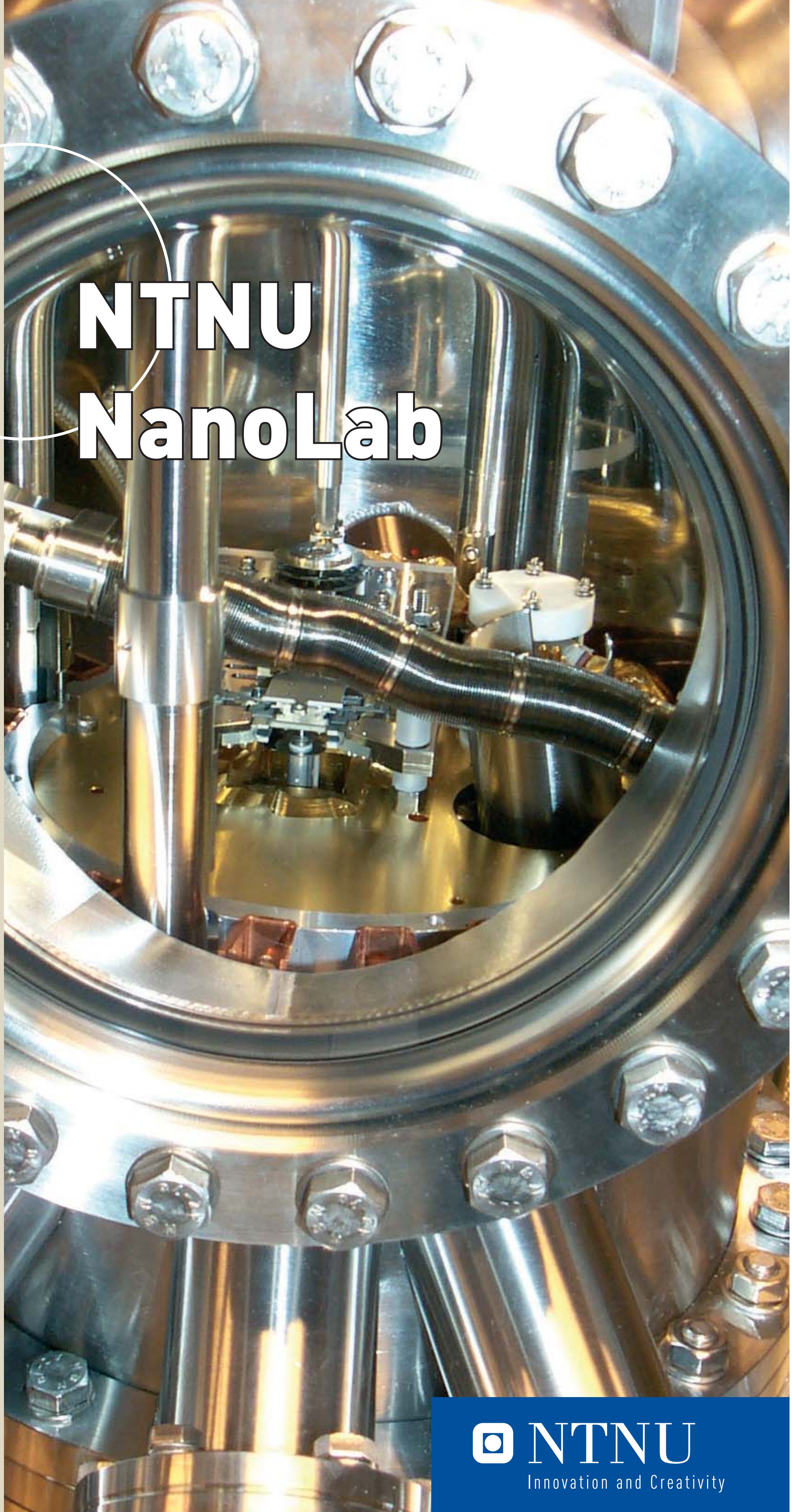
# NTNU NanoLab

Annual Report 2005



NTNU
Innovation and Creativity

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NTNU
Innovation and Creativity

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- Professor Tor Grande, head of Department of Materials Science and Engineering, NTNU
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**Coordinator NTNU NanoLab:** Hanna Gautun (hanna.gautun@nt.ntnu.no)

**Leader Group**

- Prof. Thomas Tybell (leader)
- Prof. Mari-Ann Einarsrud
- Prof. Tore Lindmo
- Prof. Helge Weman
- Associate prof. Kjell Ove Kongshaug
- Associate prof. Pawel Sikorski
- Associate prof. Erik Wahlstrøm

# NTNU NanoLab

www.ntnu.no/nanolab

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# Introduction

2005 can be characterized as the year that the nanotechnology initiative at NTNU gained large momentum, and I would like to point to four contributing facts:

In March the board of NTNU decided to grant up to 145MNOK to support the construction of the foreseen cross-disciplinary clean-room facility, an important decision providing for NTNU to become a national centre, and an international team player within nanotechnology. The board decision spurred large activity within the scientific community and resulted in the first construction contract to be signed for the construction of the chemical based clean-room, the first part of the foreseen integrated laboratory.

