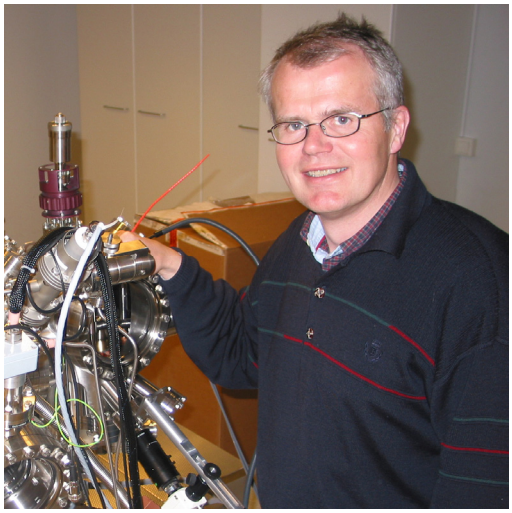

Photo: Arne Asphjell/NTNU Info

With this ongoing progress in mind, we look very much forward to the future developments within the field of nanotechnology in the coming years at NTNU.

Bjørn Torger Stokke
Chairman of the Board of NTNU NanoLab

Highlights of 2007

MOLECULAR INTERACTIONS OF TOLL-LIKE RECEPTORS

Toll-like receptors (TLR) are pattern recognition receptors that form a crucial part of the innate immune system. Upon invasion of bacteria, viruses or fungi, TLRs mount an inflammatory response which enables the host to deal with the infection. In humans, ten different TLRs have been identified. Recently, the crystal structure of the extracellular domains of TLR3, TLR4, and the TLR1-TLR2 heterodimer were determined by diffraction studies [Ref 1-3]. Exactly how the interaction with the ligand triggers the innate immune response is still unresolved. However, developments in nanotechnology make the studies of nanometer-size structures and single molecules possible. Thus, experiments on the nano-scale can provide crucial information regarding molecular details of receptor-ligand interactions.

At NTNU, a collaboration between the group of Prof. T. Espevik at the Institute of Cancer Research and Molecular Medicine and the Biophysics group lead by Prof. B.T. Stokke has undertaken a study of molecular interactions of toll-like receptors. Collaboration has been established with Dr. E. Latz at the University of Massachusetts Medical School, Division of Infectious Diseases and Immunology. Recent work within this collaboration indicates that a ligand-induced conformational change is responsible for the initiation of an immune signalling response in TLR9 activation [Ref 4].

We have made high-resolution atomic force microscopy (AFM) images of the extracellular part of TLR9 receptor (see Figure1) and its ligand CpG DNA. Three different classes of short, CpG-containing DNA evoke different types of immune reactions, and were used as immune modulators. The differences in the higher order structure of the three classes of CpG DNA were clearly resolved in our AFM images and are assumed to influence the type of immune response.

In addition to AFM imaging studies, the binding interaction between TLR9 and CpG DNA have been measured using AFM. The first results of these studies are described in Ref. 5.

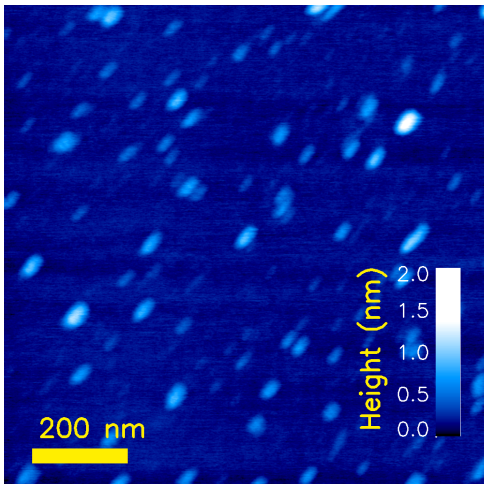

Figure 1. AFM image of the extracellular part of TLR9 receptors on a mica surface. The image was taken in tapping mode in air. Photo: Dionne Klein, NTNU

A graph of the measured interaction force between TLR9 and CpG DNA is shown in Figure 2. The measured interaction forces were in the range of 50 to 100 pN. This work is still in progress. By varying the class of CpG DNA, we hope to be able to identify differences in the specific interaction between TLR9 and the various CpG DNA classes, which will be very helpful information for understanding the molecular details of TLR9-CpG DNA interaction.

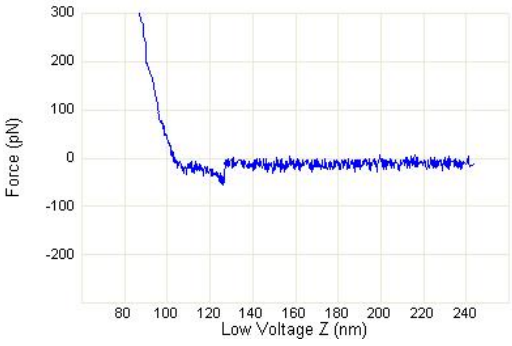

Figure 2. This curve shows the unbinding force between a DNA-modified AFM tip and a surface containing TLR9. Photo: Kirsti Marie Øvrebø and Dionne Klein, NTNU.

To gain insight in the intracellular trafficking of TLRs, experiments with fluorescence recovery after photobleaching (FRAP) of HEK293 cells expressing TLR4-cherry were performed. In these studies an intense laser beam bleaches the fluorescent TLR4 molecules in a defined area of the plasma membrane, see Figure3. From the recovery of the fluorescence intensity in the bleached region, the diffusion of TLR4 and the binding interaction with its ligand lipopolysaccharide (LPS) can be deduced. By comparing the recovery process in cells that were stimulated with LPS to unstimulated cells, we were aiming at understanding the details of the molecular interaction between TLR4 and LPS, and the resulting immune signalling.

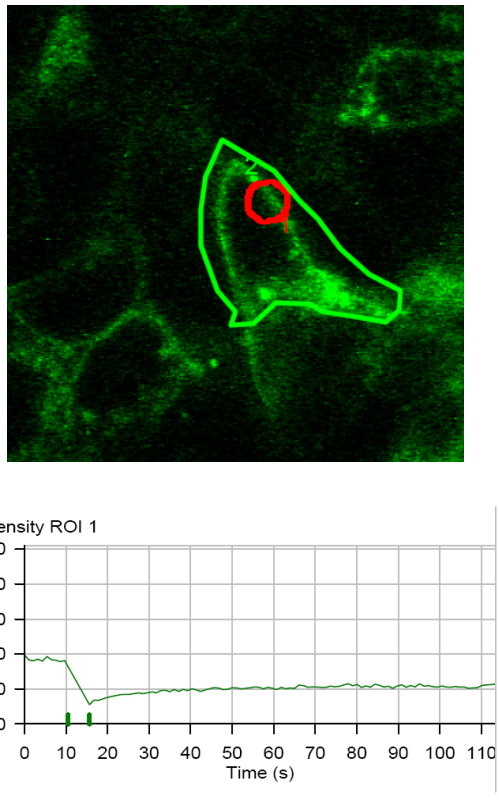

Figure 3. HEK293 cells expressing TLR4-cherry/MD-2 were transfected with CD14. The red circle shows the bleaching area. Below, the fluorescence intensity curve for the bleaching area is shown. Photo: Harald Husebye and Dionne Klein, NTNU.

References:

1. Choe J., Kelker M.S. and Wilson I.A. (2005) *Crystal structure of human Toll-like receptor 3 (TLR3) ectodomain.* **Science** 309, 581-585.

2. Kim H.M., Park B.S., Kim J.-I., Kim S.E., Lee J., Oh S.C., Enkhbayar P., Matsushima N., Lee H., Yoo O.J. and Lee J.-O. (2007) *Crystal Structure of the TLR4-MD-2 Complex with Bound Endotoxin Antagonist Eritoran.* **Cell** 130, 906-917.

3. Jin M.S., Kim S.E., Heo J.Y., Lee M.E., Kim H.M., Paik S.-G., Lee H. and Lee J.-O. (2007) *Crystal Structure of the TLR1-TLR2 Heterodimer Induced by Binding of a Tri-Acylated Lipopeptide*. **Cell** 130, 1071-1082.

4. Latz, E., Verma, A., Visintin, A., Gong, M., Sirois, M., Klein, D. C. G., Monks, B. G., McKnight, C. J., Lamphier, M. S., Duprex, W. P., Espevik, T. and Golenbock, D. T. *Ligand-induced conformational changes allosterically activate Toll-like receptor 9,* **Nature Immunology** 8, 2007, 772-779.

5. Øvrebø, K. M. *Direct Measurement of the Interaction Force between CpG-DNA and Toll-like Receptor 9 by Atomic Force Microscopy*, Project Work Report, Trondheim, December 2007.

