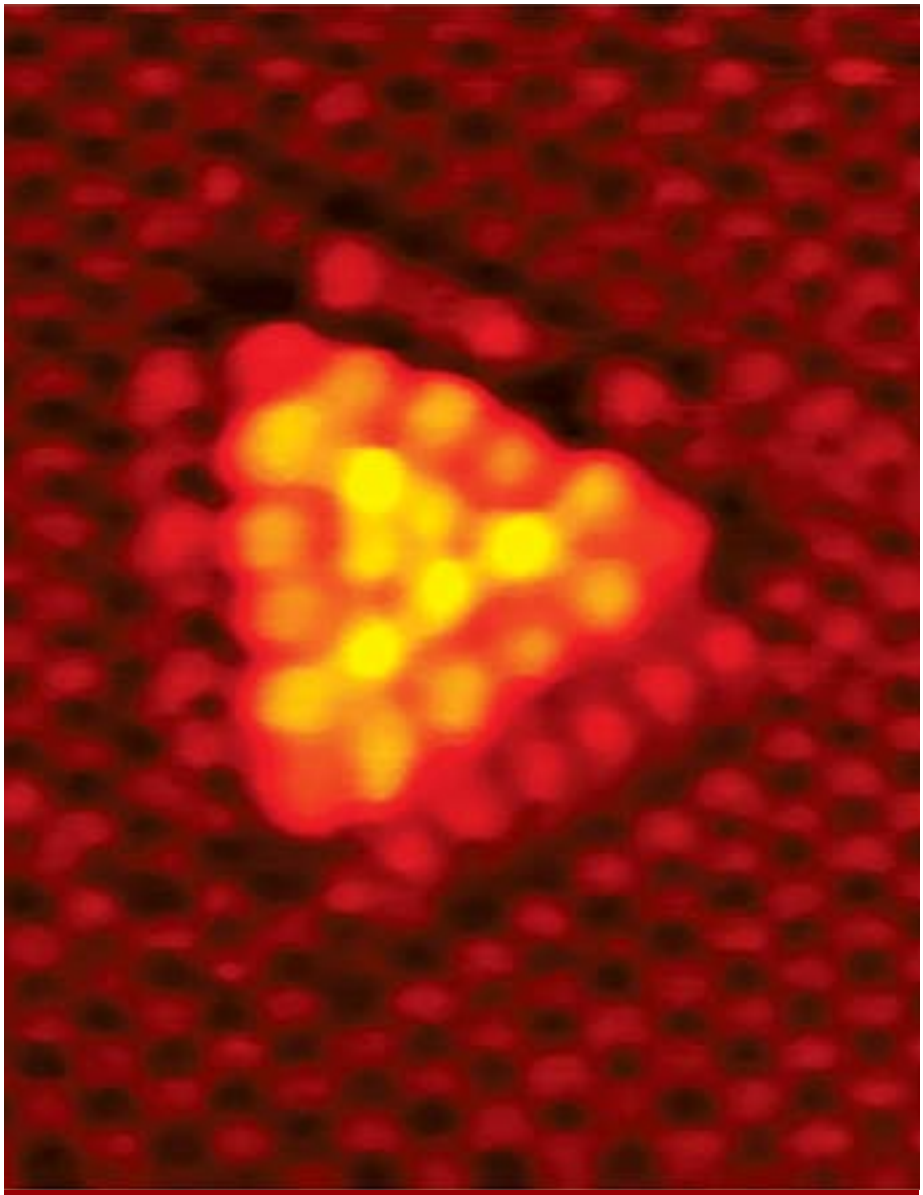

iNANO
Annual Report 2006
iNANO - Interdisciplinary Nanoscience Center



The cover image is a 3D representation of a Scanning Tunneling Microscopy (STM) image of a MoS_2 nanocluster on a Au(111) support. The raw STM image (5nm ´ 5nm) can be seen here. The individual protrusions represent the gold atoms of the support and the sulfur atoms in the topmost layer of the MoS_2 nanocluster, respectively

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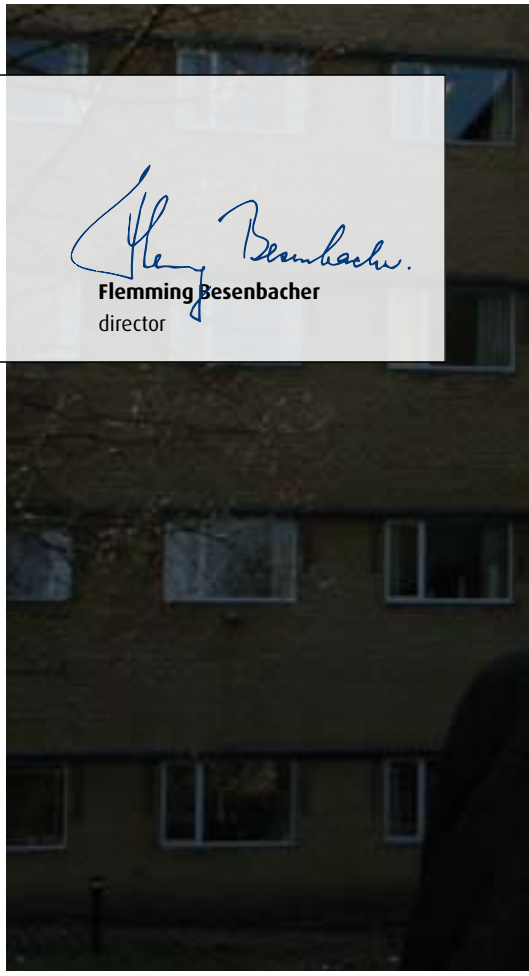
Message from the Director



Flemming Besenbacher
director

I take great pleasure in presenting the third annual report for iNANO, the Interdisciplinary Nanoscience Center hosted by the University of Aarhus and Aalborg University. I can without hesitation state that 2006 was a great year for iNANO, as we witnessed continuous growth in our activities. A positive development which we expect to continue throughout 2007.

By Flemming Besenbacher

The iNANO mission is based on the following three equally important pillars:

- **Education:** iNANO aims to educate talented students to the highest international standard and thereby secure the next generation of gifted and skilful nanoscience researchers for Danish industry and other stakeholders.
- **Research:** iNANO strives to conduct excellent interdisciplinary research in nanoscience and to catalyze collaboration with other nanoscience centers of excellence
- **Innovation:** iNANO is committed to provide an innovation interface and to facilitate the conversion of nanoscience knowledge into nanotechnology to the benefit of Danish or international industrial companies and society.

At the end of 2006, 62 senior researchers, 47 postdocs and assistant professors, and 92 PhD students were associated with iNANO. At the beginning of the year the management of iNANO was strengthened by the establishment of an independent administrative unit.

Education in 2006

Internationally, iNANO has played a pioneering role in establishing a new interdisciplinary curriculum in nanoscience and nanotechnology at the University of Aarhus in September 2002. The curriculum includes central elements of physics, chemistry, molecular biology, biology, and mathematics, and covers a broad spectrum of introductory, advanced, and specialized interdisciplinary courses. The portfolio of courses is continuously being evaluated and developed. As an example, a new course in "Innovation and Entrepreneurship" was held for the first time in 2006. The aim of the course is to strengthen the theoretical and practical insight of the students into research-based innovation and creation of new businesses.

The first group of students who started in 2002 will obtain their Master's degree in the second half of 2007. We are confident that Danish companies will value these talented young nano students, who will have a much broader interdisciplinary background in the natural sciences in general than students graduating from the more conventional study lines.

After four years of study the best qualified nano students may apply for admission to our graduate school, iNANOschool. Many PhD projects are carried out and financed in collaboration with an industrial partner.

At the end of 2006 iNANOschool had 92 PhD students, which represents a moderate increase from the 85 PhD students at the beginning of the year. We hope to attract additional funding to make it possible for us to award further PhD stipends under the auspices of iNANOschool in the future, and we aim at 25% of our PhD students being foreign to strengthen the degree of internationalization at iNANO.

New research activities in 2006

The iNANO center provides the framework for interdisciplinary research activities, focusing on basic fundamental aspects of nanoscience as well as activities oriented towards nanotechnology applications. Current research activities focus on the following seven areas:

- Nanomedicin (e.g. drug delivery from nanoparticles and biocompatible materials)
- Nanobiotechnology
- Nanofood
- Functional Nanomaterials
- Nanocatalysis and energy related research
- Nanophotonics and nanoelectronics
- Toxicological and ethical aspects of nanoscience and technology

As in previous years, the iNANO scientists obtained many excellent research results in 2006, as evidenced by the list of publications, which includes many papers in high-impact journals. Furthermore, many iNANO scientists have maintained very high international standing as reflected by the long list of invited talks at international conferences and meetings. Similar to the two previous years, we will highlight a few research activities in this annual report. The iNANO scientists were also very successful in attracting external funding from many different sources in 2006. The total grants received, which are administered by iNANO and started in 2006, amounted to DKK 71 million – a very satisfactory increase from the DKK 42 million obtained in 2005. At this point I shall restrict myself to highlighting some of the most significant.

In 2006, iNANO scientists participated in several applications to the Danish National Advanced Technology Foundation (Højteknologifonden).

Funding for one advanced technology platform entitled "PROSURF, Protein-based functionalisation of surfaces" was obtained together with funding for three additional projects entitled, "OnBoardNMR", "FUTURECHEM" and "CatLink". These projects are briefly described on pages 24-31.

Applications to the Programme Commission on Nanoscience, Biotechnology and IT (NABIIT) were also successful in 2006, and three major grants were obtained with the titles "Risk assessment of free nanoparticles", "Development of new metal- oxide and sulphide catalysts", and "Mobile quantum security".

Finally, it should be added that at the end of 2006 the Danish National Research Foundation (Danmarks Grundforskningsfond) established two new research centers, which are both headed by iNANO scientists: "Center for DNA Nanotechnology" headed by Professor Kurt V Gothelf, and "Center for Membrane pumps in cells and disease" headed by Professor Poul Nissen.

Innovation and collaboration with industry

In accordance with the iNANO mission we have established and maintain very fruitful and close collaborations with a large number of Danish companies. iNANO is now committed to six projects funded by the Danish National Advanced Technology Foundation (Højteknologifonden). This clearly underlines iNANO's success in this respect. Often the collaboration between iNANO and a Danish company begins as a co-financed PhD project, and quite frequently such projects have spearheaded the identification of larger collaborative projects as well as migration of iNANO students into the companies. iNANO is dedicated to expanding the portfolio of such projects continuously.

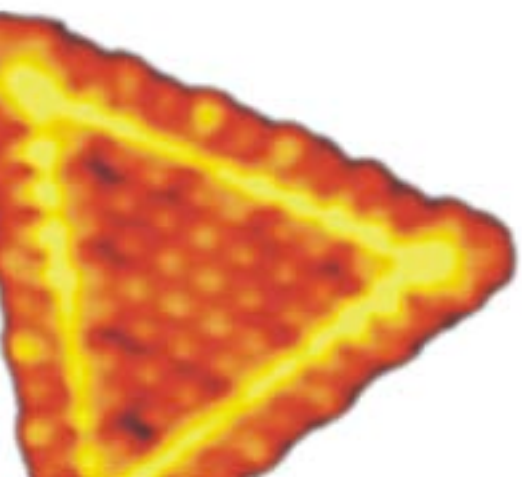
The NanoFood consortium was established in 2005 with the objective to strengthen the interaction between the University of Aarhus and the food sector, which has a strong basis in Eastern Jutland. The consortium focuses on improved food safety and more healthy nutrition. The partners include a large number of strong companies, institutes and institutions.