We were also glad to welcome three new faculty members to NTNU, hired specifically to strengthen the nanotechnology initiative within central fields for NTNU and Norway. Associate professor Kjell Ove Kongshaug, interested in the application of nanoporous coordination polymeric materials as host structures for various functional groups, joined the Department of Materials Science and Technology. Professor Helge Weman was appointed at the Department of Electronics and Telecommunications, and will study the application of nanowires as optical sensors. Finally, associate professor Pawel Sikorski wishes to investigate the ways in which nanostructured materials harvested from nature can be used in specific applications,.He was employed at the Department of Physics. We are positive that they will contribute to the scientific excellence within nanotechnology at NTNU, and be team players in our continuous efforts to excel further.

National collaboration is important, and in order to be strong internationally we decided together with SINTEF and the University of Oslo to form the Norwegian Micro and Nano Laboratories (NMNL). NMNL consists of MiNaLab in Oslo and our facilities under construction. These laboratories will have complementary state-of-the-art infrastructure, providing a national basis for nanotechnological research.

*Prof. Thomas Tybell*
*Photo: Gorm Kallestad, Scanpix/NTNU Info*

Finally, in order for industry to be able to actively use nanotechnology education is important. We were therefore pleased with the NTNU board decision to establish a 5-year MSc study programme in nanotechnology. The study programme, scheduled to start in the fall of 2006, will be a cross-disciplinary based programme where nanotechnology related subjects constitute guide lights through the curriculum. Ethical and environmental aspects of nanotechnology will also be part of the programme. We believe that this study-programme will help increase the interest for natural sciences in general, and anticipate that the students will provide resources to existing and yet unborn Norwegian industry when graduating.

*Thomas Tybell*
*Director NTNU NanoLab*

# Focus Areas – High Lights

Based on a survey of existing activity and excellence within nanoscience and nanotechnology at NTNU, four focus areas have been chosen:

- Nanostructured materials
- Nanoelectronics, nanophotonics and nanomagnetism
- Bionanotechnology
- Nanotechnology for energy and environment

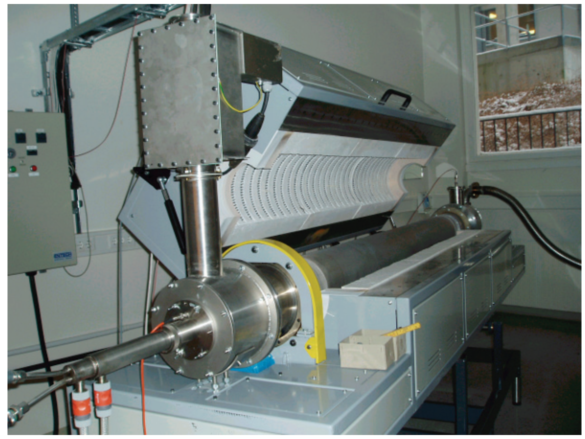
In the following representative projects which have gained scientific publicity in 2005 are presented.

## NANOSTRUCTURED MATERIALS;

### *Production of nano-sized ceramic powders by spray pyrolysis*

Oxide based ceramics exhibit a number of useful functional properties varying from piezoelectricity to fast oxygen ion conductors, hence, future prospects with respect to applications are numerous, ranging from environmentally friendly production of electric energy from natural gas to production of lead free ferroelectric materials. Basically, all these materials are produced from powders and due to the current development of nanocrystalline ceramics and ceramics with improved properties, there is a large demand for high quality ceramic oxide powders. The materials of interest are normally multi component, and a high homogeneity is needed. A powerful method to obtain nano-homogeneity is to use a solution of nitrates with cationic elements in correct proportions and spray pyrolyze the solution.

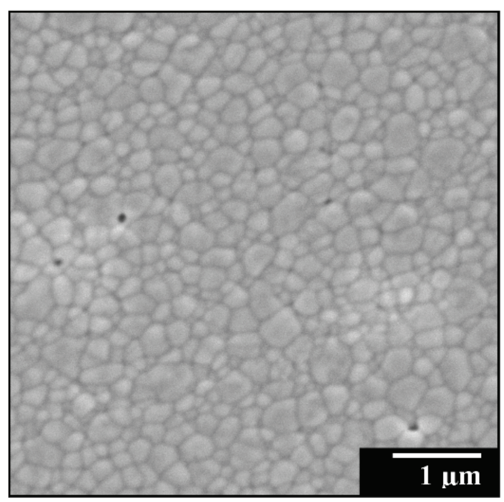
At the Department of Materials Science and Engineering, NTNU a complete pilot plant for powder production based on spray pyrolysis has been established. The production capacity is several kilos of powder per day, and powders are supplied on a regular basis.