DEVELOPMENT OF NANOSTRUCTURED MEMBRANES

While membranes for separation of liquids have been used since the mid sixties, membranes for gas separation is still a young technology. Membranes for industrial gas applications must have a very thin skin allowing a high gas flux. This skin must be highly selective in favour of one of the gas components. The commercial installations for gas separation existing today use polymeric membranes. However, these do not exhibit optimised separation properties. During the last ten years, the research on sophisticated membrane materials for separation of almost any mixtures of gasses has nearly exploded. It is now better understood how the materials can be tailored on a molecular level to change their properties, how pores can be tailored, how addition of nanoparticles may affect the materials, and last but not least; how the transport mechanisms of the gases will vary with the structure of the material, and hence give variations in separation performance.

The crucial feature of an efficient membrane is to have both a high flux (permeation rate through the material), and a high selectivity

between various gases. There is usually a trade-off between these two characteristics in membranes. In the Membrane Research Group, Memfo, at NTNU, this challenge has been in focus within a NANOMAT funded project, by investigating the high free-volume polymers, PMP [poly(4-methyl-2-pentyne)] and PTMSP [poly(1-trimethylsily-1-propyne)] (see Figure 1 for structures).

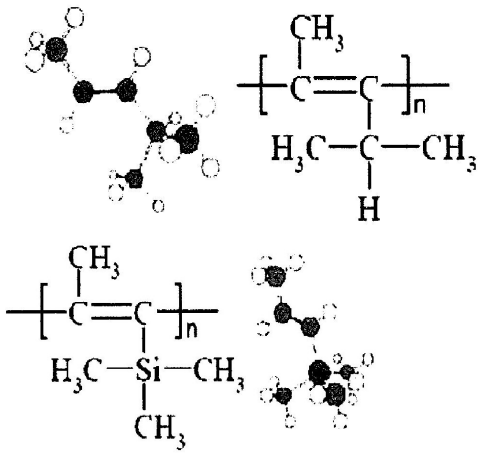

Figure 1. Molecular structure of PMP (top) and PTMSP(bottom).

As can be seen, these two molecules are very bulky and have quite a lot of free space in their structure for gases to move in (~30%). These materials will hence exhibit high flux, but will hardly be able to discriminate between the gas molecules. They have very low selectivity, if any at all. They are also quite unstable.

By cross linking the material, the membrane becomes more stable, but also slightly more dense. Hence, the selectivity increases while the flux decreases. This is illustrated for the gas pair N_2 – H_2 in Figure 2. When, however, nanoparticles (here fumed silica, FS) were added at increasing concentrations, both flux and selectivity in favour of H_2 were improved. This may seem very strange at a first glance, but can be explained by the hindrance the nanoparticles represent, affecting the larger N_2-molecules most. At the same time, the more free space available speeds up the flux of the smaller H_2- molecules. This way of tailoring nanocomposites is quite fascinating. The effect will, however, vary strongly with the type of gases to be separated.

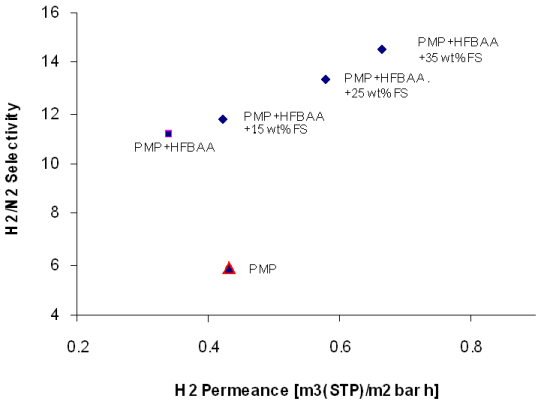

Figure 2. Illustration of how cross linking and addition of nanoparticles (here FS) may affect separation properties of a membrane material

The nanoparticles should, for instance, not exceed 50 nm in size, otherwise the effect may be reversed. Figure 3 shows a SEM-picture of PMP with 25% FS

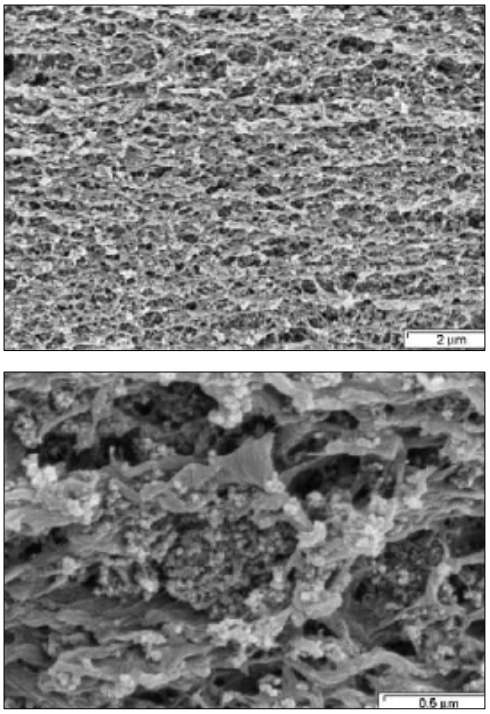

Figure 3. SEM-pictures of pure cross linked PMP (top), and cross linked PMP with 25w% FS (bottom).

Another type of nanostructured membrane developed at NTNU is the CO_2-selective fixed-site-carrier (FSC) polyvinlyamine (PVAm) membrane, which has been patented. This membrane mimics the way our lungs transport CO_2 as a bicarbonate ion (HCO_3^-) at the alveolar level. This demands a sufficiently

high concentration of amino groups on the polymer backbone chain, that water is present, and that the membrane (again) has been sufficiently cross linked in order to avoid swelling. As the membrane layer itself is only about 500 nm thick, it is essential that the polymeric support structure is correctly designed so that it provides support, but does not add any significant resistance to the gas transport through the membrane.

When produced as hollow fibres, these membranes have a huge potential for industrial applications as they can be densely packed in modules giving large permeation area (m^2) per m^3 volume of the module. In Figure 4, a simple illustration of the transport mechanism through the selective layer of the membrane is shown.

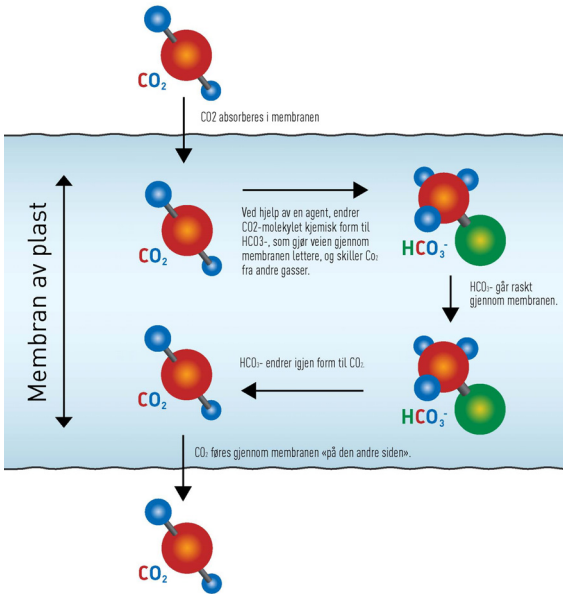

Figure 4. Illustration of CO_2 transport mechanism through a facilitated transport membrane.

There is, in principles, no limit to how membrane materials can be tailored for specific separations; whether it is gases or liquids. It requires fundamental knowledge of materials technology; how to synthesise the membranes, their durability when exposed to certain components, combined with an understanding of the process conditions where we want our membranes to be used. Membrane separation of gasses is an environmentally friendly technology with a great potentioal.

SMART MICROSYSTEMS FOR DIAGNOSTIC IMAGING IN MEDICINE (SMiDA)

It is believed that more than 80% of sudden heart attacks are caused by rupture of vulnerable plaques leading to the formation of blood clots and subsequent coronary stenosis and infarction. As opposed to a stable calcified plaque, the unstable plaque is atherosclerotic and consists of fatty lipids covered by a thin fibrous cap. Currently, due to lack of suitable miniaturized technology, many mildly stenotic vulnerable plaques are left untreated at a significant risk for the patient. Hence, additional techniques and technologies for invasive procedures which can distinguish between plaques of different kind are of great desire.

The SMiDA program at the Department of Electronics and Telecommunication at NTNU focuses on research and development of micro system technologies for imaging of plaques based on invasive procedures. Such imaging systems should combine the results of various physical sensors to provide detailed information on which an accurate diagnosis can be based. In particular, the program focuses on technologies that will enable identification of chemical alterations in atherosclerotic tissue, measurement of local temperature, blood pressure, and blood flow velocity, guided by 3D ultrasound imaging. Blood pressure, blood flow and imaging will be implemented in one silicon-based is Capacitive Micromachined Ultrasonic Transducer (CMUT). This may be combined with temperature and spectroscopy into one physical sensor, but this is a challenge without any definite road map today.