Last year the Board of Directors of the University of Aarhus approved our suggestion to build a iNANO house, a new large laboratory/office building with a total area of about 8500 m^2, including a 140 m^2 clean room facility. The clean room building is expected to be finished in the early summer of 2008, whereas the rest of the iNANO house has experienced a major delay. It is now expected to be ready in 2011.

The iNANO house will give the iNANO researchers excellent opportunities to collaborate closely in well-equipped competence laboratories, and thereby strengthen interdisciplinary research even further. Furthermore, the iNANO house will give our students outstanding possibilities to conduct first-class research during their PhD projects. We aim at having 25% of the iNANO-house area allocated to employees of industrial companies, who will work on special innovative iNANO collaborative projects.

Acknowledgement

Finally, I would like to place on record my sincere appreciation for the tireless efforts which the scientists and administrative staff of iNANO have made in 2006. Their commitment and enthusiasm is the fuel which keeps the wheels of iNANO turning. The prospects for 2007 are very encouraging. We will strive to make the impact of iNANO even more visible both nationally and internationally, and iNANO will continue to be committed to integrate nanoscience and nanotechnology in Danish society for the benefit of the entire population.



Educational activities

Undergraduate studies

A new interdisciplinary study line in Nanotechnology was introduced in September 2002, where 37 new students commenced their study at the University of Aarhus. This new educational initiative has been very well received among prospective students, and the number admitted has increased from 37 in 2002 to a stable yearly uptake of around 60 highly motivated and very skilled young people. In 2006 the frontrunners on the nanotechnology study line reached the last year of their Master's degree programme, and some commenced their Master's project, while as many as 11 were accepted to the PhD programme at iNANOschool. Thereby the goal of creating a full educational nanotechnology program from Bachelor to PhD level was fulfilled.

The philosophy behind the interdisciplinary Bachelor's degree programme in nanotechnology is to provide the students with a broad and solid foundation in physics, chemistry, molecular biology, and mathematics, and therefore they follow courses along with students of these disciplines. In addition, they are presented with courses specifically targeted at the nano area, such as Introduction to Nanotechnology where the students make a small project in the research groups of the iNANO center already during their first year, and subsequent courses with nanoprojects and exercises, ending in the two courses Nanocharacterisation and Current Nanoscience that introduce a number of experimental characterisation techniques for nanoscience as well as important subject areas for current nanoscience research. The Bachelor's degree programme is terminated by a Bachelor's project individually supervised by iNANO researchers.

Master project in nanotechnology		
Specialisation - 4	Innovation/patent	Specialisation - 10
Specialisation - 3	Specialisation - 6	Specialisation - 9
Specialisation - 2	Specialisation - 5	Specialisation - 8
Specialisation - 1	Student's colloquium	Specialisation - 7
Current nanoscience	Theory of Science	Bachelor project
Nanocharaterisation	Experimental mol.bio.	Bachelor project
Solid state physics	Bionanotechnology	Nano project
Statistical mechanics	Elective-2	Fourier analysis
Introduction to quantum mechnics	Elective-1	Statistics and data processing
	Chemical binding	Linear algebra - 1
Experimental exercises	Inorganic chemistry	Basic molecular biology
Introduction to programming	Thermodynamics/kinetics	Basic biochemistry
Waves and optics	Organic chemistry	Nano intro
Electromagnetism		Basic biology
Mechanics/thermodynamics	Numerical physics	Calculus - 2
Introductory mechanics	Introductory chemistry	Calculus - 1

Course programme for new nanotechnology students. Legend: blue: physics courses, yellow: chemistry courses, orange: molecular biology courses, red: mathematics/computer science courses, green: nanoscience courses, grey: specialisation modules.

Master project in nanotechnology			
Materials	Bio	Physics	
Nanofabrication and characterisation	Quality control	Physical Chemistry	
Nanostructures in biological organisms	Biochemical reactions in the body	Optical, electronic, magnetic properties of nanostructures	
Fluid dynamics in small structures	Biosensors	Statistical mechanics	Solid state physics and chemistry
		Organic and inorganic nanostructures	
Spectroscopy	Data processing	Differential equations	
Quantum mechanics	Structure of solids and liquids	Molecular biophysics	Computer modelling
Laboratory training	Fourier and Vector Analysis		
Electromagnetic fields in nanostructures	Gene technology	Basic optics	Ethics
The composition of matter	Chemical and biological molecular structures		Scientific communication and methods
Mathematics	Mechanics	Thermodynamics	Scientific models of the universe
Mathematics	Scientific models of the universe	Basic chemistry	IT
		Atoms and molecules	

Course programme for the Bachelor's degree programme in nanotechnology at Aalborg University. Numbers in parenthesis are the length of the course in ECTS.

During the Master's degree programme the students specialize in the branches nano-physics, nano-chemistry or nano-biology by choosing from the large course catalogue at the Faculty of Science. In the compulsory Student Colloquium the students gain experience in presenting a subject of their own choice to a wider audience, and in the Patent/Innovation course they are introduced to concepts of commercialisation highly relevant to anyone who wishes to enter into a commercial exploitation of nanotechnology. The specialisation courses followed on the fourth year of study enable the students to commence their one-year Master's project, or alternatively to seek admittance to the PhD programme of iNANOschool.

At iNANO we strive to provide the best possible environment for our students. On the freshman year, the students follow the same class of 20 people in all their courses, and each class is assigned their own room with computers and internet access that can also be used for group work, discussions and social activities between courses. A number of other new initiatives such as individual counselling, "nano café", extra instructors, etc., help facilitate the transition from high school to university. For some of the older students, iNANO arranged in 2006 a very successful four-day study trip to the nanoscience centres in Göteborg, Linköping and Lund, with which iNANO has established multiple collaborative research projects.

At Aalborg University, an engineering programme focused on nanotechnology started in 2003 (www.physics.aau.dk), and in 2006 60 students were enrolled. The programme consists of a combination of courses and projects with different themes for each semester (see Figure 2).

Two-year Master's programmes with specialisations in physics, materials and in biotechnology are currently running.

Graduate studies - iNANOschool

A vocationally oriented graduate school, iNANOschool (www.inanoscool.dk), was started in 2002 shortly after the inauguration of iNANO. The activities in iNANOschool (mainly PhD projects and graduate courses) are based on a large grant of DKK 12 million from the Danish Research Training Council (FUU). There has been another two large contributions from FUU to the iNANOschool. In 2005 iNANOschool were awarded 5 million to 10 PhD stipends, and in 2006 5,1 million were awarded to another 10 PhD stipends. These grants cover 1/3 of the 10 PhD stipends in a so-called co-financing scheme, where the Faculty of Science and the Faculty of Health Sciences contribute another 1/3 and the remaining 1/3 coming from private companies or a public body, in our case the County of Aarhus.

iNANOschool has also been successful in obtaining International Stipends from FUU. In 2005 the school was awarded one stipend, starting in 2006, and in 2006 the school was awarded another five stipends all starting in the beginning of 2007. As part of this three-year program the graduate students will spend up to half of their PhD studies at a university abroad, thereby further establishing collaboration between iNANO and other internationally renowned nano-centers (Duke University in US, The Ian Wark Research Institute in Australia, Chalmers University of Technology in Sweden, Institute de Biologie Structurale in France and University of Osnabruck in Germany, respectively).

Currently, 31 PhD projects are financed by the FUU funds. The total number of PhD students enrolled in iNANOschool in 2006 is, however, as high as 92 (of which 37 percent are women, and 13 percent have an education from abroad), the remainder being financed by, e.g. faculty funds or funds obtained from other sources by individual research groups at iNANO. The funding profile for iNANO is presently; 39 percent of the funding of PhD student is faculty funding, 31 percent is funding from national research councils, 14 percent is funding from FUU, 8 percent is funding from the industry, 5 percent is funding from the County of Aarhus, and the last 3 percent is international funding such as EU or appointed scholarship from foreign governments.

During 2006 12 PhD students completed their PhD studies, and 21 new PhD students were enrolled in iNANOschool (a list of the PhD titles is listed under PhD Theses 2006)

In 2006, a number of graduate courses were held as part of the iNANOschool activities:

N3: Surface reactivity and nanocatalysis
N6: Nanobiocompatibility
N9: Bionanotools and protein structure
N11: Drug delivery
N21: Innovation and Entrepreneurship

Two of these courses (N3 and N6) were organised as very successful one-week intense courses at Fuglsøcentret near Aarhus. Nanobiocompatibility, (organised in collaboration with the EU network of excellence "Frontiers") was held in week 22, 2006 with attendees from seven countries. This course aimed to give an introduction to the interaction between artificial biomaterials and biological systems with emphasis on the mammalian physiological systems, including humans. Surface reactivity and Nanocatalysis was held in week 24, 2006 with attendees from eleven countries. This course aimed to give an introduction to the concepts of catalysis followed by specialized talks covering subjects like: surface reactivity, surface science studies of model catalysts, in-situ studies, industrial catalysis, homogeneous and enzymatic catalysis and theory in catalysis. These one week intense courses give the students an opportunity to interact with each other and with the lecturers in an informal setting (full program can be found at the iNANO webpage).

Two other courses (N9 and N11) were organised at the University in order to be able to use the experimental facilities. Bionanotools and protein strucuture was held from week 34, 2006 and Drug delivery was held from week 12, 2006. The aim of the Bionanotools and protein structure course was to introduce the students to a number of analytical measurement and analytical tools used for the structure-function analysis of biological macromolecules, or biological nanomachines such as functional proteins, membrane pumps and channels. The aim of the Drug delivery course was to provide insight into theory and technical requirements for delivery of nucleic acidbased gene silencing therapeutics in established cell lines, primary cells and animals.
The last course Innovation and Entrepreneurship introduces concepts of commercialization which are highly relevant to anyone who wishes to enter into a commercial exploitation of nanotechnology. The course was co-organized as an undergraduate and graduate course.