*Spray pyrolysis unit for production of nano-sized oxide powders.*

Using pressurized air for atomization the minimum attainable droplet size is approximately 10 µm.

*A well defined nano-structured functional oxide Material produced from spray pyrolyzed powder Photo: T. Mokkelbost.*




The raw powders produced will typically be weakly bonded aggregates of crystallites being less than 100nm. The spray pyrolysis plant is one of only a few production facilities in Scandinavia.

*Kjell Wiik*

## NANOELECTRONICS, NANOPHOTONICS AND NANOMAGENTISM;

***Fundamentals of Nano-scale systems: Spin and charge flow in nanostructures***

Since the 60's the number of transistor in electronic devices doubles every eighteenth month. Transistors reduce their size at the same pace. The exponential growth in computing power and the exponential reduction in transistor size follows Moore's law and is the basis for small cell phones, mp3 players, digital cameras and lap-top computers.

With a continued exponential development in nanotechnology the transistor becomes the size of an atom by 2020! Fundamental research in nanoelectronics therefore faces important and interesting challenges. We study novel methods to increase the storage and computing capacity of material systems, and one of these possibilities is within spintronics that exploit a usually hidden nature of the electrons.

An electron has, in addition to its electrical charge, an internal magnetic moment, a "spin". Our research is on the fundamental understanding of the motion of spins in materials. Below, two examples of the research in within this field in 2005 are given:

*Spin and charge transport in magnetic semiconductors*

There is a great interest in magnetic semiconductors since they integrate the features of conventional semiconductors with magnetism that can give increased functionality. A magnetic domain wall is the transition between two magnetic domains with different magnetizations. The domain wall dictates e.g. the minimum current required to induce changes in the magnetization by an applied electric current. In this way a magnetic "bit" can be reversed. We have investigated spin and charge transport through magnetic semiconductor domain walls. It is found that these magnetic domain walls exhibit an intrinsic domain wall resistance that is independent of the domain wall shape and size.

*Spin and electron-electron interaction in quantum*

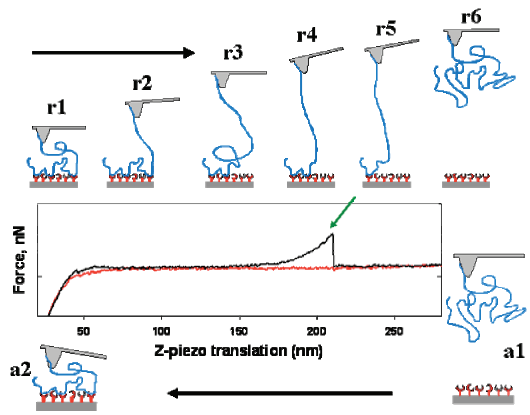
Electrons are confined in quantum dots. The electronic properties are similar to that of atoms and quantum dots are therefore often considered artificial atoms. In a quantum dot, the interaction between the electrons can be strong. We have demonstrated that the electron-electron interaction influences the electron spin. Since the electron-electron interaction can be tuned in quantum dots, our results indicate that the electron spin can be manipulated and controlled accurately in quantum dots and possibly be used as spin transistors.

*Arne Brataas*

## BIONANOTECHNOLOGY

***Single-molecule force spectroscopy: biopolymer interactions***

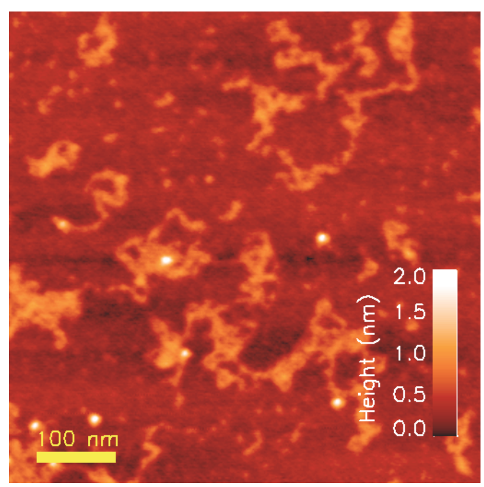
Virtually all biological processes (i.e. recognition, adhesion, signalling, activation and regulation) rely on successive events of intermolecular recognition and complex formation followed by molecular pair dissociation. Recent advances in instrumentation, including the biomembrane force probe, optical tweezers and scanning probe-based techniques, have opened for determination of forces from a few pN combined with position control in the sub-nm range. These instruments therefore support experimental determination of non-covalent interactions at the single-molecule level, a level at which the dynamic nature of non-covalent forces manifests itself in the lifetime of the interaction. Applying a continuous force ramp allow determination of the most probable unbinding force at various force loading rates. This corresponds to tilting the energy landscape of the physical forces governing the interaction along the unbinding pathway. Analysis of the experimental data thus provides information about the unbinding force and the distance $x_\beta$ between the bound complex and the rate-limiting barrier towards dissociation.