The CMUTs represent an attractive alternative to the traditional piezoelectric ultrasound transducers, due to high bandwidth, possibility of high volume production at a low cost and integration of transmit and receive electronics. The active part of a CMUT is a metal coated silicon nitride membrane. A silicon substrate constitutes the bottom electrode. For the transducer to fit on the tip of a catheter that is to be inserted into the coronary arteries, the maximum diameter is 1 mm. An image resolution of 25µm along the ultrasound wave

is needed to resolve thickness details in the vessel wall and beyond. This means a transmit frequency of 30MHz. To be able to image a sector of 90 degrees the element size cannot be larger than 25µm. The complete 2D array will contain up to 2000 quadratic elements. The first CMUTs produced in this project were manufactured in the SINTEF MiNaLab in Oslo. One of the key challenges is scaling down dimensions to the nanoscale range. The smallest dimension is the membrane thickness, which is only 100 nm. SEM pictures of fabricated CMUTs are shown in Fig. 1. Electrical characterization shows that these transducers have a centre frequency of 30 MHz in air and 8 MHz in oil.

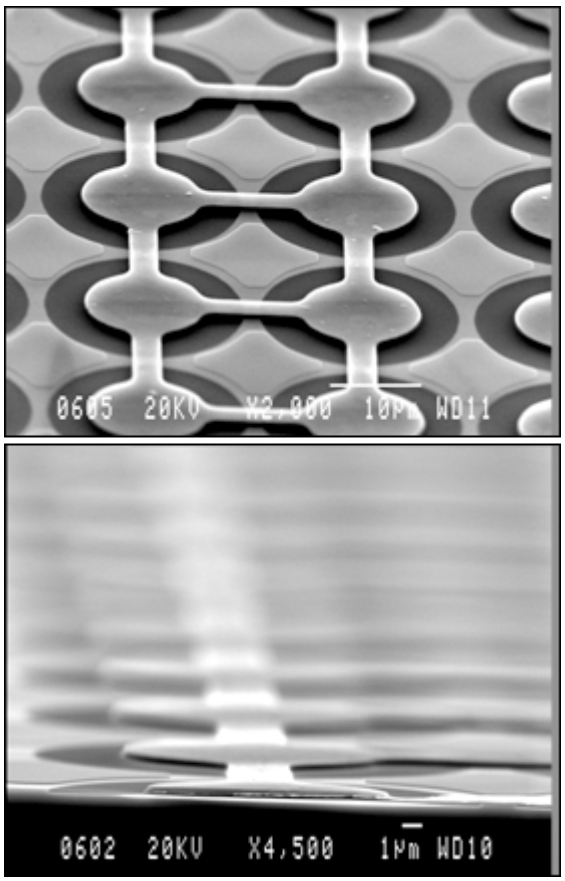

Figure1. SEM pictures of first generation CMUTs developed in the SMiDA program.

The 2nd generation of CMUTs is now in production. Unwanted acoustic effects are reported by many research groups. Simulations performed within the program have shown that adding a few micrometers of a soft, lossy material can help reduce some of these harmful effects.

To actuate and read such small CMUTs, we implement the electronic circuits in nanoscale CMOS technologies to be able to meet the high-speed, low-power, and small size requirements in the SMiDA program. Several prototype circuits have been successfully fabricated in 90nm CMOS applying the most advanced electronic devices available at present and in the near future. The evolution of CMOS technologies follows Moore's law, which predicts an exponential reduction in feature size and growth in performance. In line with this, a new generation of such devices is now being introduced, with new types of geometries at nanoscale dimensions. In order to predict the device behaviour and to design reliable circuits based on these devices, new, accurate device models are needed. This poses special challenges since, at these small dimensions, “new” physical phenomena such as quantum effects and ballistic electron transport are strongly enhanced, complicating dramatically the mathematical description.The work with the SMiDA program on this issue has contributed significantly to the international effort in this area.

To minimize the form factor, it is desirable to use the CMUT elements for both transmit and receive. This mode requires a switch to switch in each CMUT element between the transmitter and receiver. Research and process development of MEMS switches aimed for this use is currently in progress. Important aspects of the MEMS switch are switching time, control voltage and isolation. The work has been performed in collaboration with the SINTEF MiNaLab. This research has led to a number of different MEMS switches and filter designs that have been successfully tested.

The lack of commercial equipment for characterization of CMUTs has motivated the development of a heterodyne interferometer for characterization of ultrasound vibrations. The setup is designed to measure phase and absolute amplitude in the entire frequency range 0-1.2GHz. A 3D map of the object modulation can be obtained by scanning in the x- and y- direction with micrometer precision. The noise limit for vibration is a few picometers for 1Hz bandwidth. By combining phase data and absolute amplitude, various signal processing can be performed such as 2D Fourier analysis. Single CMUT elements and

arrays of CMUTs have been characterized. Frequency scan measurements along a row of CMUTs reveal a variation in resonance frequency. A reason for this may be found in variations of material properties, dimensions such as thickness and transverse dimensions, and other manufacturing variance. The frequency scan revealed the fundamental mode and two closely spaced higher order modes (see Fig. 2). The optical measurements contribute to validation or complement the simulations and assumptions they rely on. The heterodyne interferometer is therefore a valuable tool for quality control in the conception, design and manufacturing of new acoustic devices.

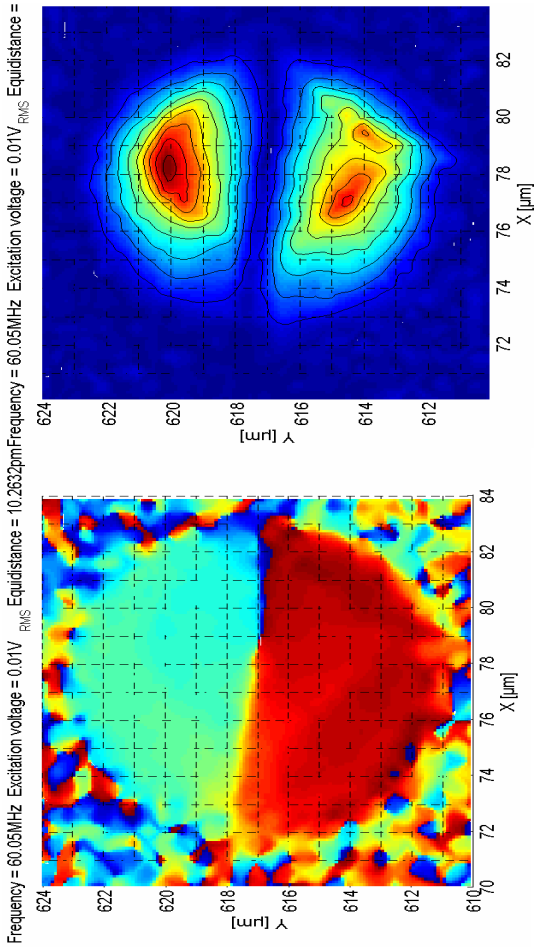

Figure 2. An x-y scan of a single CMUT performed at a higher order mode (60MHz). The top and bottom graphs show the amplitude and phase distribution, respectively.

Another important part of the project is focused on near-infrared (NIR) optical reflectance spectroscopy. In contrast to ultrasound which can provide information on the structural properties of plaques, optical spectroscopy can identify the chemical properties of plaques. Both the structural and chemical properties of a plaque are believed to be important factors in a plaque rupture. Combining these modalities in a single fiber optic probe would therefore be of great interest, hopefully improving the sensitivity and specificity on locating these vulnerable plaques. NIR optical reflection spectroscopy is particularly well suited for identifying the lipid content of plaques. Remaining challenges lie in identifying other spectrally prominent constituents, and in overcoming difficulties such as absorption due to blood which effectively masks most other spectral signatures. A fiber-optic probe has been successfully tested in another project to monitor in vivo oxygen saturation and fluorescence levels during photodynamic therapy of rat urinary bladder cancer.

The results of the research performed within the SMiDA program so far has been published in a number of international journal papers, conference proceedings, and more popular science magazines. A complete list of publications can be found at the SMiDA web-site http://www.iet.ntnu.no/projects/smida/.

NANOMECHANICAL STUDIES

Nanoindentation represents a technique for studying the mechanical properties of various materials. Based on ultra-sensitive depth sensing measurements, mechanical properties like hardness of the samples may be determined. The tests are located in a dimension of tens of atoms and may reveal fundamental mechanisms for the deformation and fracture of the materials.

NTNU Nanomechanical Laboratory (NML) has currently established two sets of nanoindentation systems and developed new measurement methods for practical applications.

The research activities at NML to this date are mainly concentrated on characterization and simulation of the mechanical properties of polymer particles. Three ongoing research projects, financed by the Norwegian Research Council and the industry partners Invitrogen Dynal AS and Conpart AS, focus on the deformation mechanisms and functional performances of various polymer particles with diameters ranging from sub-micron to hundreds microns. Multi-scale modelling is also being performed to determine the link between the microstructures and mechanical properties. So far, fracture behaviour, stress-strain relations, viscoelasticity and delamination between metal coatings and polymer cores taken as mechanical properties of polymer particles and metal-coated polymer particles have been investigated systematically. The microstructures, the cross linking degree and the polymer types are considered to define the particle properties. Further work in this field will focus on the effect of variations in the synthetic processes of the polymer particles on their mechanical properties.