Nanorama

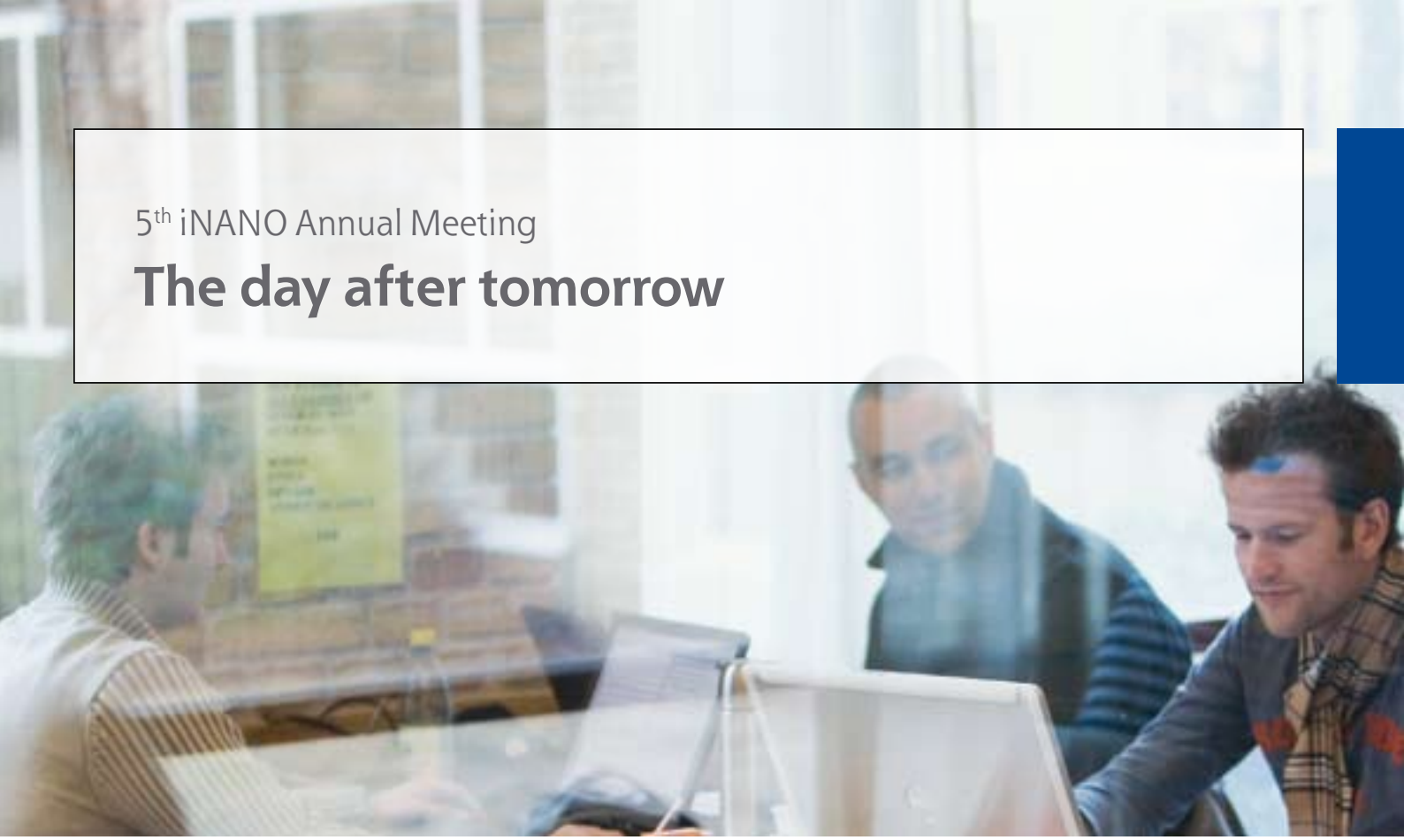
Nanorama is a student organization run by undergraduate students at iNANO and was first established in the spring of 2005. Nanorama arranges a range of different social activities, such as "Friday Nanobar" once every quarter – sometimes in collaboration with other student organizations.

By the board of Nanorama

Nanorama also arranges a Christmas lunch for nanostudents each year in December, and this year the turnout was excellent with lots of students from every year. To make our arrangements even more enjoyable we have purchased a music system for our nanobar. This purchase was made possible by a grant from the Tuborg Foundation .

Besides these social activities, Nanorama also arranges visits to industrial companies, whose research and development activities are of great relevance to nanostudents. We recently arranged a visit to Danisco, in which 70 students participated. Other events include a visit from B&O in March where a representative talked about their interests in nanotechnology.

So far the support for our activities has been overwhelming, and since the number of students increases every year, we expect to expand our activities in various ways. Our goals for the coming year include participation in the Aarhus 1900 race, further collaborations with other student organizations and a music café, where local artists can demonstrate their talents.



5th iNANO Annual Meeting

The day after tomorrow

William Shakespeare once wrote "If you can look into the seeds of time, and say which grain will grow and which will not, speak then to me". This desire for certainty applies to nanoscience as well. However, there is no doubt that some of the seeds will grow into nanotechnologies that will transform our lives in the 21st century.

By Rolf Haugaard Nielsen Science journalist

Moore and beyond

It was the first speaker at the 5th iNANO Annual Meeting; Colin Lambert from Lancaster University in the UK, who quoted Shakespeare's Macbeth and drew the above-mentioned conclusion. Lambert focused on the future of information and communication technologies and noted that the semiconductor industry has already entered the nanoscale by producing transistors with critical dimensions below 100 nanometres. Transistors are expected to be further downsized to 22 nanometres in 2011, but thereafter it will no longer be possible to keep pace with Moore's Law, predicting that the number of transistors per unit area will double every 18 months - unless new technologies are introduced. Some of the most promising candidates are optical data processing and data storage based on spintronics.

However, after 2020 we will need "more than Moore", Lambert emphasised. Instead of merely increasing the density of transistors on a chip, researchers should aim to increase functionality by integrating a range of emerging nanotechnologies on a single platform. The current CMOS technology might be combined, not only with optical data processing and spintronics, but also with optical detectors, biological sensors, molecular electronics and GPS units. "The chips of the future may be almost self-aware. They will know precisely where in the world they are, be capable of sensing the environment, and be able to talk to each other", Lambert predicted.

Further down the road nanoscience may take us far "beyond Moore", leading to entirely new paradigms abandoning transistors all together. It could be intramolecular computers, where calculations are performed inside molecules, solid state quantum computers for number crunching of epic dimensions, nanoelectronics based on self-organised biology or neuromorphic computers working like the ever changing and learning human brain.

Going back to the wisdom of William Shakespeare, it is not yet possible to identify the winning nanotechnologies, but some of the potential barriers can be pointed out right away. "We have to deal with the interconnecting problem to achieve fully integrated systems. Today, wires are a hundred times bigger than the minuscule nanotransistors based on carbon nanotubes, and they cannot be downsized by conventional means. Some possible solutions may be 3D architectures, where wires can be shortened, or neural networks", Colin Lambert said.

Connected by weak forces

One promising route to solve the interconnecting problem is to exploit the intermolecular weak forces, such as interactions between polar molecules or hydrogen bonding that plays a critical role in nature. "In order to control these weak forces in functional nanostructures we need to have a deeper understanding of how they work at the atomic level", said Chen Wang from China's National Center for Nanoscience and Technology in Beijing.

Wang's group has made great achievements in that direction by developing methods for selective adsorbtion of organic molecules to semiconductor and metal surfaces. When binding to the surface, these molecules form self-assembled monolayers with a range of functionalities. The monolayers have been characterised by STM.

By adding long carbon chains that stick out from the core of the molecules, their affinity for the surface is improved due to weak molecular interactions between the chains and the surface. Furthermore, the orientation and the conformation of the organic molecules can be tailored by varying the length of the carbon chains. "These monolayers are able to link metals and semiconductors in nanocontacts, and we can reverse the

The day after tomorrow

flow of electrons over the contact by shifting the voltage", Chen Wang said.

The magic of nanopores

Sarah Tolbert from the University of California in Los Angeles told the audience about nanoporous inorganic semiconductors. These structures self-organise by chemical reactions between organic and inorganic molecules. During the self-assembly the organic molecules form rods surrounded by semiconductor walls. Afterwards the organic cores are removed, leaving a rigid semiconductor structure with perfectly aligned, long and straight nanopores with diameters between 2 and 10 nanometres.

Nanoporous inorganic semiconductors have a range of applications. An example is their ability to enhance the electric conductivity of organic semiconductors. In a standard organic semiconductor the polymer chains resemble spaghetti on a plate, and the electrons hop from chain to chain, leading to reduced conductivity. In samples with the smallest nanopores single polymer chains can be fully stretched out inside the pores, and the electrons run easily along the chain. This improves the conductivity dramatically. Nanoporous materials can also polarize and tune the optical properties of semiconducting polymers, and it is even possible to achieve very efficient lasing without a traditional lasing cavity when the aligned polymer chains inside the pores are pumped with an optical laser.

Magnetic nanoparticles can be sucked into the pores as well. These nanomagnets have the potential to store data in extremely small volumes, but at room temperature this is prevented by quantum effects that destabilise the magnetic field of the small particles. When rows of nanomagnets are coupled inside the nanopores, their magnetic stability is greatly enhanced.

The inorganic nanoporous semiconductors have highly tuneable electronic properties. Tolbert's group has recently produced very thin nanoporous structures with walls only one nanometer thick. "In these structures it is possible to red-shift the band gap, enabling us to tune it, and we have produced nanoporous semiconductors with a broad range of different band gaps. Such materials may one day lead to highly efficient nanoscale solar cells", Sarah Tolbert said.

DNA as Gutenberg types

Francesco Stellachi from Massachusetts Institute of Technology in the USA first presented brand new results of mixed self-assembled monolayers on gold nanoparticles. Due to the curvature of the particles the adsorbed molecules self-organise in alternating hydrophilic and hydrophobic rings around them. The rings are only 5 nanometres wide, and this hydrophilicity pattern conformationally frustrates proteins, leading to the inhibition of protein binding to the nanoparticle surface. Proteins that bind to body implants often trigger inflammation and bacterial infection, necessitating the removal of the implant.

Then Stellachi switched to his next topic; the creation of a nanostamping method that not only transfers a pattern, but the highest amount of information possible within that pattern. For this purpose the MIT group exploits the unique properties of the natural molecular information carrier DNA. "Gold wafers covered with monolayers of multiple DNA strands each encoding different information can be used as masters for a novel printing technique, much like the Gutenberg moveable type", Francesco Stellachi said.

A master is produced by attaching thousands of single DNA strands to the surface of the wafer. Then the wafer is placed in a solution with complementary single DNA strands, and each strand finds its right partner, and they join in the double helix. Afterwards the complementary stands are separated from the originals and transferred to another wafer, creating a mirror image of the master. When a copy of this mirror image is made, the master is reproduced.

Stellachi envisioned that the new method may lead to cheap one cycle fabrication of DNA microarrays that could be used for personal genetic and genomic testing. Further into the future the DNA technique may even print substrates for DNA computing.

Attolitre model cells

Understanding cellular signalling mediated by cell surface receptors is the key to modern biomedical research and drug development. To fully examine the complex signalling processes across the cell membrane you need to carry out lots of experiments on identical samples. This has recently become possible using small attolitre containers formed by pieces of the cell membrane. An attolitre is a very small quantity; just a billionth

of a billionth litre. The small globular model cells measure from 100 nanometres to a few microns in diameter.

"Each vesicle maintains the properties of a living cell with the transduction machinery and the intracellular communication intact. A hundred vesicles can be produced from a single cell, and consequently, a hundred different experiments can be performed on identical probes", said Horst Vogel from the Swiss Federal Institute of Technology Lausanne.

The vesicles are drawn from mammalian cells expressing human receptors in their membranes, and they contain these receptors as well. Human membrane receptors are the most important drug targets, and vesicles displaying these receptors may be utilised to screen huge libraries of drug candidates.