*Schematic illustration of forced unbinding experiments. When the experiment starts, the polysaccharide-functionalised AFM tip is positioned high above the AlgE4-functionalised surface (a1). The tip is allowed to approach the surface by controlling the z-piezo movement of the AFM. The tip deflection is continuously recorded (grey line). The polymers immobilised onto the tip are allowed to bind to enzymes (a2). The tip is then retracted from the surface (r1 – r6). If a polymer-enzyme complex has formed, the polymer will, at a certain height above the surface, be pulled taught between the tip and the surface (r4-r5) giving rises to a deflection of the tip. Upon further retraction of the tip the polymer-enzyme complex will dissociate, and the tip returns to its rest position (r6).*

We have applied dynamic force spectroscopy to study alginate (a polysaccharide)-epimerase (an enzyme) non-covalent interactions. The biosynthesis of these polysaccharides proceeds by polymerisation to the homopolymer of mannuronic acid followed by epimerisation at the polymer level converting a fraction of the mannuronic acid units into guluronic acid. Analysis of the residue sequence of the mature alginates obtained using various epimerases, has previously suggested that epimerase AlgE4 either work processively by conversion of several residues yielding a regular alternating sequence before detaching, or by preferred attack.

Dynamic force spectroscopy of the interaction between different epimerases and mannuronan was carried out using loading rates between 0.3 and 40 nN/s. The experimental procedure was optimized to yield unbinding of single-molecular pairs by controlling the grafting densities of the components, and the specificity of the interaction was proven in separate studies. The mean protein-mannuronan unbinding forces were determined to be in the range 73 - 144 pN, depending on the protein, at a loading rate of 0.6 nN/s, and were found to increase with increasing loading rate. The parameter $x_\beta$ was determined to be 0.23±0.04 nm for the AlgE4- mannuroan interaction. The ratio between the epimerase – mannuronan dissociation rate and the catalytic rate for epimerization of single sugar residues suggests a processive mode of action of the AlgE4 epimerase. The results suggested a processive mode of action of the AlgE4 epimerase. Processive enzymes are natural existing molecular devices, and most known examples work on protein polymers, DNA or RNA. The relevance of the identification of AlgE4 as a processive enzyme for further advances in the research aiming at constructing artificial molecular devices will be explored.




*AFM topograph showing polysaccharides with epimerase AlgE4 bound to some of the strands (bright dots).*

*Marit Sletmoen*

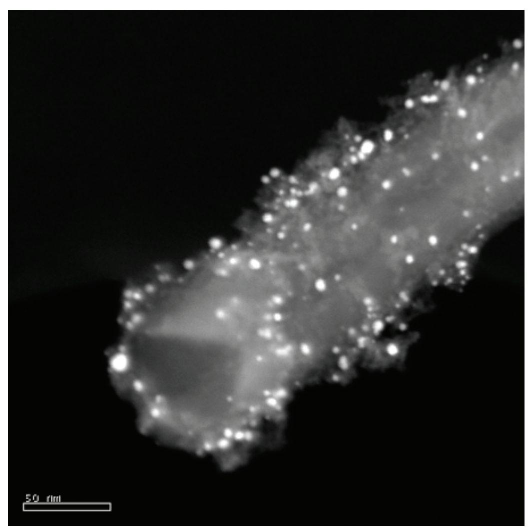
## NANOTECHNOLOGY FOR ENERGY AND ENVIRONMENT;

### *Catalysis – a short path from basic science to industrial application*

Research in heterogeneous catalysis at the NTNU Department of Chemical Engineering, is performed in close collaboration with SINTEF, and together they form the KinCat Group (appointed strong point centre in 1998). The joint research is strongly related to energy and environmental issues, such as production of hydrogen, upgrading of natural gas, improved refinery processes for better and cleaner gasoline and diesel fuels, and end-of-pipe removal of harmful emissions. In addition, the group has built a substantial activity on production of carbon nanofibers over the recent years.