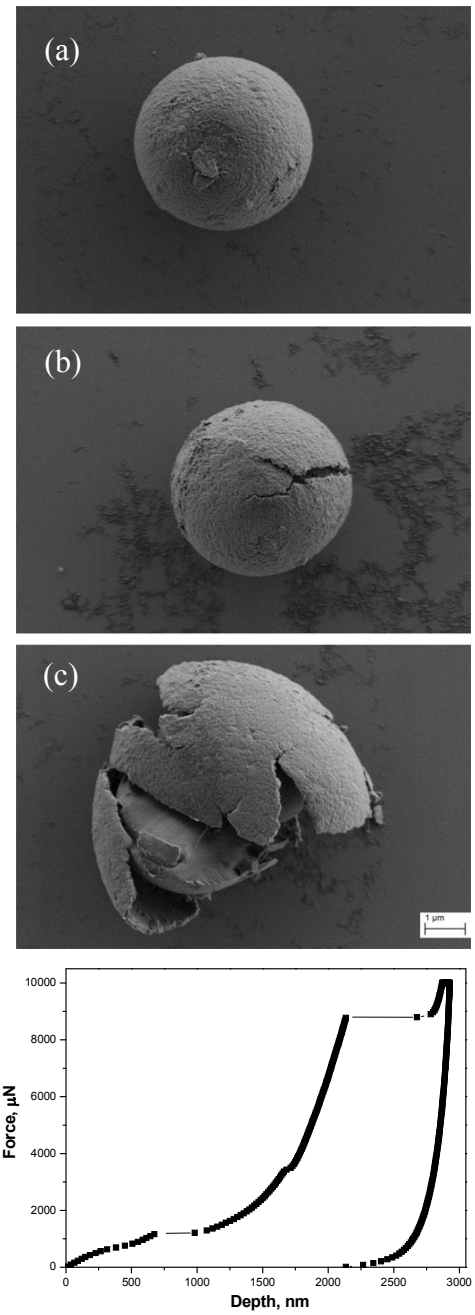

Figure: SEM photographs of 3.8µm gold coated acrylic particles after flat-punch indentation with peak loads (a) 1000µN, (b) 2000µN and (c) 10000µN. Below, the load-displacement curve for the nanoindentation test is shown. Photo: Tor A Nilsen

2nd NTNU NanoLab User Meeting Including the Opening of NTNU NanoLab's Clean Room Area for Chemical Methods

The 2nd NTNU NanoLab User Meeting was arranged as a one-day seminar in the beautiful premises of Lerchendal Gård in Trondheim, on the 7th of March 2007. The purpose of the meeting was to display the ongoing research activities within nano-technology at NTNU and promote cross-disciplinary cooperation. The event gathered 62 participants from 7 Departments, as well as SINTEF. This broad participation was reflected by the variety of the 22 presentations:

- *Dionne Klein;* Toll-like receptor 9 and its ligand CpG-DNA studied with AFM and FCS
- *Bjørn E. Christensen;* Multi-detection SEC analysis of polysaccharides
- *Signe Kjelstrup;* Unifying thermodynamic and kinetic descriptions of single-molecule processes. RNA folding under tension.
- *Sabina Strand;* Kitosane-based nanoparticles for transfer of DNA and siRNA in Genetherapy
- *Hanne Martinussen;* SMiDA - Smart Microsystems for Diagnostic Imaging
- *Øyvind Mikkelsen;* Possible use of NTNU NanoLab within the field of sensor development
- *Magnus Saxegaard;* STM based point contacts for laterally resolved measurements of magnetoresistance
- *Chang Chuan You,;* STM: a nanoscale structuring tool
- *Øystein Dahl;* Switching properties of sub 100 nm thick ferroelectric films
- *Ryota Takahashi;* Photocatalyst as a tool to study nanoscale ferroelectrics
- *Sverre Magnus Selbach;* Multiferroic $BiFeO_3$; wet chemical synthesis and finite size effects
- *Per Martin Rørvik;* Growth of $PbTiO_3$ nanorods on substrates by hydrothermal method
- *Guozhong Wang;* Synthesis of $KNbO_3$ nanorods by hydrothermal method
- *Tor Grande;* Preparation of nanomaterials by wet chemical routes
- *Sedsel Fretheim Thomassen;* Growth of quantum dots for intermediate band solar cells
- *Hilde Lea Lein;* Asymmetric proton and oxygen conduction oxide membranes and fuel cells
- *Cedric Lesaint;* Synthesis, functionalisation and characterisation of mesoporous Alumina materials for Fischer-Tropsch catalysis
- *Magnus Rønning;* Nanomaterials for catalysis
- *Jianying He;* Nanomechanics of nanostructured polymer particles
- *Lei Shao;* Nanostructured membranes
- *Øyvind Bork;* Methanol adsorption on NiAl(110): Density functional theory
- *Astrid Lund Ramstad;* NTNU NanoLab's "Clean Room for Synthesis by Chemical Methods"

After the oral presentations, aperitifs were served in Chemistry Building 2, followed by the symbolic opening of the clean room area for chemical methods by the vice rector of NTNU, Professor Astrid Lægreid.

From the right: Vice-rector Prof. Astrid Lægreid, Prof. Thomas Tybell and the leader of the planning committee for The clean room area for chemical methods, Ass .prof. Astrid Lund Ramstad. Photo: Synnøve Resem/NTNU Info.

The meeting was concluded with dinner and poster session displaying 16 poster contributions.

Seminars and Colloquia

During 2007 several seminars and colloquia focusing on various aspects of nanoscience and nanotechnology have been arranged at NTNU.

An NTNU NanoLab Workshop on Bionanotechnology was organized in January 2007. The meeting was attended by 16 researchers from NTNU, representing five faculties: NT, DMF, IVT and IME faculties) and 7 participants from SINTEF. The purpose of the meeting was to discuss and identify common interests and prepare a list of equipment important for the future development within the clean room are for bionanotechnology at NTNU.

The nanoC network is a platform promoting fundamental investigations related to carbon nanomaterials, with a focus on synthesis, characterization and applications. The backbone of the nanoC network has been a series of seminars with national and international participants. In February 2007, the 3rd NTNU seminar on Synthesis and Applications of Carbon Nanofibres / Nanotubes was arranged at NTNU by the nanoC network. The seminar was attended by four invited international keynote speakers, and about 50 participators. The focus was on largescale synthesis and industrial applications, as well as potential commercial opportunities of carbon nanomaterials for upgrading Norwegian natural gas. The network has also established a cooperative relationship with the East China University of Science Technology (ECUST) on the use of carbon nanofibre for catalyst supports and catalysts. Three guest researchers came from ECUST to visit the NTNU catalysis group in 2007. A project to use carbon nanofibre supported Pt catalysts for using organic hydrides in hydrogen storage has been initiated.

In November 2007, NTNU hosted a workshop on nanomechnical testing of structural materials. The main invited speaker was Dr. Afrooz Barnoush from Saarland University (UdS), who has specialized in nanomechanical testing of hydrogen-embrittled nickel and duplex stainless steel. 23 participants from NTNU, StatoilHydro and SINTEF attended the workshop. In addition to the presentations, new applications of nanomechanical testing were discussed.

Several colloquia have been given by invited guests:

Dr. Harold Weinstock, US Air Force Office of Scientific Research, Washington DC: "Nanotechnology – A short History and Selected Applications".

Prof. Sadamichi Maekawa, Institute for Materials Research, Tohoku University, Sendai, Japan: "Spin Current vs. Charge Current in Magnetic Nanostructures".

Prof. Yuji Matsumoto, Tokyo Institute of technology, Japan: "New Photochemistry on Nano-scale Designed Oxide Surfaces and Interfaces by Oxide Epitaxy".

Study Programme in Nanotechnology

In the second year after its start-up in 2006 the master programme in nanotechnology at NTNU continued to attract highly qualified students. In 2007, 991 coming students applied for the 30 available positions! Along with this narrow gap for admittance follows high expectations to the content and quality of the study programme offered. "Does NTNU manage to live up to these high expectations?" we asked second year student Andreas Bertheussen:

- During the first year I found it a bit hard to grasp the essence of what nanotechnology represents. Apart from an introductory course in nanotechnology the first semester, the curriculum includes mostly basic subjects within a broad spectrum of scientific fields. The characteristic features, as well as the overall plans of the study programme were a bit unclear to me. Fortunately, this frustration vanished in the course of the third semester. I still wish, though, that I had a bit better understanding of the various fields of specialization that we are currently about to choose between.

Andreas Bertheussen, student at the MSc study programme at NTNU. Photo: Ida Hederström

In times when science and technology experience a lack of interest among young people, nanotechnology has received exceptional attention. Are there any specific highlights within the study programme so far you would like to point out?

- That must be being allowed to use an electron microscope already in the second year! In general, the hands-on philosophy towards the instrumentation, the fact that we are allowed to operate advanced instrumentation ourselves rather than just observe demonstrations gives great pleasure and boosts the motivation. I believe we are allowed to do this at a much earlier stage than students on many other study programmes.