Vogel's group has developed micron-sized arrays closely packed with thousands of immobilized attolitre vesicles, which are used to study the human olfactory system. "Humans have 315 different odour receptors in the cell membranes of the olfactory neurons able to detect 10,000 chemicals by pattern recognition. So far we have expressed 30 of these receptors in vesicles for experiments with odorants", Horst Vogel said.

Nanomedicine is on the move

The last speaker, Chiming Wei from the Johns Hopkins University School of Medicine in the USA defined nanomedicine as medical diagnosis, monitoring and treatment at the level of single molecules or molecular assemblies.

"The world market for nanopharmaceuticals reached 380 billion dollars in 2005. Half of the applications are products modified by nanotechnology for oral, inhalative and dermal administration, and another important area is drug delivery based on nanoemulsions or nanoparticles. Meanwhile, the market for nanodiagnostics, such as DNA chips, protein chips and lab-on-a-chip systems, reached 40 billion dollars", Chiming Wei said. In basic biomedical research a promising development is the application of quantum dots; small nanocrystals that emit fluorescent light when illuminated with lasers. Quantum dots can be specifically targeted to bind to selected biomarkers in order to elucidate the cellular dynamics of living cells.

For diagnostics and monitoring of medical treatment, electrochemical and magnetic nanobiosensors show great promise. These minuscule sensors can detect cancer markers present at ultra-low levels during the early stages of the disease. Hence they may enable early diagnosis of a range of cancers, which is crucial for successful treatment of the disease. "Nanodiagnostics and nanopharmaceuticals for cancer is a fast moving area", Chiming Wei said.

The need is urgent too. While the mortality due to heart diseases and cerebrovascular diseases, such as strokes, has been reduced dramatically since 1950, this is not the case for cancers that kill as many people as five decades ago. Wei presented promising pharmaceutical developments using liposomes and nanoparticles for drug delivery, hitting the tumour hard and limiting the drug exposure in healthy tissues of the body. Finally, Chiming Wei took the audience on a tour-de-force summing up the state-of-the-art in areas such as stem cell therapy, gene therapy and immunotherapy.

The speakers at the 5th iNANO Annual Meeting 2007 clearly showed that a bounty of seeds is evolving from nanoscience. But "which grain will grow, and which will not", we shall not know until the day after tomorrow.

Coding for nanoscale assembly with DNA

Cover illustration from Org. Biomol. Chem. 2005, issue 22 by Gothelf and LaBean. An artist's impression shows how complementary DNA strands joined in the double helix bring two building blocks together.

Centre for DNA Nanotechnology explores fundamental aspects of DNA as a programmable tool for directing the assembly of molecules and materials into functional nanoarchitectures.

By Kurt V. Gothelf

One of the fundamental challenges in nanoscience is the assembly of nanoscale materials. Organic molecules and other nanosized materials such as nanoparticles and carbon nanotubes have a variety of fascinating properties, but there are still no simple and efficient methods for assembling individual components into functional devices such as electronic circuits, photonic networks, or nanorobotics.

Nature is on the other hand extremely efficient in constructing such functional macromolecular structures. The unimaginably complex machinery of a living cell is formed and operated by self-assembly. The precision and efficiency of this process derive from specific molecular interactions between especially proteins, DNA and RNA. At Centre for DNA Nanotechnology we will explore nature's strategy. The research focuses on the design and preparation of DNA sequences attached to organic molecules, biomolecules, nanoparticles and carbon nanotubes. We will investigate how these encoded materials are able to self-assemble into predesigned nanoarchitectures and explore the basic properties of these nanostructures.

Communication between biological and artificial structures is another important area. The interaction between targeted DNA sequences in living cells and artificial DNA nanostructures may trigger built-in functions and provide new routes to monitor and potentially treat diseases.

Controlling chemical reactivity

Chemical reactions between small organic molecules can be controlled by short DNA sequences attached to the molecules. Only when the sequences are complementary, will the molecules be brought in proximity and react. Hence, the reactions of thousands of molecules in the same solution can be completely controlled by the attached DNA sequences.

At Centre for DNA Nanotechnology we are constructing organic macromolecules by DNA-programmed assembly of various building blocks. We are also developing new methods for specific chemical functionalization of DNA sequences. In collaboration with the company Vipergen we are exploring new opportunities for chemical reactivity in DNA junctions.

Design and imaging of DNA structures

The American researchers at Centre for DNA Nanotechnology, Hao Yan from Arizona State University and Thom LaBean from Duke University, have built a new nanoscale DNA motif known as a cross tile structure. This nanostructure self-assembles into 2D lattices containing periodical square cavities. Each unit cell can be considered as an individual pixel. Arrays of these DNA cross-shaped tiles were decorated with pixels of individual protein molecules to write the letters D, N and A. With unique DNA labels assigned to each cross structure, we will use them to construct 2D arrays with individually addressable binding sites.

In the AFM laboratories of Flemming Besenbacher's group we will develop improved techniques for imaging of such 2D DNA nanostructures.

Extremely sensitive biosensors

In diagnostics and for detection of genetic material in the environment there is a growing need for

Kurt V. Gothelf

Centre for DNA Nanotechnology

In March 2007, the Center for DNA Nanotechnology (CDNA) was established and received a DKK 40 million grant for 5 years from the Danish National Research Foundation. The highly interdisciplinary center is primarily located at iNANO, University of Aarhus, but also involves two American research groups that are leading in the design of advanced nanostructures.

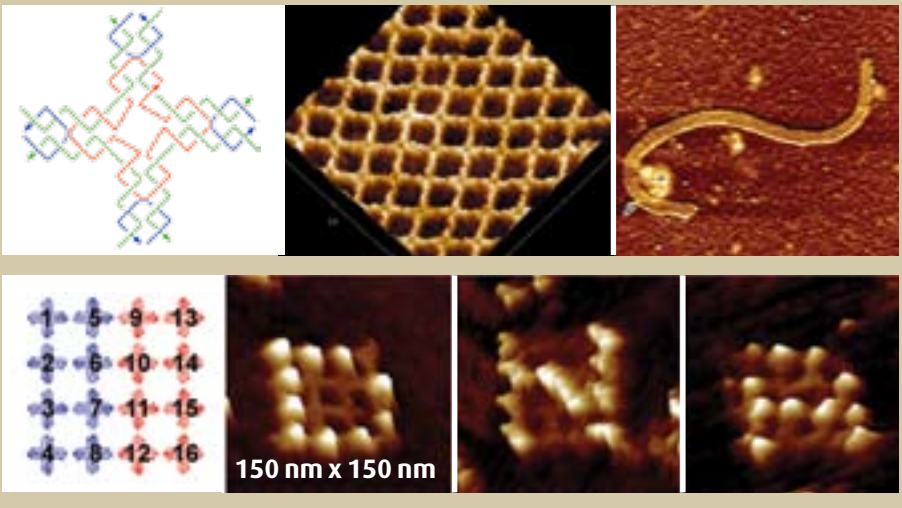
sensors that can detect arrays of DNA sequences within minutes.

At the center we have developed an electrochemical quantum dot based approach that could detect down to 0.1 femtomol of DNA. This method is based on a competition assay in which a labelled probe hybridized to an immobilized sequence is outcompeted in the presence of the target.

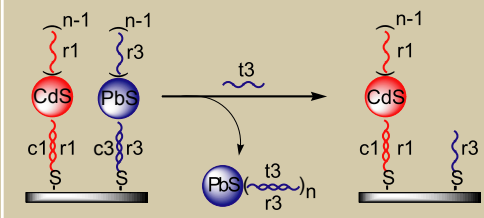
Artificial DNA in living cells

In collaboration with Professor Peter Ogilby at the Department of Chemistry, we have recently developed the first approach for a DNA-triggered on- and off- switching of a sensitizer to produce singlet oxygen, which is toxic in living cells. Professor Jørgen Kjems' group is now extending these studies to cell cultures, where the formation of singlet oxygen will be controlled by the presence of a specific messenger RNA sequence in the cells, e.g. from an activated oncogene or a virus.

In cell lines where such messenger RNA is expressed, the molecular assembly will be opened, and upon irradiation the opened structure will produce singlet oxygen. It is known that critical concentrations of singlet oxygen induce cell death by apoptosis. The plan is to develop this system into a new method for selective photodynamic therapy by which cells are killed if disease related messenger RNA is expressed in the cell.



A) A 4x4 DNA tile used for construction of a DNA lattice or a DNA wire. B) Individually addressable 16 pixel DNA print board used for writing D-N-A; imaged by AFM on mica. C) Self-assembling molecular pegboard containing individually addressable sequences.



Competition assay for detection of a natural DNA target. When the target t3 is present in the sample, the labelled probe c3 is outcompeted.

Chiral switching on surfaces

Chiral molecules are mirror images like the right and left hands. Life is exclusively left-handed, and thus chirality plays a key role in biochemistry and drug design. Powerful microscopes can image chiral molecules bound to surfaces, and a recent breakthrough made at iNANO paves the way for a more efficient synthesis of homo-chiral organic structures on surfaces.

By Trolle Linderoth and Sigrid Weigelt

The chemical and biological properties of molecules depend not only on their constituent atoms, but also on how these atoms are positioned in space. Certain molecules exist as two mirror-image forms like the right and left hands; they are chiral. Nature itself is homo-chiral in the sense that only left-handed forms are involved in life processes. Therefore, chirality plays a critical role in biochemistry, and pharmaceuticals are thus often required to be synthesized only in one chiral form that exercises the therapeutic effect, while molecules with the opposite handedness may lead to adverse side effects.

It is a formidable task to produce homo-chiral compounds, but a breakthrough made at iNANO may pave the way. In 2006 iNANO scientists described a novel chiral switching process for organic molecules adsorbed on surfaces by combining organic synthesis, theoretical modelling and the ability to follow the motion of individual molecules using high-resolution, time-resolved Scanning Tunneling Microscopy. This mechanism may enable a more efficient path to the formation of homo-chiral surface structures of relevance to medicine, catalysis, and chirally specific bio-sensors.

A direct view of bottom-up self-assembly

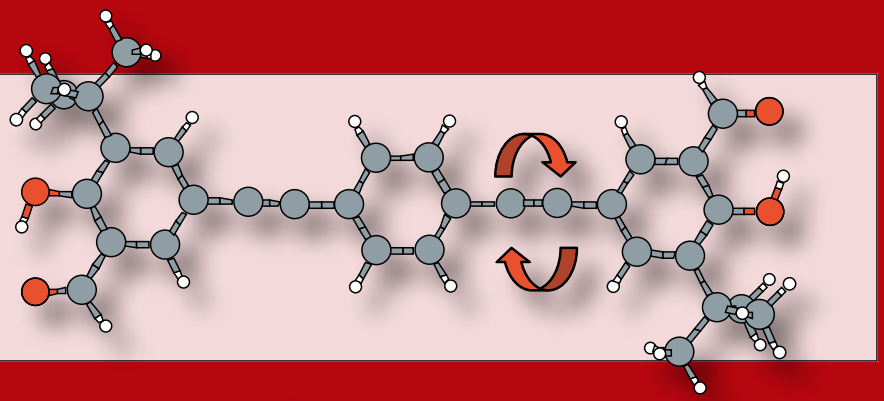
An essential paradigm within nanoscience is the bottom-up self-assembly of functional nano-architectures utilizing autonomous organization of molecular or atomic building blocks. By confining the building blocks in two dimensions on a surface, the process of self-assembly can be investigated by Scanning Tunneling Microscopy (STM), which allows the structure of conducting substrates to be imaged at resolutions down to the atomic level by raster-scanning with a sharp tip.