The importance of understanding and controlling the nanostructure of catalysts has long been recognized within catalysis. For example, the importance of Pt nanoparticles with close to 100 % dispersion (all the Pt atoms are available on the surface form reaction, implying particle sizes as small as 1 nm), in catalysts for raising octane numbers in gasoline – a widely applied refinery technology – has long been known. Tools for linking the exact structure to the catalytic activity and selectivity have not always been available. This is a complex task, since we are talking about the atomic structure of complex, three-dimensional materials under conditions that usually are severe in terms of temperature, atmosphere and pressure. In recent years, the development in characterization techniques for studying nanostructure and local chemical composition has made this information more accessible. This has led to an extensive collaboration with NTNU Department of Physics, in particular the NTNU/SINTEF Transmission Electron Microscopy group. The first and pioneering work was initiated in 1997. In 2005 alone, the collaboration resulted in 10 scientific papers. One paper that attracted much attention was titled "Characterization of alumina-, silica-, and titania-supported cobalt Fischer–Tropsch catalysts", as it appeared second on the top 25 list over the most downloaded papers in Journal of Catalysis (the most prestigious journal in the field). The Fischer-Tropsch synthesis is the key step in converting natural gas to high quality diesel; a liquid, easily transportable fuel. This has long been a research subject in the group, in close collaboration with Statoil.

The group wants to proceed from understanding the catalyst nanostructure to tailoring the nanostructure to obtain optimum catalyst properties. To achieve this, much can be learnt from studying catalysis by gold. Gold was usually considered inert and with no functionality as a catalyst material. However, if the size of particles is below 10 nm, gold suddenly starts to show activity in a range of reactions. Thus, the surface reactivity of small gold clusters is fundamentally different from larger crystals. The figures show medium and large magnification electron microscopy images of gold nanoparticles on carbon nanofibers; a catalyst applied in selective oxidation of carbon monoxide.




*STEM-HAADF: A carbon nanofibre covered with $TiO_2$ and Au nanoparticles (bright spots)*

*Hilde Venvik*

# Strategic Initiatives

## NEW SCIENTIFIC POSITIONS

In order to strengthen and promote research activity within nanotechnology at NTNU three new academic positions were appointed in 2005 within the following fields:

***Associate professor Kjell Ove Kongshaug***

has been employed within nanostructured materials, at the Department of Materials Science and Engineering. Kongshaug received his PhD in materials chemistry at the University of Oslo in 2000. He has since then been a post doctor at the University of Oslo, a research scientist at the Institute of Energy Technology at Kjeller (IFE). His research interests lies within synthesis and characterization of nanoporous coordination polymer materials. He has been involved in projects to develop such materials for applications like gas storage, gas adsorption and catalysis. At NTNU he will focus his research on the application of nanoporous coordination polymeric materials as host structures for various functional molecules and on fabrication of porous nanoparticles. In this context, characterization of the optical, magnetic and pore properties of the materials will be essential.

***Professor Helge Weman***

has been employed within nanoelectronics, nanophotonics and nanomagnetism at the Department of Electronics and Telecommunications. Weman obtained his PhD at the University of Linkjöping in Sweden in 1988 and has since then has various academic positions. From 1989 he was a post doctor at the University of California, Santa Barbara, where he carried out pioneering research on semiconducting nanowires. In 1994 he worked as an invited professor at NTT Optoelectronics Lab in Japan. Since 1996 and till 2005 he held a position as leader of a project on optoelectronic quantumwire components at "the Swiss Federal Institute of Technology" in Lausanne (EPFL). At NTNU, Weman wishes to channel his research towards the fabrication and characterization of directly "bottom-up" grown III-V semiconducting nanowires. He will furthermore study the application of such nanowires in nanometer size optical components, such as diods, lasers and wave guides, as well as integration of such nanowires with biomaterials with the aim of sensor application. Of special interest in this context is electronic and optical characterization of these structures and devices below the diffraction limit, using techniques like low-temperature scanning near field optical microscopy (SNOM) and photon scanning tunnelling microscopy (PSTM).

***Associate professor Pawel Sikorski***

has been employed within bionanotechnology at the Department of Physics. Sikorski graduated for Wroclaw University of Technology, Poland in 1998. He completed his PhD in Physics at the University of Bristol, UK, in 2001. Since 2002 he worked as a post doctor at NTNU. Sikorski wishes to focus his research on characterisation of natural nanostructured materials and fabrication of nanostructures adopting the strategies inspired by nature. Sikorski wishes to investigate the ways in which nanostructured materials harvested from nature can be used in specific applications, for example as templates for fabrication of inorganic nanowires and nanotubes. By obtaining detailed descriptions of the structures of such materials, a better understanding of nature's design principles in the nm-scale may emerge and result in novel designs and fabrication strategies. Sikorski is also interested in biomineralisation, organization and processing of biopolymers in nature, crystal structure of polymers and biopolymers, as well as self-assembly and structure of amyloids.