What about disappointments?

- Can't think of any. I don't like to focus on negative aspects…

You are a member of the board of Timini, the study programme's student association. What is your impression of the social environment?

- We are only 30 students in each class, which is quite few compared with many other study programmes here at NTNU. This makes it easy to learn to know everyone and develop a good setting for learning and socializing. This has been very fulfilling.

This study programme is still under development. As a former student representative of the "Study programme council", how do you feel the possibilities are for influencing the development of the programme?

- The students definitely have the opportunity to participate in the development of this programme, especially since it is so new and still in the process of being established. However, it clearly requires some scientific knowledge and experience in order to be able to contribute adequately.

What are your expectations for the study years to come?

- Oh! I'm really looking forward to it! The number of nanorelated courses will defiantly increase, and along with it the insight in nanotechnology.

So, finally, would you at this point recommend the study programme to future students?

-Definitely! Grins Bertheussen enthusiastically.

Construction of Clean Room Facilities

The construction of state-of-the-art clean room facilities at NTNU is in progress. When finalized, the facilities will constitute an integrated entity specially designed for cross-disciplinary research activities. The entire clean room area will cover 700m^2 and be GMOII:2 compatible. The facilities will be organized in several zones dedicated various purposes:

- Area dedicated chemical methods
- Area dedicated physical methods
- Area dedicated bionanotechnological methods
- Area for characterization
- Area for tuition

These areas will hold cleanness between class 10.000 and 100 and local vibration free zones down to VC-E, depending on the requirements of the local processes. The laboratories will be furnished with state-of-the-art equipment for nanotechnological research within prioritized areas that will complement the facilities of SINTEF's MiNaLab in Oslo. Great emphasis has been put on designing a flexible infrastructure that may easily be adapted to future demands. In addition to specialized equipment, the facilities will include general support laboratories, offices and meeting areas.

The area designated for chemical methods was opened for researchers in 2007. It is especially equipped for structuring and characterization of nanomaterials and nanoparticles. Available processes include:

Nanosyntheses:

- Wet chemical methods (dip / spin / spray coaters, microwave oven)
- Hydrothermal syntheses (high temperature ovens, autoclaves)
- Nanoparticle separation (centrifuges, ultrasound)
- Chemical Vapour Deposition

Nanoscale characterisation:

- AFM (atomic force microscope)
- SECM (Scanning electrochemical microscope)
- Particle size determination (from 2 nm)

Senior engineer Trine Ø. Østlyng ready to assist in the clean room area dedicated chemical methods. Photo: Anne Støre.

The remaining parts of the research facilities will be built in two phases. The clean room areas and support laboratories will be constructed in 2008, and be open for users in the early spring of 2009. Finally, the furnishing of adherent offices and meeting rooms will take place in 2010.

The area designated for physical methods has been planned as a fully equipped thin film growth / processing laboratory with emphasis on diversity in materials and high resolution work. The following methods will be available in the fully furnished laboratory:

- Thin film growth: sputter deposition, PECVD, e-beam deposition, metallisation.
- Lithography methods: Dual beam focused ion beam etching system, DUV-lithography, e-beam lithography and nanoimprint lithography.
- Etching methods: wet etching, dry etching (RIE, ICP-RIE, IBE, CAIBE, PE).

The area dedicated to bionanotechnology will incorporate tools for nanoscale fabrication based on biological methods or fabrication using biological materials. Key activities will

include work on biopolymers, nanostructured surfaces, studies related to drug delivery and fabrication of new contrast agents for medical imaging. The facilities will also allow work with cells and micro-organisms.

The area for characterization is planned to host among others, the following facilities:

- High resolution SEM
- Two darkrooms for optically demanding characterisation and manipulation (combined AFM/optical microscopy, spectroscopy, optical tweezers).
- AFM suitable for wafer inspection.

The laboratories will be open to all researchers interested in nanotechnology, both at NTNU, SINTEF and other Norwegian research establishments.

Dissertations

The following candidates have defended their thesis for a PhD degree at NTNU within fields related to nanotechnology in 2007.

- Martin Andresen: *Surface modification of micro fibrillated cellulose.*
- Daniel Bondeson: *Biopolymer-based Nanocomposites: Processing and Properties*
- Øyvind Borg: *Role of Alumina Support in Cobalt Fischer-Tropsch Synthesis.*
- Esther Ochoa Fernández: *CO_2 Acceptors for Sorption-Enhanced Steam Methane Reforming.*
- David Grainger: *Development of carbon membranes for hydrogen recovery.*
- Mari Juel: *Properties of novel bimetallic surface structures*.
- Sigbjørn Kolberg: *Modelling of Electrostatics and Drain Current in Nanoscale Double-Gate MOSFETs.*
- Ingvar Kvande: *Carbon nanofiber supported platinum catalysts*
- Ingvild Kvien: *Characterization of Biopolymer Based Nanocomposites.*
- Marián Palcut: *Cation diffusion in $LaMnO_3$, $LaCoO_3$ and $LaFeO_3$ materials.*
- Linnea Peterson: *Biopolymer-based Nanocomposites.*

Photo:Thor Nielsen/NTNU Info

Publications

The scientific community within nanotechnology at NTNU as published a significant number of articles in 2007. In the following a few selected publications are sited within the four prioritized areas of *NTNU NanoLab.*

NANOSTRUCTURED MATERIALS

Chen, S., Øye, G. and Sjøblom, J. *Effect of pH and salt on rheological properties of Aerosil suspension,* **Journal of Dispersion Science and Technology,** 28, 845, 2007.

Dahl, P. I., Kaus, I., Zhao, Z., Johnsson, M., Nygren, M., Wiik, K., Grande, T. and Einarsrud, M.-A. *Densification and properties of zirconia prepared by three different sintering techniques*, **Ceramics International**, 33, 1603, 2007.

Dahl, P. I., Haugsrud, R., Lein, H. L., Grande, T., Norby, T. and Einarsrud, M.-A. *Synthesis, densification and electrical properties of strontium cerate ceramics,* **Journal of the European Ceramic Society**, 27, 4461, 2007.

Chytil, S., Glomm, W., Kvande, I., Zhao, T., Walmsley, J. and Blekkan, E. A. *Platinum incorporated into the SBA-15 mesostructure via deposition-precipitation method: Pt nanoparticle size estimation and catalytic testing,* **Topics in catalysis,** 45, 93, 2007.

Forbord, B., Mathiesen, R. H. and Roven, H. J. *X-ray diffraction studies of grain growth in an ultra-fine grained 6060 aluminium alloy*, **Materials Science Forum**, 558-559, 1299.

Garcia-Bordeje, E., Kvande, I., Chen, D. and Rønning, M. *Synthesis of composite materials of carbon nanofibres and ceramic monoliths with uniform and tuneable nanofibre layer thickness,* **Carbon,** 45, 1828, 2007.

Ge, J., Bedeaux, D., Simon, J.-M. and Kjelstrup, S. *Integral relations, a simplified method to find interfacial resistivities for heat and mass transfer,* **Physica A: Statistical Mechanics and its Applications,** 385, 421, 2007.

Ge, J., Kjelstrup, S., Bedeaux, D., Simon, J.-M. and Rousseau, B. *Transfer coefficients for evaporation of a system with a Lennard-Jones long-range spline potential*, **Physical Review E,** 75 (1) 061604, 2007.

Glimsdal, E., Carlsson, M., Eliasson, B., Minaev, B. and Lindgren, M. *Excited States and Two-Photon Absorption of Some Novel Tthiophenyl Pt(II)-Ethynyl Derivatives,* **Journal of Physical Chemistry A** 111 (2) 244, 2007.

Glomm, W., Ese, M.-H., Volden, S., Pitois, C., Hult, A. and Sjøblom, J. *Europium(III)-cored fluorinated dendrimers at the air-water surface,* **Colloids and Surfaces A, Physicochemical and Engineering Aspects**, 299, 186, 2007

Hallem, H., Forbord, B. and Marthinsen, K. *Development of aluminium alloys with ultimate recrsyatllization resistance,* **Materials Science Forum,** 167, 539, 2007.

Hammer, N., Kvande, I., Chen, D. and Rønning, M. *Au-TiO2 catalysts stabilised by carbon nanofibres*, **Catalysis Today,** 122, 2007.

Hammer, N., Kvande, I., Xu, X., Gunnarson, V., Tøtdal, B., Chen, D. and Rønning, M. *Au–TiO2 catalysts on carbon nanofibres prepared by deposition-precipitation and from colloid solutions,* **Catalysis Today**, 123, 245, 2007.

He, J., Zhang, Z. and Kristiansen, H. *Mechanical properties of nanostructured polymer particles for anisotropic conductive adhesives,* **International Journal of Materials Research (Zeitschrift f. Metallkunde),** 05, 389, 2007.

Inzoli, I., Simon, J.-M., Kjelstrup, S. and Bedeaux, D. *Thermal effects during adsorption of n-butane on a silicalite-1 membrane: A non-equilibrium molecular dynamics study,* **Journal of Colloid and Interface Science,** 313, 1, 2007.