Organic molecules adsorbed on solid surfaces can be imaged by STM with sub-molecular resolution, and the fundamental mechanisms behind atomic and molecular self-organization on surfaces can be addressed. The kinetics of thermally activated dynamic processes on surfaces can furthermore be studied in detail with sequences of successive STM images.

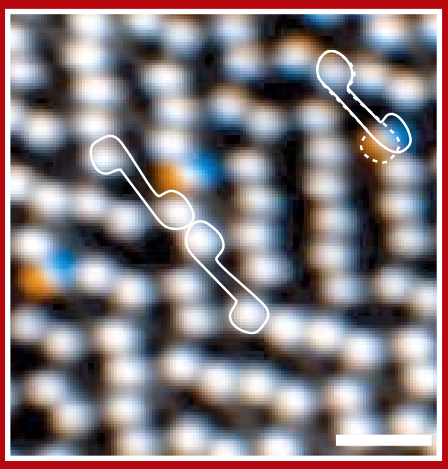
Switching without removal

The molecular model system used in the recent iNANO investigation involves a compound with a backbone formed from three connected benzene rings substituted at the ends with bulky tert-butyl groups. In the gas phase, the end groups can rotate freely around the molecular spoke, but when the molecule binds to a surface, the benzene rings are fixed with the bulky tert-butyl groups positioned off-axis compared to the backbone.

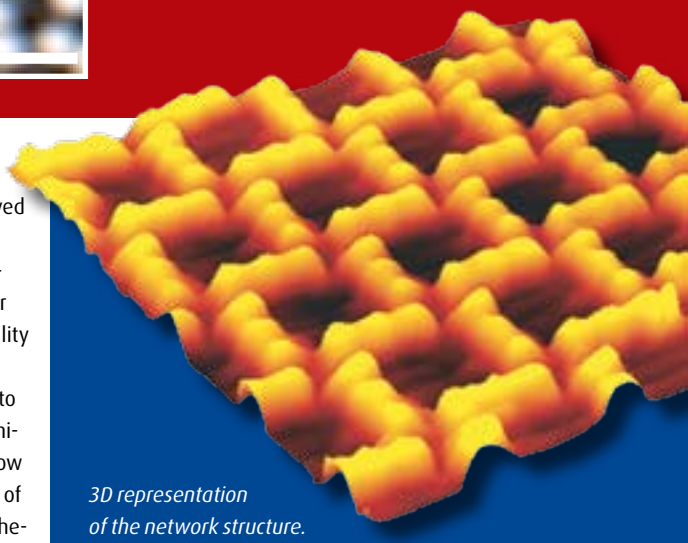
Trolle Linderoth and Sigrid Weigelt



Chemical structure of the investigated molecules. The arrows show where the switching between left-handed and right-handed forms takes place. The molecular chirality is defined by the relative positions of the bulky tert-butyl groups positioned to the sides of the outermost benzene rings.

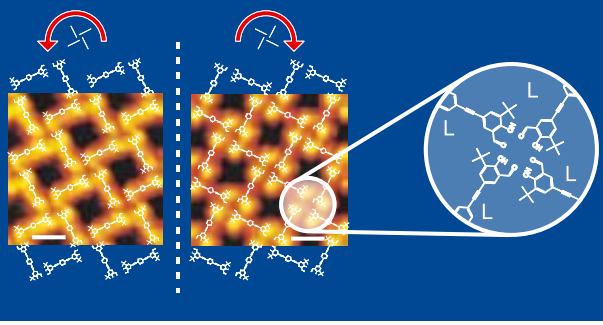


Overlay of two STM images with a time separation of 168 seconds, colour coded to show changes occurring between the images. Blue indicates the initial positions of the chemical groups that change position, while orange shows the final position after the chiral conversion. The contour of three molecules is outlined. The tert-butyl groups show up as bright protrusions.



3D representation of the network structure.

STM images and schematic models of the chiral network structure.



Two of these conformations are opposite chiral forms, and when Ph.D. student Sigrid Weigelt acquired STM movies of the resulting surface structures, a surprising discovery was made; these compounds can switch between the different chiral surface forms even after adsorption on the surface. The result was highly unanticipated because the chiral forms had hitherto been assumed to be irreversibly fixed upon adsorption due to the strength of the molecule-substrate interaction. The ability to switch from one chiral form to another has now been shown to be general to an entire class of organic compounds, all synthesized in the group of Kurt Gothelf, and the mechanism behind the rotation has been modelled theoretically by the group of Bjørk Hammer.

Homo-chiral structures

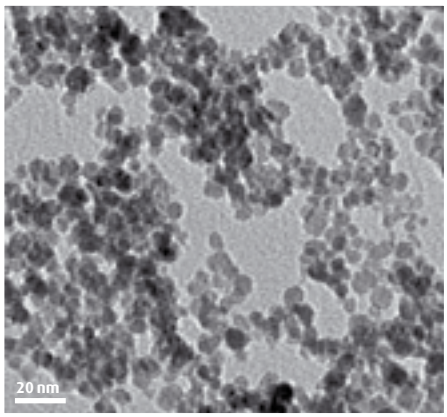
The chiral switching mechanism enables a novel pathway towards the formation of homo-chiral surface assemblies. When chirality emerges on surfaces, it always leads to equal quantities of left- and right-handed species. Typically, these have been observed to separate into homo-chiral regions through a process of lateral motion.

The chiral switching process now observed enables a more efficient separation mechanism, termed chiral accommodation, in which the molecules switch their chiral form to accommodate to the chirality of the surrounding molecular structure.

In an effort to utilize this mechanism to form surface assemblies in which one chiral form covers the entire surface, it is now being explored if truly chiral derivatives of the investigated compound can be synthesized and used to seed the surface in order to force all the switching molecules into the same chiral form.

The described results were published in Nature Materials in 2006: S. Weigelt, C. Busse, L. Peteresen, E. Raul, B. Hammer, K.V. Gothelf, F. Besenbacher and T.R. Linderoth, Chiral switching by spontaneous conformational change in adsorbed organic molecules, Nature Materials (2006) vol 5, pp 112-117 and commented upon in News & Views of the same issue, pp 91-92

Leif Østergaard, Peter Vestergaard-Poulsen and Niels Chr. Nielsen



Nanoparticles used for bioimaging with MRI.

Nanoparticles detectable by non-invasive MRI scans may be the tools of the future to diagnose and heal deadly diseases such as cancer, dementia, heart attacks, and strokes. The strategy combines imaging and drug delivery, and the methods are being developed in a new iNANO research consortium.

By Leif Østergaard, Peter Vestergaard-Poulsen and Niels Chr. Nielsen

Over the past decades biological imaging techniques such as positron-emission-tomography (PET) and magnetic resonance imaging (MRI), have found widespread applications in medical research and in hospitals. Bioimaging has revolutionized our ability to investigate disease processes in non-invasive ways and to provide early diagnoses. Recently, bioimaging has also been used to verify that drugs are delivered to the right tissues and to plan individual pharmaceutical treatment of patients.

In the future bioimaging may benefit vastly from nanotechnology. It is possible to design nanoparticles that enable imaging of specific cells and tissues which are subject to drug treatment or gene therapy. The vision is to use the same particles for diagnosis and treatment. For medical therapy the nanoparticles will be loaded with drugs and targeted for delivery to the right spot. This kind of therapy may enable administration of much lower doses than today, reducing the risk of adverse side effects. However, when designing nanoparticles for application in humans, safety is crucial, and years of testing will lay ahead before the particles can be used in patients.

Targeted nanoparticles

To make the vision come true, we have designed MRI-visible nanoparticles with specialized surface properties in order to target cells specific to certain diseases. An example is vulnerable atherosclerotic plaques in patients suffering from vascular disease. These plaques may rupture at any time, causing myocardial infarction or a cerebral stroke. By detecting vulnerable plaques in time, we may save patients from severe disease or even death. The spread of cancer, e.g. by metastases, is diffi-

An interdisciplinary alliance

In an interdisciplinary effort researchers from the Danish Research Foundation Center for Functional Integrative Neuroscience (CFIN), Danish Research Foundation Center for Insoluble Structures (inSPIN), Lundbeck A/S, the Department of Experimental Oncology and the Department of Cardiology at Århus University Hospital, and iNANO investigate the potential of bioimaging and nanoscience for exploring diseases such as arteriosclerosis, cancer, and neurological diseases. The consortium combines expertise in chemistry, molecular biology, medicine, and ultra-high-field MRI.

Imaging of nanoparticles for diagnosis and targeted drug delivery

A mouse fixed in a MR probe (right) to be inserted into the new 16.4 Tesla microimaging instrument.

cult to detect by current imaging techniques, and hence we aim to develop precise methods for imaging tumours. By designing nanoparticles that bind to areas where the tumours spread, we hope to promote early diagnosis, and also to enable killing of all cancer cells by targeted radiation therapy.

Ironically, the human immune system has proven a powerful ally in the development of nanoparticles for drug delivery and disease targeting; it may ferry nanoparticles to areas of disease, helping to locate them. To facilitate the design of nanoparticles that will be tolerated by the body, we have developed assays to study the interaction of nanoparticles and the immune system.

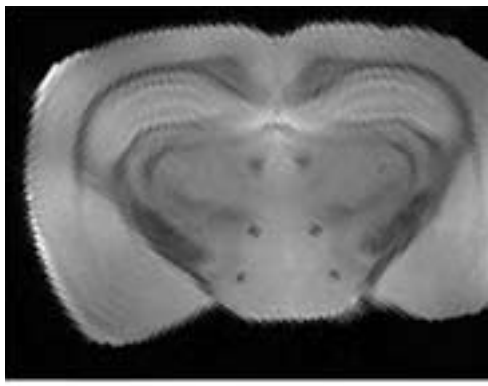
In a more subtle approach deficient cells in, e.g. neurological diseases, may be repaired by gene therapy. Successful gene delivery is monitored by forcing the target cells to produce their own nanoparticles, ferritin, which shines up clearly in MR images.

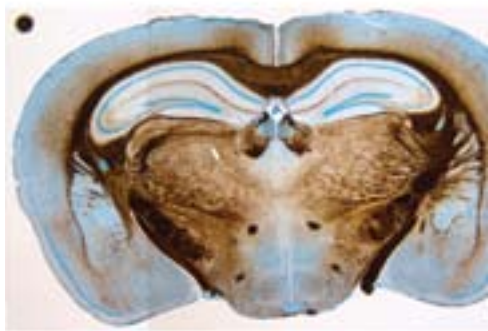
MRI with ultra-high magnetic fields

For magnetic resonance imaging the object – a human, an animal, an organ or a tissue sample – is placed in a strong magnetic field. Using strong field gradients and radiofrequency pulses, it is possible to obtain an image of the object with contrasts depending on local environments of the nuclei observed.