## INCENTIVE MEANS

In order to promote cross-disciplinary research within nanotechnology at NTNU several initiatives were awarded incentive means from *NTNU NanoLab* in 2005.

***Prof. David Embury was awarded 50.000 NOK for organizing a series of seminars related to nanostructured materials. This is a joined initiative between the Department of Materials Science and Engineering and NTNU NanoLab, which will be continued in 2006.***

The series comprised lectures by researchers at NTNU as well as institutions elsewhere in Europe and were kept at an informal level to encourage discussions. The speakers invited in 2005 were:

- Prof. Mari-Ann Einarsrud, NTNU: "Synthesis of Inorganic and Ceramic Nanomaterials".
- Prof. Tor Grande, NTNU: "Stresses in Finescale particles".
- Prof. Hans Jørgen Roven, NTNU: "Ultra fine grain size materials by ECAP processing".
- Prof. Jason Nadler, ONERA France: “Ultra fine scale cellular Materials for Aerospace applications".
- Prof. David Wilkinson, McMaster Univ., Canada: "Tomographic studies of Damage and Fracture".
- David Wilkinson, McMaster Univ., Canada: "Studies of Formability in Al alloys".
- Oscar Paris, Max Planck Institute Postdam Germany: "Transformation of Heirachical biological materials to anorganic carbon + ceramic materials".
- Prof. Thomas Tybell, NTNU: "An overview of Nanomaterials present and future at NTNU".

***Jens-Petter Andreassen (Dept. of Chemical Engineering), Gisle Øye (Dept. of Chemical Engineering, Mari-Ann Einarsrud (Dept. of Materials Science and Enigneering) and Tor Grande (Dept. of Materials Science and Engineering) were awarded 30.000 NOK for establishing a cross-disciplinary cooperation for preparation of nano-particles and -rods. The cooperation also included Randi Holmestad’s group within electronmicroscopy (Dept.of Physics). The means were intended to cover running costs related to TEM-microscopy.***

As a result of this financial support extensive TEM-studies of nanoparticles of both lead- and barium-titanates have been conducted in order to elucidate their growth mechanisms. This work was carried out at the Dept. of Chemical Engineering in cooperation with the electron microscopy group.

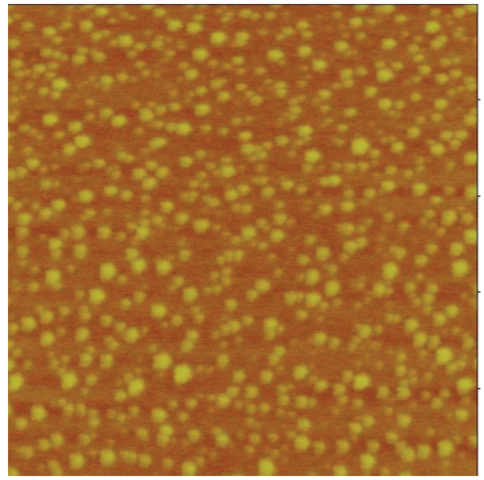
As part of an on going project on development of feasible routs for the synthesis of nanostructured complex ferroelectric oxides, special focus has been put on preparation of nanorods. Several strategies are being studied in parallel as the preparation of these structures is very demanding. The products have been studied by X-ray diffraction and SEM, but TEM studies are crucial in order to evaluate the composition, structure and quality of the nanorods.

In order to address this need an undergraduate student was trained in the use of TEM during a summer job financed by the incentive means from NTNU NanoLab. She completed a project involving TEM studies of nanostructured complex alkali titanates by determining the composition and structure of the nanorods. These studies demonstrated a clear need for further development of the synthetic methodology. The close coupling between the expertise on thorough analysis and preparation has been very fruitful and will be continued as a project for a master thesis in 2006.

***Terje Espevik (Dept. of Cancer Research and Molecular Biology) and Bjørn Torger Stokke (Dept. of Physics) were awarded 36.000 NOK for the project: "Activation of Toll-like receptors of the immune system studied by atomic force microscopy (AFM) and confocal microscopy". The support given by NTNU NanoLab constituted 10% of the total costs for guest researcher, Dr. Dionne Klein's visit (8 months) at NTNU.***

Toll-like receptors (TLR) are part of the innate immune system. In the last few years, many of the trafficking and signalling processes that play a role in TLR mediated immune response have been characterized. However, the exact mechanisms of interaction between TLR and various ligands and other interacting partners during activation are not known yet. The project focused on unraveling these mechanisms on the molecular level for selected TLRs using ultramicroscopy.