Juel, M, Samuelsen, B. T., Kildemo, M. and Raaen, S. *Surface alloy formation after deposition of Ce on Rh(110)*, **Surface Science**, 601, 2917, 2007.

Kjelstrup, S. and Bedeaux, D. *Heat and mass transfer across phase boundaries: Estimates of coupling coefficient,* **Atti dell´Accademia Peloritana dei Pericolanti Classe di Scienze Fisiche, Matematiche e Naturali,** 85, 2007.

Kvande, I., Briskeby, S. T., Tsypkin, M., Rønning, M., Sunde, S., Tunold, R. and Chen, D. *On the preparation methods for carbon nanofiber-supported Pt catalysts,* **Topics in catalysis**, 45(1-4), 81, 2007.

Lind, P., Boström, D., Carlsson, M., Eriksson, A., Glimsdal, E., Lindgren, M. and Eliasson, B. *Structural, Photophysical, and Nonlinear Absorption Properties of trans-Di-arylalkynyl Platinum(II) Complexes with Phenyl and Thiophenyl Groups,* **Journal of Physical Chemistry A,** 111, 1598, 2007.

Lindgren, M., Minaev, B., Glimsdal, E., Vestberg, R., Westlund, R. and Malmström, E. *Electronic states and phosphorescence of dendron functionalized platinum(II) acetylide,.* **Journal of Luminescence,** 124(2) 302, 2007

Liu, M. and Roven, H. J. *High density hexagonal and rhombic shaped nanostructures in a fcc aluminum alloy induced by severe plastic deformation at room temperature*, **Applied Physics Letters**, 90, 083115-1, 2007.

Liu, M., Roven, H. J. and Yu, Y. *Deformation twins in ultrafine grained commercial aluminium,.* **International Journal of Materials Research (Zeitschrift f. Metallkunde)**, 98(3), 184, 2007.

Meland, A.K. and Kjelstrup, S. *Three steps in the anode reaction of the polymer electrolyte membrane fuel cell. Effect of CO*, **Journal of electroanalytical chemistry and interfacial electrochemistry,** 610(2), 171, 2007.

Mokkelbost, T., Andersen, Ø. S., Strøm, R. A., Wiik, K., Grande, T. and Einarsrud, M.-A. *High-temperature proton-conducting LaNbO4-based materials: powder synthesis by spray pyrolysis,* **Journal of the American Ceramic Society**, 90(11), 3395, 2007.

Nilsen, M. H., Nordhei, C., Ramstad, A. L., Nicholson, D. G., Poliakoff, M. and Cabañas, A. *XAS (XANES and EXAFS) investigations of nanoparticulate ferrites synthesized continuously in near critical and supercritical water,* **Journal of Physical Chemistry C,** 111(17) 6252, 2007.

Rubi, M., Bedeaux, D. and Kjelstrup, S. *Unifying thermodynamic and kinetic descriptions of single-molecule processes: RNA unfolding under tension,* **Journal of Physical Chemistry. B, Condensed Matter, Materials, Surfaces, Interfaces & Biophysical,** 111, 9598, 2007.

Rubi, M., Naspreda, M., Kjelstrup, S. and Bedeaux, D. *Energy Transduction in Biological Systems: A Mesoscopic Non-Equilibrium Thermodynamics Perspective*, **Journal of Non-Equilibrium Thermodynamics,** 32, 351, 2007.

Selbach, S. M., Tybell, T., Einarsrud, M.-A. and Grande, T. *Size dependent properties of nanocrystalline BiFeO3 particles,* **Chemistry of Materials**, 19, 6478, 2007.

Selbach, S. M., Einarsrud, M.-A., Tybell, T., and Grande, T. *Synthesis of $BiFeO_3$ by wet chemical methods,* **Journal of The American Ceramic Society,** 90(11), 3430, 2007.

Selbach, S. M., Wang, G., Einarsrud, M.-A. and Grande, T. *Decomposition and crystallization of a sol-gel-derived $PbTiO_3$ precursor,* **Journal of the American Ceramic Society**, 90, 2649, 2007.

Shao, L., Samseth, J. and Hagg, M.-B. *Crosslinking and Stabilization of TiO2 Nanoparticle Filled Polymeric Membranes for Gas Separations*, **International Journal of Polymeric Materials,** 97, 976, 2007.

Simon, J.-M. Inzoli, I., Bedeaux, D. and Kjelstrup, S. *Numerical evidence for a thermal driving force during adsorption of butane in silicalite,* **Molecular Simulation**, 33, 839, 2007.

Solberg, J.K., Løken, S., Mæhlen, J.P., Denys, R. V., Lototsky, M. V., Tarasov, B. P. and Yartys, V. *Nanostructured Mg-Mm-Ni hydrogen storage alloy: Structure-properties relationship,* **Journal of Alloys and Compounds,** 114, 446, 2007.

Solberg, J. K., Wu, Y. and Yartys, V. *The effect of solidification rate on microstructural evolution of a melt-spun Mg-20Ni-8Mm hydrogen storage alloy*, **Journal of Alloys and Compounds,** 446-447, 178, 2007.

Strøm, R. A., Masmoudi, Y., Rigacci, A., Petermann, G., Gullberg, L., Chevalier, B. and Einarsrud, M.-A. *Strengthening and aging of wet silica gels for up-scaling of aerogel preparation,* **Journal of Sol-Gel Science and Technology**, 41, 291, 2007.

Tollefsen, H.,; Berstad, L. J. and Raaen, S. *Characterization of Ce-Pd(111) and Ce-Pd(110) surface alloy,*. **Journal of Vacuum Science & Technology. A. Vacuum, Surfaces, and Films** 25(5) 1433, 2007.

Valiev, R.Z.; Zehetbauer, M.J.; Estrin, Y.; Hoeppel, H.W.; Ivanisenko, Y.; Hahn, H.; Wilde, G.; Roven, Hans Jørgen; Sauvage, X.; Langdon, T.G. *The innovation potential of bulk nanostructured materials*, **Advanced Engineering Materials**, 9(7) 527, 2007.

Vermang, B; Juel, M. and Raaen, S. *Temperature programmed desorption of C2H2 from pure and graphite-covered Pt(111)*, ***Journal of Vacuum Science & Technology. A. Vacuum, Surfaces, and Films,*** 25, 1512, 2007.

Vullum, P. E., Holmestad, R., Lein, H. L., Mastin, J. R.M., Einarsrud, M.-A. and Grande, T. *Monoclinic ferroelastic domains in LaCoO3-based perovskites*, **Advanced Materials,** 19, 4399, 2007.

Wang, G., Sæterli, R., Rørvik, P. M., Van Helvoort, A., Holmestad, R., Grande, T. and Einarsrud, M.-A. *Hierarchical nanostructures of PbTiO3 through mesocrystal formation*, **Journal of Nanoscience and Nanotechnology**, 7, 2538, 2007.

Wang, G., Sæterli, R., Rørvik, P. M., Van Helvoort, A., Holmestad, R., Grande, T. and Einarsrud, M.-A. *Self-assembled growth of PbTiO3 nanoparticles into microspheres and bur-like structure,*. **Chemistry of Materials**, 19, 2213, 2007.

Zhao, T., Chen, D., Dai, Y.-C., Yuan, W-K. and Holmen, A. *The effect of graphitic platelet orientation on the properties of carbon nanofiber supported Pd catalysts prepared by ion exchange,* **Topics in catalysis**, 45, 87, 2007.

Zhao, T., Sun, W-Z., Gu, X.-Y., Rønning, M., Chen, D., Dai, Y.-C., Yuan, W.-K. and Holmen, A. *Rational design of the carbon nanofiber catalysts for oxidative dehydrogenation of ethylbenzene,* **Applied Catalysis A: General**, 323, 135, 2007.

Zhou, J.-H., Sui, Z.-J., Zhu, J., Li, P., Chen, D., Dai, Y.-C. and Yuan, W.-K. *Characterization of surface oxygencomplexes on carbon nanofibers by TPD, XPS and FT-IR,* **Carbon,** 45, 785, 2007.

Zhu, Y-A., Dai, Y.-C., Chen, D. and Yuan, W.-K. *First-principles study of C chemisorption and diffusjon on the surface and in the subsurfaces of Ni(111) during the growth of carbon nanofibers,* **Surface Science,** 601, 1319, 2007.

Zhu, Y-A., Dai, Y.-C., Chen, D. and Yuan, W.-K. *First-principles study of carbon diffusion in bulk nickel during the growth of fishbone-type carbon nanofibers*, **Carbon** , 45, 21, 2007.

Zhu, Y-A., Dai, Y.-C., Chen, D. and Yuan, W.-K. *First-Principles Study of C Adsorption and Diffusion on the Surface and in the Subsurfaces of Nonreconstructed and Reconstructed Ni(100),* **Journal of Physical Chemistry C**, 111, 3447, 2007.