MRI is typically accomplished using magnetic fields of 1–3 Tesla in hospital whole-body scanners. Such equipment is an obvious area of application for functionalized nanoparticles, but the project will also take advantage of unparalleled new possibilities offered by ultra-high-field MRI instrumentation.

In a joint effort inSPIN and CFIN have recently established the first ultra-high-field MRI scanner in Denmark working at 16.4 Tesla. The resulting boost in sensitivity and resolution is enormous, and this renders it possible to study small nanoparticles in low concentrations with a resolution down to 25 microns, approaching cellular resolution.



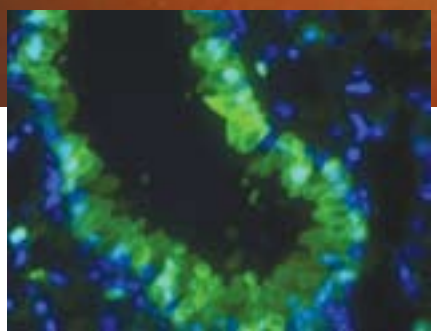


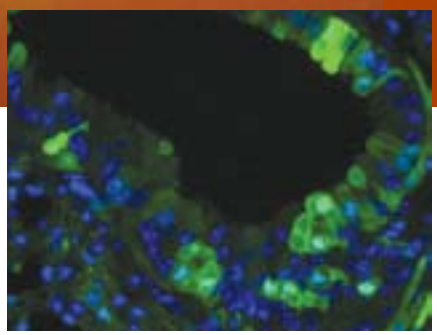
High-field imaging of a mouse brain from studies of plasticity and structural changes in brain cells in relation to prolonged states of mental stress. A MR image is shown at the top, and a corresponding histological section at the bottom. The MR images provide detailed information about the state of the brain cells.

Sugar bullets:

a bitter pill for disease

Jørgen Kjems and Kenneth Howard





The delivery potential of the nanocarriers is initially tested in "green mice" that are transgenic for the Enhanced Green Fluorescence Protein. A picture taken with a fluorescent microscope of the lung reveals that the nasally administered chitosan/siRNA nanoparticles are capable of down-regulating the EGFP gene in bronchiole cells (reduced green colour in right picture compared to untreated in left picture). The blue colour is the stain for the cell nucleus.

Small interfering RNA is a powerful tool to silence disease genes and may lead to highly efficient therapies for serious diseases. The key to successful clinical application of siRNA drugs is targeted delivery to the affected tissues; sugar-based nanocarriers may provide the solution.

By Kenneth Howard and Jørgen Kjems

Certain genes produce proteins implicated in disease. These genes can be silenced, and the production of their proteins can be interrupted by the natural process of RNA interference (RNAi) mediated by small interfering RNA (siRNA). The significance of siRNA in the fields of functional genomics and therapeutics was recognised recently with the award of the 2006 Medicine and Physiology Nobel Prize to Fire and Mello for their research on RNAi. The possibility to silence genes associated with disease by siRNA has led to a rapidly evolving area in drug development. However, the effectiveness of any drug is determined by the ability to migrate through the body and reach diseased tissue in therapeutically relevant doses. Scientists within the iNANO drug delivery initiative are working on the design and development of novel sugar-based nanocarrier systems to increase the delivery and clinical potential of siRNA.

These "sugar bullets" are conceptually simple self-assembling nanoparticles composed of the polysaccharide chitosan and siRNA. In contrast to sugar cubes the nanocarriers are spherical in appearance, ranging in size from 50-300 nanometres. iNANO scientists have previously shown that these systems are able to ferry and release siRNA inside cancer cells, and we are now turning our attention to delivery in diseased animals.

Lung diseases

The chitosan shell protects the siRNA core and facilitates interaction with biological surfaces; especially the sticky layer that lines the respiratory, gastrointestinal and urinary tracts acting as glue. Nasal and oral administration of the adhesive nanocarriers allows siRNA to reach these tracts commonly invaded by pathogens.
The team works on respiratory siRNA delivery as a strategy to treat lung diseases such as influenza. Gene silencing in respiratory tissue after intranasal administration of nanocarriers has been demonstrated in "green mice" expressing the Enhanced Green Fluorescence Protein (EGFP). Nanoparticle deposition in the lung and effective downregulation of EGFP has been achieved in bronchiole cells using the chitosan siRNA nanocarriers.

Aerosol sprays of the nanocarriers are being developed to further improve lung deposition. An air driven nebuliser system has been used to form aerosol droplets containing nanocarriers in the 5-20 um size range. Using this device, fluorescent labelled siRNA delivered within an aerosolised mist show widespread distribution throughout the lung.

In collaboration with the Max Planck Institute Berlin, iNANO scientists have shown inhibition of influenza infectivity in mouse cells using nanocar-

riers containing siRNA targeted to essential influenza structural proteins. Studies at present are evaluating the potential of aerosolised systems to inhibit flu in an influenza mouse model.

Rheumatoid arthritis

Another key area is new treatments of inflammatory disorders such as rheumatoid arthritis and Crohn's disease, and in this context our target is the gene coding for the TNF-α protein. The iNANO team has recently shown reduced swelling and inflammation in the joints of arthritic mice treated with nanocarriers delivering TNF-α siRNA compared to non-treated controls. The potential implication of this approach is a safer alternative to present anti-inflammatory drug treatments.

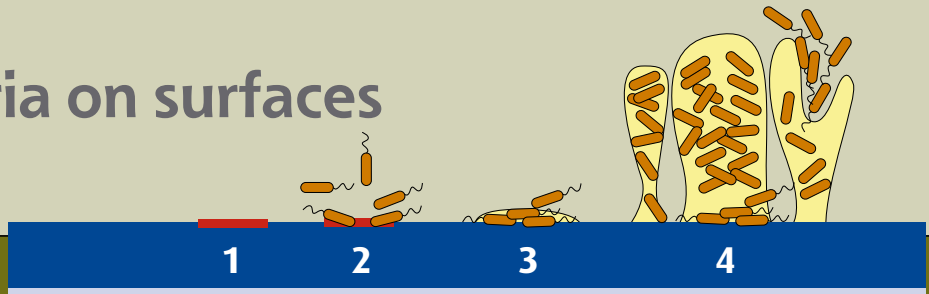
Promising results in diseased animals underscore the important role of targeted drug delivery in order to maximise the therapeutic potential of siRNA pharmaceuticals. Further development of drug delivery systems using sugar bullets requires an interdisciplinary research initiative ranging from basic and applied nanoscience to clinical evaluation. This unique environment is found within the iNANO structure, supported by national and international research collaborations.

To enhance delivery to the lungs, aerosol droplets are produced in a nebuliser system. By labelling the siRNA with fluorescent dyes (orange colour), it is possible to visualize the mist and the deposition in the lungs upon inhalation (right panels).

Intense public and media interest

The iNANO drug delivery work has attracted intense public and media interest with the discovery featured on Danish national television (DR2 "Viden om" and TV2 news), Radio (P1 "Videnskabens Verden") and in several newspapers, in addition to global interest from several prominent organisations such as US National Institutes of Health and the Foresight Nanotech Institute.

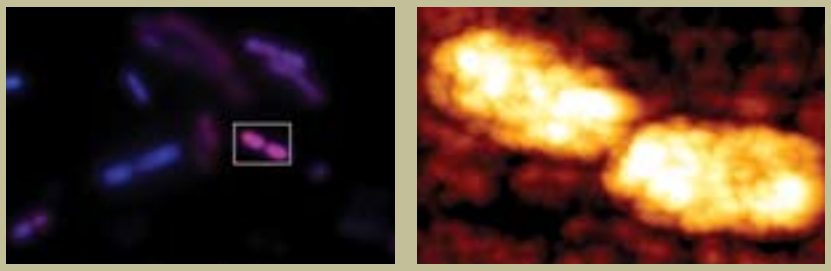
Fighting bacteria on surfaces



A city of microbes: 1) Proteins cover the surface. 2) The first bacteria adhere. 3) The bacteria excrete polysaccharides that form the biofilm matrix. 4) The biofilm grows, protecting the bacteria from biocides.

Biofilm formation is a hygiene problem in the food processing industry and rigid and costly cleaning procedures are required to keep equipment surfaces free of bacteria. At iNANO, we design and test new surface coatings with antibacterial properties based on nanotechnology.

By Rikke L. Meyer



Optical microscopy and AFM of bacterial cells. In the optical image (left), magenta cells are stained with a protein-specific stain, indicating the presence of proteins on the cell surface. Blue cells are other bacteria with less protein. AFM image (right) shows a 2.5x4.5 micrometer topographical image of the cells indicated in the white square. The height scale is 0-200 nm.

Many bacteria adhere to surfaces and form biofilms, composed of a mixed community of microorganisms embedded in a matrix of polysaccharides attached to a solid surface. Biofilms are a hygiene problem in the food industry, and the bacteria are difficult to eliminate because they attach firmly to equipment surfaces and are protected from biocides when growing inside a biofilm. It is therefore important to prevent biofilm formation at the early stage where the first bacteria adhere to a surface.

At iNANO, we collaborate with the Danish Technological Institute (TI) to design and test new surface coatings with antibacterial properties based on nanotechnology. The work is funded by the meat and dairy industry associations, and the aim is to develop surface coatings for stainless steel that can be applied directly to food processing equipment in these sectors.

Sol-gel ceramic coatings

The coatings are produced at TI using sol-gel technology; a method to create ceramic surface coatings from a solution. In solution metal-organic compounds undergo a gelation process and aggregate by polymerisation. Then the liquid part of the solution is evaporated, leaving a ceramic coating with a nanoscale surface topography reflecting the structure of the metal organic aggregates.

The microscale and nanoscale topography can have a dramatic effect on whether a surface attracts water or repels it; an important factor affecting the adhesion of bacteria. In the sol-gel process the surface structure of the coating can be controlled with high accuracy, and we are testing the antibacterial properties of coatings designed with different surface topography and wetting properties. Sol-gel coatings are also suitable for embedding or binding of chemical compounds, and we are exploring several avenues for enhancing the antibacterial properties of the coatings by adding antibacterial biomolecules and nanoparticles to the sol-gel. Of course, appropriate toxicological tests are carried out to ensure the approval of the surfaces for food processing equipment.

Tailored to the relevant bacteria

It appears that if a surface repels one type of bacteria, it will attract another. This is due to the enormous diversity amongst bacteria. The key to success in designing antibacterial surfaces is to know the types of bacteria that come into contact with the surface in the environment where it will be used. To get this information, samples of biofilms from industrial equipment are analysed in the laboratory.

We can then prevent the relevant bacteria from colonising the surface either by controlling the nanoscale structure or chemistry of the surface, or by exposing the bacteria to antibacterial agents that either kill them or prevent them from adhering.

The mechanisms of bacterial adhesion

Biofilm formation begins when proteins from, e.g. milk or meat juice bind to equipment enabling the bacteria to adhere to the surface. It is known that the properties of the bacterial cell surface and substances excreted by the bacteria are involved in the adhesion process. To obtain new insights into the mechanisms, we use a combination of advanced microscopy methods to study the first steps of biofilm formation.