During Klein's visit she performed research on TLR9 and its ligand CpG DNA. Members of the TLR9 subfamily sense viral and bacterial infections at the endosomal subcellular compartment. It has not yet been determined whether CpG-DNA induces clustering of the TLR9 receptor or not. Klein studied the effect of CpG-DNA on TLR9 clustering behaviour using atomic force microscopy (AFM). Clusters of TLR9 have been imaged, but more measurements have to be performed, on a new version of TLR9 fusion protein, and an *in situ* calibration method will have to be developed.



*AFM image of TLR9 fusion proteins on mica, imaged in tapping mode in air. The image size is 1 μm x 1 μm and the height is from 0 to 4 nm.*

It was also desirable to study CpG-DNA interaction with TLR9 in membrane fragments. For this reason, development of a method to isolate endosomes, containing both TLR9 and CpG-DNA, from HEK cells was initiated. CFP-TLR9 expressing HEK293 cells stimulated with CpG-DNA were homogenized, centrifuged, and the post-nuclear supernatant was imaged with the confocal microscope. Since no co-localization of TLR9 and the late endosomal membrane protein LAMP1 were found, it was decided to switch to a new cell line. This work is being continued.

Based on these introductory studies, Dr. Klein obtained a personal post doctor grant from The Norwegian Research Council for three years (Fribiomol) at the Department of Physics and the Department of Cancer Research and Molecular Medicine, NTNU. In addition, an international cooperation with the University of Massachusetts Medical School, USA, and the Bio AFM Lab at Leiden University in The Netherlands has been established.

# Construction of Laboratory Facilities

The planning of the laboratory facilities for nanotechnological research at *NTNU NanoLab* has been carried forward. The facilities will be located in chemistry buildings 1 and 2, as well as the connecting building, "Mellombygget". Great emphasis has been put on designing an integrated, flexible infrastructure that may be adapted according to future demands. The laboratories will be furnished with state-of-the-art equipment for nanotechnological research within prioritized areas, and will complement the facilities of SINTEF's MiNaLab in Oslo. In addition to the specialized laboratories, the facilities will include general support laboratories, offices and meeting areas. The laboratories will be open to all researchers interested in nanotechnology, both at NTNU, SINTEF and other Norwegian research establishments.

*Chemistry building 1.*
*Photo: Thomas Tybell*

The "Laboratory for synthesis by chemical methods" will be located in the basement of chemistry building 2 and maintain clean-room class 10.000. Detailed plans for infrastructure, as well as scientific equipment have been drawn and contracts with tenders agreed on. The construction work will start in January 2006 and be completed within September, same year.

Chemistry building 1 will host a physical nanostructuring laboratory, including a bionanotechnology part. These laboratories (clean-room class 100 / 10.000 ) will be GMO-II:2 classified, enabling cross disciplinary research including studies of gene modified samples. The planning of these laboratories has been focused on identifying desired processes and overall demands on the infrastructure. The detail planning of these facilities will take place in cooperation with external consultants within 2006, enabling construction to be finalized by the end of 2007.

The planning of the facilities, including targeting desired processes and equipment has been carried forward by three committees, in close cooperation with SINTEF:

*Planning committee for "Clean room for chemical methods":*

- Mari-Ann Einarsrud (Dept. of Materials Science and Engineering, leader)
- Astrid Ramstad (Dept. of Chemistry)
- May-Britt Hägg (Dept. of Chemical Engineering)
- Arne Petter Ratvik (SINTEF Materials and Chemistry)

*Planning committee for "Clean room for physical methods":*

- Erik Wahlstrøm (Dept. of Physics, leader)
- Arne Rønnekleiv (Dept. of Electronics and Telecommunications)
- Bjørn Ove Fimland (Dept. of Electronics and Telecommunications)
- Otto Lone (Dept. of Materials Science and Engineering)
- Dag T. Wang (SINTEF IK)

*Planning committee for "Clean room for synthesis based on biological methods":*

- Tore Lindmo (Dept. of Physics, leader)
- Pawel Sikorski (Dept. of Physics)
- Bjørn Christensen (Dept. of Biotechnology)
- Christian Brekken (NTNU MR centre)
- Lars Kilaas (SINTEF Materials and Chemistry)

# New Study Programme in Nanotechnology

A new 5-year MSc study programme in Nanotechnology has been launched with start-up in the autumn of 2006. Initially, 30 students will be admitted. The programme will emphasize on the cross disciplinary nature of nanotechnology, giving the candidates a broad background in mathematics, physics, chemistry and life-sciences. In addition, the students will read nano-related courses from the first semester. During the last two years the students will specialize in one of the four focus areas within nanotechnology at NTNU.