NANOTECHNOLOGY FOR ENERGY AND ENVIRONMENT

Bichon, P., Asheim, M., Jordal, A., Sperle, T., Fathi, M., Holmen, A. and Blekkan, E. A. *Hydrogen from methanol steam-reforming over Cu-based catalysts with and without Pd promotion,* **International journal of hydrogen energy**, 32, 1799, 2007.

Blekkan, E. A., Borg, Ø., Frøseth, V. and Holmen, A. *Fischer-Tropsh synthesis on cobalt catalysts: the effect of water,* **Catalysis**, Cambridge, UK: The Royal Society of Chemistry, ISBN 978-0-85404-244-9. p13-32, 2007.

Borg, Ø., Blekkan, E. A., Eri, S., Akporiaye, D., Vigerust, B., Rytter, E. and Holmen, A. *Effect of calcination atmosphere and temperature on γ-Al2O3 supported cobalt Fischer-Tropsch catalysts*, **Topics in catalysis**, 45, 39, 2007.

Borg, Ø., Eri, S., Blekkan, E. A., Storsæter, S., Wigum, H., Rytter, E. and Holmen, A. *Fischer-Tropsch synthesis over γ-alumina-supported cobalt catalysts: Effect of support variables*, **Journal of Catalysis**, 248, 89, 2007.

Borg, Ø., Frøseth, V., Storsæter, S., Rytter, E. and Holmen, A. *Fischer-Tropsch synthesis. Recent studies on the relation between the properties of supported cobalt catalysts and the activity and selectivity,* **Studies in Surface Science and Catalysis**, 164, 117122, 2007.

Borg, Ø., Rønning, M., Storsæter, S., van Beek, W. and Holmen, A. *Identification of cobalt species during temperature programmed reduction of Fischer-Tropsch catalysts,* **Studies in Surface Science and Catalysis**, 163, 255, 2007.

Dyrbeck, H. and Blekkan, E. A. *Au/TiO1 as a catalyst for the selective hydrogen cmbusiton (SHC) applied to the catalytic dehydrogenation of propane*, **Studies in Surface Science and Catalysis**, 167(Natural Gas Conversion VIII) 331, 2007.

Dyrbeck, H., Hammer, N., Rønning, M. and Blekkan, E. A. *Catalytic oxidation of hydrogen over Au/TiO2 catalysts,* **Topics in catalysis**, 45(1-4) 21, 2007.

Frøseth, V. and Holmen, A. *CO hydrogenation on Co/γ-Al2O3 and CoRe/γ-Al2O3 studied by SSITKA*, **Topics in catalysis**, 45, 45, 2007.

Grainger, D. R. and Hagg, M.-B. *Evaluation of cellulose derived carbon molecular sieve membranes for hydrogen separation from light hydrocarbons*, **Journal of Membrane Science,** 306, 307, 2007.

Hammer, N., Kvande, I., van Beek, W., Chen, D. and Rønning, M. *Identification of calence shifts in Au during the water-gas shift reaction,* **Topics in catalysis**, 45, 25, 2007.

Hammer, N., Zarubova, S., Kvande, I., Chen, D. and Rønning, M. *A Novel Internally Heated Au/TiO2 Carbon-Carbon Composite Structured Reactor for Low-Temperature CO Oxidation*, **Gold Bulletin** 40(3) 234, 2007.

Huber, F., Yu, Z., Walmsley, J.C., Chen, D., Venvik, H. J. and Holmen, A. *Nanocrystalline Cu-Ce-Zr mixed oxide catalysts for water-gas shift: Carbon nanofibers as dispersing agent for the mixed oxide particles*, **Applied Catalysis B: Environmental**, 71, 7, 2007.

Huber, F., Meland, H., Rønning, M., Venvik, H. J. and Holmen, A. *Comparison of Cu-Ce-Zr and Cu-Zn-Al mixed oxide catalysts for water-gas shift*, **Topics in catalysis,** 45, 101, 2007.

Håkonsen, S. F. and Holmen, A. *Oxidative dehydrogenation of ethane at short contact times*, **Studies in Surface Science and Catalysis**, 164, 337, 2007.

Håkonsen, S. F.,Silberova, B. and Holmen, A. *Oxidative dehyrogenation of ethane on Pt-Sn impregnated monoliths,* **Topics in catalysis** , 45, 61, 2007.

Lie, J. A., Vassbotn, T., Hagg, M-B., Grainger, D. R., Kim, T. J. and Mejdell, T. *Optimization of a membrane process for CO2 capture in the steelmaking industry*, **International Journal of Greenhouse Gas Control,** 1, 309, 2007.

Lindbråthen, A., Grainger, D. R. and Hagg, M.-B. *Membranes for Purificaton of Chlorine in the Chlor-Alkali Industry: A Viable Option,* **Separation science and technology (Print),** 42, 3049, 2007.

Lødeng, R., Bjørgum, E., Enger, B. C., Eilertsen, J. L., Holmen, A., Krogh, B., Rønnekleiv, M. and Rytter, E. *Catalytic partial oxidation of CH4 to H2 over cobalt catalysts at moderate temperatures,* **Applied Catalysis A: General**, 333, 11, 2007.

Ochoa-Fernandez, E., Haugen, G., Zhao, T., Rønning, M., Aartun, I., Børresen, B., Rytter, E., Rønnekleiv, M. and Chen, D. *Process design simulation of H2 production by sorption enhanced steam methane reforming: evaluation of potential CO2 acceptors,* ***Green Chemistry***, 9, 654, 2007.

Ochoa-Fernandez, E., Lacalle-Vilà, C., Zhao, T., Rønning, M. and Chen, D. *Experimental Demonstration of H2 Production by CO2 Sorption enhanced Steam Methane Reforming Using Ceramic Acceptors,* **Studies in Surface Science and Catalysis**, 164, 159, 2007.

Ochoa-Fernandez, E., Lacalle-Vilà, C., Christensen, K. O., Walmsley, J. C., Rønning, M. and Holmen, A. *Ni catalysts for sorption enhanced steam methane reforming*, ***Topics in catalysis,*** 45, 3, 2007.

Radstake, P. B., Breejen, J. P., Bezemer, G. L., Bitter, J. H., de Jong, K., Frøseth, V. and Holmen, A. *On the origin of the cobalt particle size effect in the Fischer-Tropsch synthesis*, **Studies in Surface Science and Catalysis,** 164, 85, 2007.

Shao, L., Samseth, J. and Hagg, Ma.-B. *Crosslinking High Free Volume Polymers - Effect on Gas Separation Properties*, **International Journal of Polymeric Materials,** 1006, 2007.

Shao, L., Samseth, J., and Hagg, M.-B. *Effect of Plasma Treatment on Gas Permeability of Poly(4-methyl-2-pentyne) Membrane,* **Plasma chemistry and plasma processing,** 4(9) 823, 2007.

Tristantini, D., Lögdberg, S., Gevert, B., Borg, Ø., and Holmen, A. *The effect of synthesis gas composition on the Fischer-Tropsch synthesis over Co/γ-Al2O3 and Co-Re/γ-Al2O3,* **Fuel processing technology,** 88, 643, 2007.

Yu, Z., Borg, Ø., Chen, D., Rytter, E. and Holmen, A. *Role of surface oxygen in the preparation and deactivation of carbon nanofiber supported cobalt Fischer-Tropsch catalysts*, **Topics in catalysis,** 45, 69, 2007.

Zhao, T., Ochoa-Fernandez, E., Rønning, M. and Chen, D. *Preparation and High-Temperature CO_2 Capture Properties of Nanocrystalline Na_2ZrO_3*, **Chemistry of Materials,** 19, 3294 2007.

Zhu, Y.-A., Dai, Y.-C., Chen, D. and; Yuan, W-K. *First-principles calculations of CH4 dissociation on NI(100) surface along different reaction pathways,* **Journal of molecular Catalysis. A, Chemical** 264, 299, 2007.

NANOELECTRONICS, NANOPHOTONICS AND NANOMAGNETISM

Brataas A, Mal'shukov AG, Tserkovnyak Y. *Spin injection in quantum wells with spatially dependent rashba interaction,* **New Journal of Physics**, 9, Art. No. 345, 2007.

Brucas, R; Hanson, M; Gunnarsson, R; Wahlström, E., van Kampen, M., Hjorvarsson, B., Lidbaum, H. and Leifer, K. *Magnetic and transport properties of Ni81Fe19/Al2O3 granular multilayers approaching the superparamagnetic limit,* **Journal of Applied Physics**, 101, 073907, 2007.

Foros J, Brataas A, Bauer G. E.W. and Tserkovnyak, Y. *Resistance noise in spin valves,* **Physical Rev.** B 75 (9), 092405, 2007.

Huertas-Hernando D., Guinea F. and Brataas A. *Spin relaxation times in disordered grapheme,* **European Physical Journal-Special topics**, 148, 177, 2007.