The composition of the extracellular substances secreted by the bacteria can be analysed by staining with fluorescent dyes specific to particular

Rikke L. Meyer

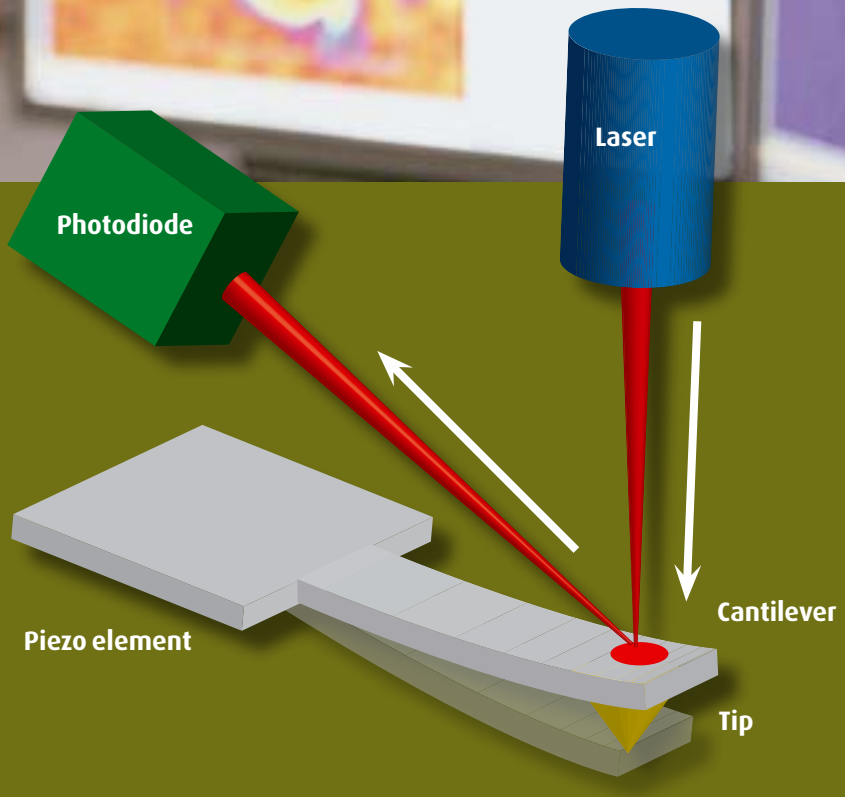
A Steno grant

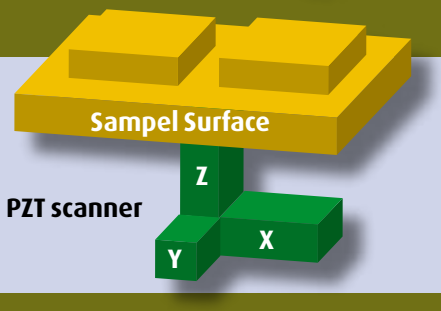
In 2005 Rikke L. Meyer received a Steno grant from the Danish Natural Science Research Council, which pays her salary and part of her research expenses.

proteins, lipids, polysaccharides, or DNA. We use fluorescence microscopy to obtain information on the biomolecules that surround individual bacteria.

However, observing the sub-micrometer structures of molecules present on the cell surface is beyond the limits of the optical microscope. Therefore, we apply atomic force microscopy to visualise these biological structures with molecular resolution. The AFM cantilever tip can scan living cells in liquid environments and show their three-dimensional cell surface topography. The atomic force microscope can also measure softness-hardness of the samples and map attractive and repulsive binding forces of biological specimens.

These properties are valuable for analysing the role of specific cell surface structures in bacterial adhesion. A new instrument installed recently at iNANO allows us to directly link optical microscopy and AFM. We hope this work will lift the veil on some of the secrets behind the success of bacteria colonising surfaces everywhere around us.





AFM – the cantilever tip moves up and down as it records the topography of a surface. These movements are measured by a laser beam that is reflected towards a photodiode.

Size matters:

Catalysis by gold

Gold is the noblest of metals, and common sense dictates that it should be a poor catalyst. However, when cast in nanoparticles, gold becomes a great catalyst. The reasons why are sought at iNANO by means of computer simulations.

The medieval masters who created the magnificent stained glass windows in ancient churches used nanotechnology unknowingly. The red colour was produced by mixing small amounts of gold with glass, and the colouring is due to sphere-shaped gold nanoparticles.

By Bjørk Hammer

A catalyst is a substance that speeds up a chemical reaction without being consumed. Most commodity chemicals are produced in catalytic processes. Likewise, catalysis is exploited for environmental protection, e.g. in car exhaust cleaning. While many platinum-group metals and the noble metals copper and silver have long been recognized as efficient catalysts, it was only recently discovered that gold may act as a catalyst.

Active nanoparticles

The catalytic activity of a metal originates from elementary chemical reactions taking place on its surface. Therefore, the catalytic activity of a metal generally increases with the size of surface area exposed to the chemical reactants. The largest surface area is achieved when the metal is cast as small particles, and hence for most metals the catalytic activity increases as the particles become smaller.

For gold, the situation is radically different because there is no measurable activity of gold particles on the millimetre or micrometer scale. Only when the size of the gold clusters is reduced to a few nanometres, a sudden and high catalytic activity sets in.

Insight gained from simulations

To unravel why gold behaves so differently from other nearby elements in the Periodic Table, we have conducted computer simulations at the nanoscale.

The calculations are performed using quantum mechanics to describe the wave character of the electrons within the gold nanoclusters. From the electron wave functions, the electron density is constructed, which in turn enables the calculation of the energy. With the energy at hand, the most likely geometries of the gold clusters can be determined, and the rate of the chemical reactions on the clusters can be discussed.

The simulations show that while metals in general are capable of reacting with most chemical elements, gold only achieves appreciable interaction strength with a few molecules such as car-bon monoxide, as more and more of the gold atoms find non-crystalline positions in the nanoclusters.

The gold, however, resists reaction with other chemicals such as oxygen, independently of the cluster size. The reason for this peculiar behaviour may be the electron affinity of gold. Whilst the CO molecules do not compete with the gold atoms to attract electrons, this is the case for, e.g. oxygen that also has a high electron affinity.

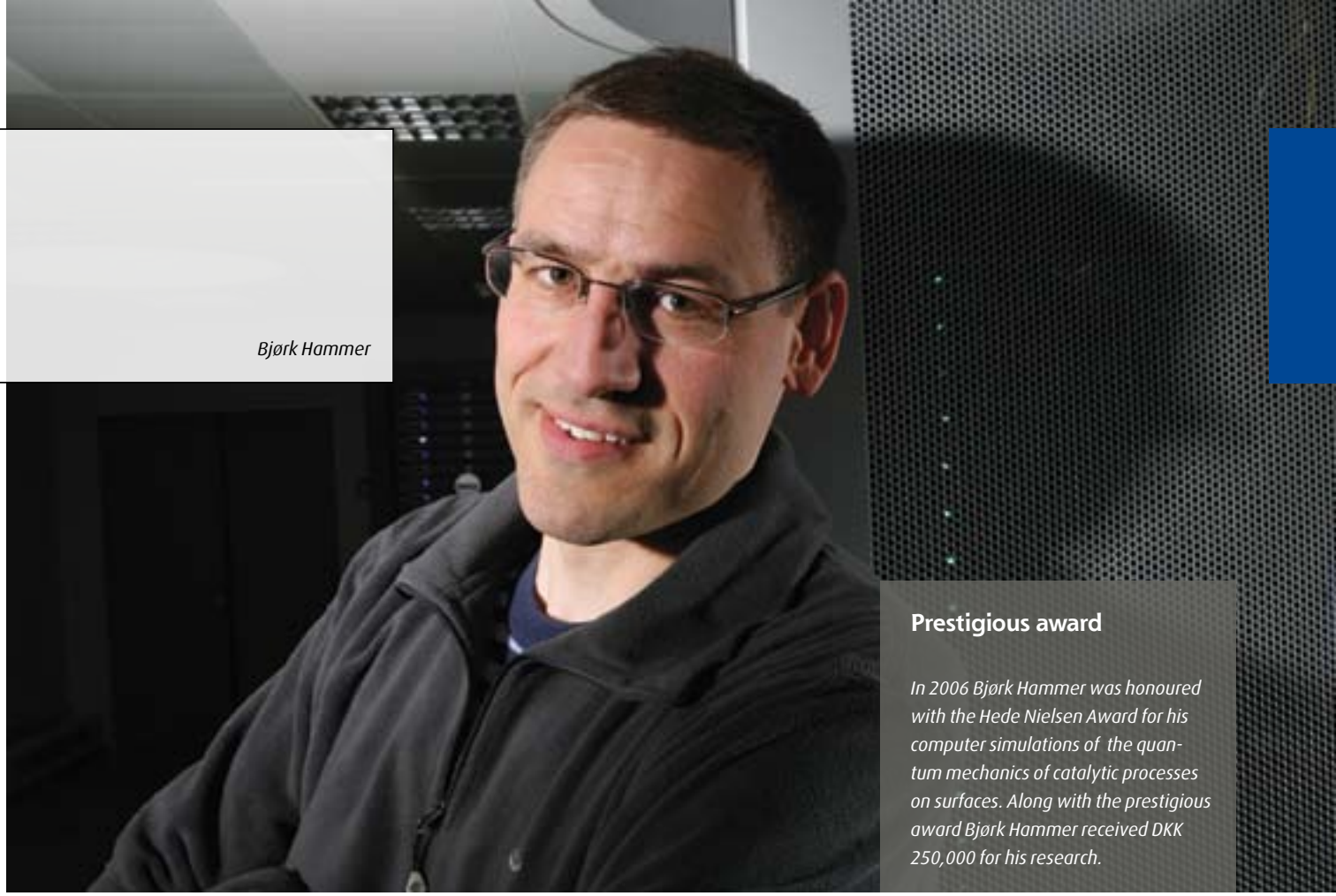
The contact area

As gold only reacts with a few chemicals, its properties as catalyst may seem limited. However, the simulations show a new effect for the smallest nanoclusters: The chemicals that cannot react with the gold atoms become trapped by the material that supports the gold clusters. Thus, precisely where the gold clusters touch their supporting material, catalytic activity may evolve.

In this situation the surface area of the gold is not the critical parameter; instead the perimeter of the contact area between a gold cluster and its supporting material is decisive. This new mechanism explains the odd behaviour of gold in catalysis, and also why very small gold nanoclusters are such impressive catalysts. In ongoing experiments using STM microscopy we are now seeking to validate the predictions of our computer simulations.