*Photo: Marianne Sjøholtstrand*

# Economy

The overall budget for 2005 was 17.658 MNOK, including 10.190 MNOK allocated for future obligations including wages, continuation of establishment of infrastructure and scientific equipment. The remaining 7.468 MNOK were distributed and spent on assumed expenses as shown below.

| | Budget | Consumption | Surplus |
|---|---|---|---|
| Running costs | 300 000 | 58 070 | 241 930 |
| Strategic means | 2 508 000 | 2 468 333 | 39 667 |
| Incentive means | 250 000 | 200 000 | 50 000 |
| Studyprogramme nanotechnology | 250 000 | 280 | 249 720 |
| New academic positions | 540 000 | 340 452 | 199 548 |
| Salaries leader / coordinator | 1 120 000 | 934 120 | 185 880 |
| Establishment of infrastructure | 1 500 000 | 1 146 896 | 353 104 |
| Scientific equipment (Chemical clean-room) | 1 000 000 | 974 698 | 25 302 |
| | 7 468 000 | 6 122 849 | 1 345 151 |
| **Allocations for future obligations** | | | |
| Wages 2007-2008 | 3 390 000 | 600 000* | 2 790 000 |
| Continued establishment of infrastructure | 2 500 000 | - | 2 500 000 |
| Scientific equipment to be delivered in 2006 | 4 300 000 | - | 4 300 000 |
| **Totalt** | **17 658 000** | **6 722 849** | **10 935 151** |

*Funds transferred to relevant departments.

# Publicity

Activities related to NTNU NanoLab have been presented in the media on several occasions:

- Adresseavisen 27.01.2005 (web): *2005 blir et nanoår*
- Under Dusken 07.03.2005 (web): *Gullivers reiser til Gløshaugen*
- Universitetsavisa 13.04.2005 (web): *Tar ledelsen på liten skala*
- Adresseavisen 31.05.2005 (web): *NTNU satser stort på smått*
- Forskning.no (web) 28.10.2005: *Nye solceller ser lyset*


*Photo: Marianne Sjøholtstrand*

# Publicity

The scientific community within nanotechnology at NTNU as published a significant number of articles in 2005. In the following a few selected publications are sited within the four prioritized areas of *NTNU NanoLab.*

***Nanostructured Materials***

T. Hansen, L. Jensen, P.-O. Åstrand and K. V. Mikkelsen, *Frequency-Dependent Polarizabilities of Amino Acids as Calculated by an Electrostatic Interaction Model,* J. Chem. Theory. Comput. 1, 626, 2005.

S. Faaland, T. Grande T, M.-A. Einarsrud, P.E. Vullum PE, R. Holmestad, *Stress-strain behavior during compression of polycrystalline* $La_{1-x}CaCoO_3$ *ceramics,* Journal of the American Ceramic Society 88, 726, 2005.

T. Vrålstad, G. Øye, M. Rønning, W.R. Glomm, M. Stöcker, J. Sjöblom, *Interfacial chemistry of cobalt(II) during sol–gel synthesis of cobalt-containing mesoporous materials*, Microporous and Mesoporous Materials 80, 291, 2005.

W. R. Glomm, S. Volden, J. Sjöblom and M. Lindgren; *Optical absorption and photoluminescence characterization of Ruthenium(II) Tris(2,2'-Bipyridine) and Europeum(III) Hexahydrate Salts Assembled Into Sol-Gel Material,* Chemistry of Materials 17(22) 5512, 2005.

C. Pitois, A. Hult, and M. Lindgren, *Lanthanide-cored fluorinated dendrimer complexes: synthesis and luminescence characterization,* Journal of Luminescence 111, 265, 2005.

N. Andersson, P. Alberius, L. Bergström, J. Örtegren, M.Lindgren. *Photochromic mesostructured silica pigments dispersed in latex films,* J. Mater. Chem. 34, 3507, 2005.

D. Chen, K. O. Christensen, Z. Yu, B.Tøtdal, N. Latorre, A. Monzón and A. Holmen. *Synthesis of Carbon Nanofibers: Effects of Ni Crystal Size during Methane Decomposition,* J. Catal. 229, 82, 2005.

Z. Yu, D. Chen, B. Tøtdal, T. Zhao, W. Yuan and A. Holmen, *Catalytic Engineering of Carbon Nanotube Production,* Appl. Catal. 279, 223, 2005.

Z. Yu, D. Chen, B. Tøtdal, and Anders Holmen, *Effect of Catalyst Preparation on the Carbon Nanotube Growth Rate.* Catalysis Today 100, 261, 2005.

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