Karlsson, K. F., Weman, H., Leifer, K., Rudra, A., Kapon, E. and Lyo, S. K. *Strongly reduced exciton transfer between parallel quantum wires*. **Applied Phys. Lett**., 90, 101108, 2007.

Kovalev A. A, Bauer G. E. W. and Brataas A. *Current-driven ferromagnetic resonance, mechanical torques, and rotary motion in magnetic nanostructures,* **Physical Review** B75 (1) 014430, 2007.

Linder, J., Grønsleth, M. and Sudbø, A. *Tunneling currents in ferromagnetic systems with multiple broken symmetries,* **Physical. Review** B75, 024508, 2007.

Linder, J., Grønsleth, M. and Sudbø, A *Conductance spectra of ferromagnetic superconductors: Quantum transport in a ferromagnetic metal/non-unitary ferromagnetic superconductor junction*, **Physical Rev**. B75, 054518, 2007.

Linder, J. and Sudbø A. *Signatures of retroreflection and induced triplet electron-hole correlations in ferromagnet–s-wave-superconductor structures*, **Physical. Rev**. B75, 134509, 2007.

Linder, J. and Sudbø A. *Quantum transport in noncentrosymmetric superconductors and thermodynamics of ferromagnetic superconductors*, **Physical. Rev**. B76, 054511, 2007.

Linder, J. and Sudbø A. *Josephson effect in thin-film superconductor / insulator / superconductor junctions with misaligned in-plane magnetic fields*, **Physical. Rev**. B76, 064524, 2007.

Linder, J. and Sudbø A *Spin-flip scattering and nonideal interfaces in dirty ferromagnet/superconductor junctions*, **Physical. Rev**. B76, 214508, 2007.

Linder, J. and Sudbø A *Dirac Fermions and Conductance Oscillations in s- and d-Wave Superconductor-Graphene Junctions*, **Physical. Rev**. **Lett.,** 99, 147001, 2007.

Martinussen, H., Aksnes, A. and Engan, H. E. *Wide frequency range measurements of absolute phase and amplitude of vibrations in micro- and nanostructures by optical interferometry*. **Optics Express,** 15, 11370, 2007.

Morten J.P., Brataas A. and Belzig W. *Circuit theory for crossed Andreev reflection and nonlocal conductance,* **Applied Physics A-Materials Science & Processing**, 89 (3) 609, 2007.

Nguyen A.K., Skadsem H.J. and Brataas A. *Giant current-driven domain wall mobility in (Ga,Mn)A,s* **Physical Rev. Lett.,** 98 (14) 146602, 2007.

Passmann, R., Kropp, M., Bruhn, T., Fimland, B.-O., Bloom, F.L., Gossard, A.C., Richter, W., Esser, N. and Vogt, P. *Optical anisotropy of cyclopentene terminated GaAs(001) surfaces,* **Applied Physics A: Materials Science & Processing**, 87, 469, 2007.

Pettersen, S. V., Grande, A.P., Tybell, T., Riechert, H., Averbeck, R. and Grepstad, J. *Formation and electronic properties of oxygen annealed Au/Ni and Pt/Ni contacts to p-type GaN,* **Semiconductor Science and Technology,** 22, 186, 2007.

Selbach, S.M., Tybell, T., Einarsrud, M.-A. and Grande, T. *Size dependent properties of nanocrystalline BiFeO3 particles*, **Chemistry of Materials**, 19, 6478, 2007.

Skadsem, H. J., Tserkovnyak, Y., Brataas A and Bauer, G. E. W**.** *Magnetization damping in a local-density approximation,* **Physical Rev.,** B75 (9) 094416, 2007.

Tserkovnyak, Y. and Brataas, A. *Spin transport in mesoscopic rings with inhomogeneous spin-orbit coupling.* **Physical Rev.,** B76 (15) 155326, 2007.

Tserkovnyak, Y., Halperin, B.I., Kovalev, A. A and Brataas, A. *Boundary spin Hall effect in a two-dimensional semiconductor system with Rashba spin-orbit coupling,* **Physical Rev.,** B76 (8) 085319, 2007.

You, C. C., Rystad, N. V., Borg, A. and Tybell, T. *Nanoscale structuring of SrRuO3 thin film surfaces by scanning tunneling microscopy.* **Applied Surface Science**, 253(10) 4704, 2007.

BIONANOTECHNOLOGY

Andresen, M. and Stenius, P. *Water-in-oil emulsions stabilized by hydrophobized microfibrillated cellulose,* **Journal of Dispersion Science and Technology**, 28, 837, 2007.

Andresen, M., Stenstad, P., Moretro, T., Langsrud, S., Syverud, K., Johansson, L. S. and Stenius, P. *Nonleaching antimicrobial films prepared from surface-modified microfibrillated cellulose,* **Biomacromolecules,** 8, 2149, 2007.

Dentini, M., Rinaldi, G., Barbetta, A., Risica, D., Anselmi, C. and Skjåk-Bræk, G. *Ionic gel formation of a (pseudo)alginate characterised by an alternating MG sequence produced by epimerising mannuronan with AlgE4,* **Carbohydrate Polymers,** 67, 465, 2007.

Glomm, W. R., Halskau, Ø., Hanneseth, A.-M. D. and Volden, S. *Adsorption Behavior of Acidic and Basic Proteins onto Citrate-Coated Au Surfaces Correlated to Their Native Fold, Stability, and pI.* **Journal of Physical Chemistry B**, 111, 14329, 2007.

Einbu, A., Grasdalen, H. and Vårum, K. M. *Kinetics of hydrolysis of chitin/chitosan oligomers in concentrated hydrochloric acid,* **Carbohydrate Research**, 342, 1055, 2007.

Einbu, A. and Vårum, K. M. *Depolymerization and de-N-acetylation of chitin oligomers in hydrochloric acid,* **Biomacromolecules,** 8, 309, 2007.

Einset, J., Nielsen, E., Conolly, E.I., Bones, A. M., Sparstad, T., Winge, P., and Zhu, J.K. *Membrane-trafficking RabA4c involved in the effect of glycine betaine on recovery from chilling stress in Arabidopsis*, **Physiologia Plantarum***,* 130, 511, 2007.

Einset, J. Winge, P. and Bones, A. M. *ROS signaling pathways in chilling stress,* **Plant Signaling & Behavior**, 2(5) 365, 2007.

Evensen, T. R., Elgsaeter, A. and Næss, S. N. *Transient molecular electro-optics Cartesian rotation vector versus Eulerian angles,* **Colloids and Surfaces B: Biointerfaces**, 56, 2007.

Jørstad, T. S., Langaas, M. and Bones, A. M.. *Understanding sample size: What determines the required number of microarrays for an experiment***? Trends in Plant Science,** 12(2) 46, 2007.

Kusnierczyk, A., Winge, P., Midelfart, H., Armbruster, W. S., Rossiter, J. T. and Bones, A.M. *Transcriptional responses of Arabidopsis thaliana ecotypes with different glucosinolate profiles after attack by Myzus persicae and oligophagous Brevicoryne brassicae,* **Journal of Experimental Botany**, 58 (10) 2537, 2007.

Latz, E., Verma, A., Visintin, A., Gong, M., Sirois, C. M., Klein, D., Monks, B. G., Mcknight, C. J., Lamphier, M. S. and Duprex, W. P. *Ligand-induced conformational changes allosterically activate Toll-like receptor 9,* **Nature Immunology,** 8(7) 772, 2007.

Makin, O. S., Sikorski, P. and Serpell, L. C**.** *A new tool for the analysis of X-ray fibre diffraction patterns and diffraction simulation from atomic structural models*, **Journal of applied crystallography,** 40(5) 966, 2007.

Maurstad, G., Danielsen, S. and Stokke, B. T**.** *The influence of charge density of chitosan in the compaction of the polyanions DNA and xanthan*, **Biomacromolecules,** 8, 2007.

Mørch, Y. A., Donati, I., Strand, B. L. and Skjåk-Bræk, G. *Molecular engineering as an approach to design new functional properties of alginate,* **Biomacromolecules,** 8, 2809, 2007.

Sikorski, P., Mo, F., Skjåk-Bræk, G. and Stokke, B. T. *Evidence for egg-box-compatible interactions in calcium-alginate gels from fiber X-ray diffraction,* **Biomacromolecules,** 8, 2098, 2007.

Sletmoen, M. and Stokke, B. T**.** *Macromolecular motion at the nanoscale of enzymes working on polysaccharides,* **Lecture Notes in Physics**, 711, 2007.

Tufto, I., Hansen, R., Byberg, D., Nygaard, K. H. H., Tufto, J. and Davies, C. de L. *The effect of collagenase and hyaluronidase on transient perfusion in human osteosarcoma xenografts grown orthotopically and in dorsal skinfold chambers,* **Anticancer Research,** 27, 1475, 2007.

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Address, contact information

NTNU NanoLab
Faculty for Natural Sciences and Technology
Realfagbygget
N-7491 Trondheim
NORWAY

E-mail: nanolab@nt.ntnu.no
Phone: (+47) 73 59 45 44

www.ntnu.no/nanolab