Room temperature catalysts

Catalysis by gold nanoparticles has appealing properties. High temperatures and pressures are not needed, and because gold does not react with neither oxygen nor nitrogen from



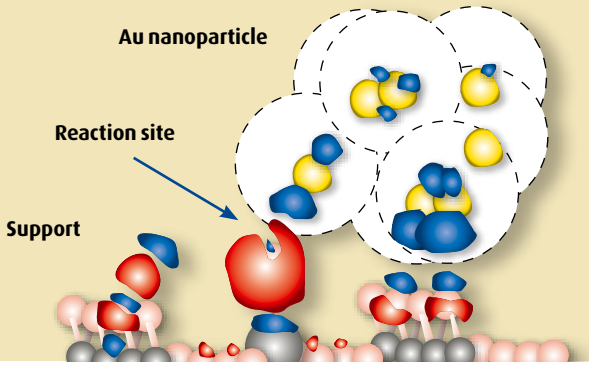
Bjørk Hammer

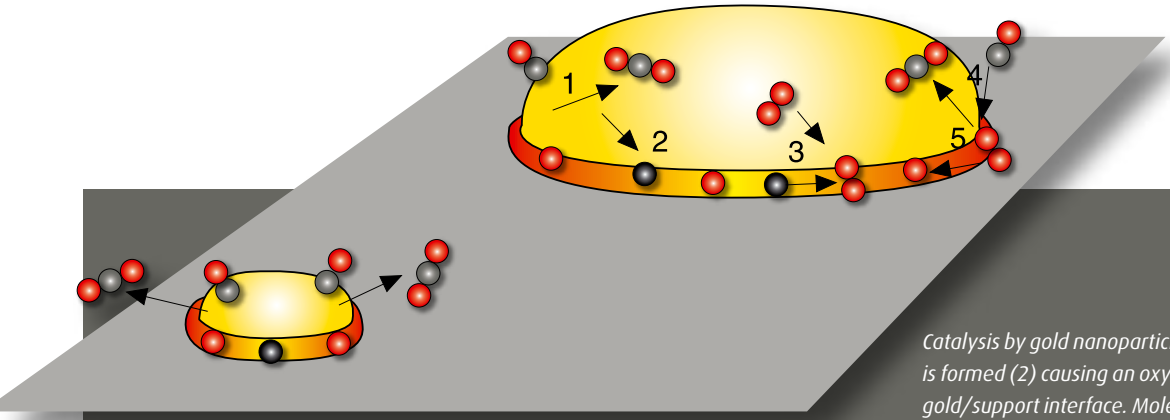
Prestigious award

In 2006 Bjørk Hammer was honoured with the Hede Nielsen Award for his computer simulations of the quantum mechanics of catalytic processes on surfaces. Along with the prestigious award Bjørk Hammer received DKK 250,000 for his research.

the air, the catalyst is not polluted easily, and no oxides form on the gold surface. A Japanese company has already exploited the unique qualities of gold nanoparticles in catalytic odour cleaners working at room temperature, and many other applications can be envisaged.

A gold nanoparticle on an oxide support. The gold-support interaction causes electrons to flow from the blue regions on the gold atoms to the red regions on the support anions. The catalytically active site is electron rich and hence favours binding of molecular oxygen, which otherwise does not bind near gold.





Catalysis by gold nanoparticles: CO binds (1) to gold and CO_2 is formed (2) causing an oxygen vacancy (3) to appear at the gold/support interface. Molecular oxygen binds (3) to the vacancy and interacts with CO (4) to form CO_2 (5) closing the catalytic cycle. Because the reactive zone is the perimeter of the gold/support interface, the activity per gold atom increases as the particles become smaller.

Turning waste into oil

Jacob Becker and Bo Brummerstedt

One of the great challenges of this century is to provide environmentally and economically sustainable alternatives to fossil fuels. The application of nanocatalysis to biomass waste holds promise of becoming a future source of biodiesel and other fuels.

By Bo Brummerstedt Iversen and Jacob Becker

Recently, a novel catalytic process which converts wet biomasses such as sewage sludge, corn silage and meat waste into useful fuels, including bio-oil, hydrogen, methane and methanol, has been developed by the Danish company SCF Technologies. Environmentally this new invention leads to a two-fold advantage; waste is turned into "green" fuels, and the need for disposal is reduced.

Sewage sludge is a good example because it is difficult to dispose of safely by the present methods, which are also very energy consuming. Through the Catliq-process, this particular problem is avoided, making the process potentially much cheaper than conventional techniques even when the income from fuel products is excluded.

Catalytic chemistry

The biomass is dissolved in water, and treatment takes place at elevated temperatures and pressures. In many ways the process resembles the subterranean transformation of biologic material into fossil fuels, only in this case the conversion is complete within a matter of minutes instead of millions of years. This tremendous acceleration is achievable because the Catliq-process is a catalytic process.

Two different inorganic catalysts are used; a solid-state catalyst and a catalyst that is dissolved in water. These catalysts are necessary to decompose the various polymeric substances in biomasses into their basic units and subsequently re-polymerize them into oil.

A range of fuels

Bio-oil is formed under moderate process conditions, and the oil is readily distillable into diesel. Ongoing experiments will elucidate how well such biodiesel performs in diesel motors compared to conventional fuel. Apart from this, the biodiesel will be miscible with ordinary diesel, and hence the Catliq technology may deliver the diesel counterpart to bioethanol enriched gasoline.

At higher temperatures and pressures biomass degradation leads to simpler products such as

Bio-oil from waste such as sewage sludge.
(Photo: SCF Technologies)

hydrogen or methane. Hydrogen may be recovered for use in fuel cells, and the methane may serve as fuel gas to maintain high temperatures.

Improving catalysts

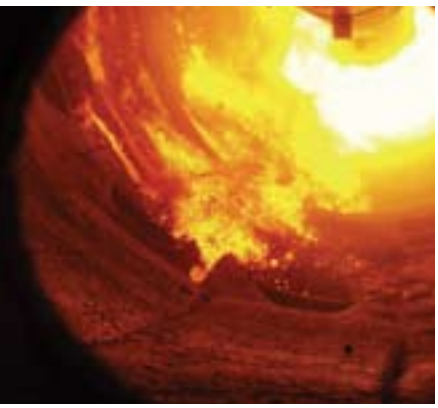
At iNANO we in particular optimize the solid-state catalyst, which consists of closely compacted nanocrystals. The performance can potentially be enhanced by reducing the size of the nanocrystals, by improved compacting or chemical manipulation. The impacts of all these possibilities will be investigated at a new process facility at iNANO, and subsequently experiments will be initiated at SCF Technologies to investigate the performance of promising new catalysts on a larger scale in a pilot-plant facility. The third partner of the project, the Institute of Energy Technology at Aalborg University uses advanced computer simulations to model the Catliq-process in order to further optimize the bio-oil production. The concerted effort is supported by the Danish National Advanced Technology Foundation with DKK 10,600,000 over three years.

The pilot plant facility at SCF Technologies.
(Photo: SCF Technologies)

Sustainable cement-based construction materials made by use of nanotechnology

The growing global consumption of cement in the construction industry along with society's increasing demand for a significant reduction in the CO_2 emission represents a major challenge for the cement industry. The vision of FUTURECEM is to use nanotechnology to develop "the sustainable cement of the future".

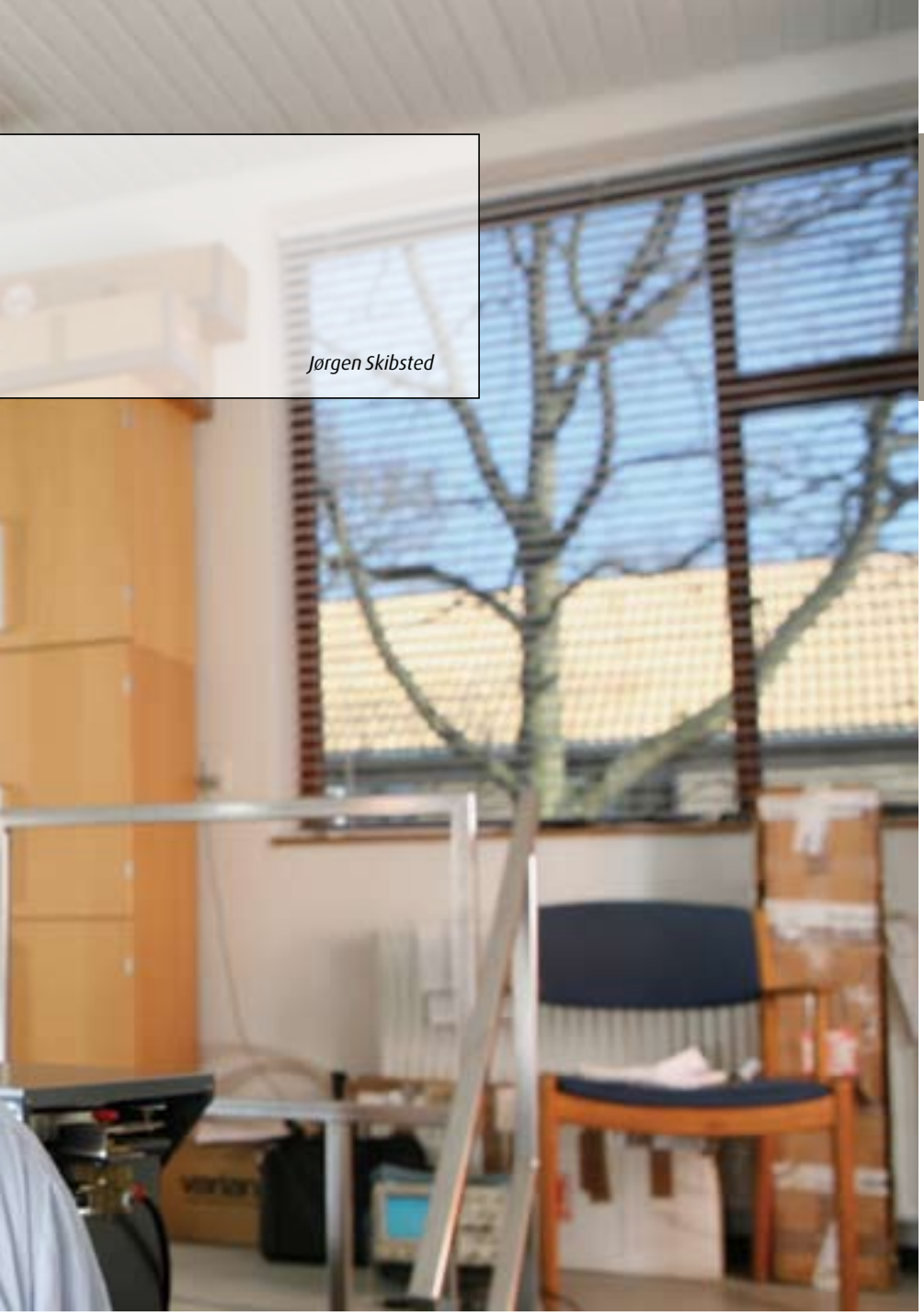
By Jørgen Skibsted



View into the hot end of a rotary cement kiln during production. Raw materials are heated to 1400-1500°C.

The global cement production exceeded two billion tons in 2006, and the demand continues to increase as a consequence of the need for infrastructure, industry and housing in high growth economies such as China and India. Thus, a two-fold increase in the global cement consumption is predicted for 2020 and a three-fold increase for 2050. With present day technology the expected growth will burden the global climate considerably. Today, the production of one ton of cement leads to the emission of 0.8 ton of CO_2, and cement production is responsible for 5 per cent of the global CO_2 emission from human activities.

The FUTURECEM project focuses on the application of nanoscience in the development of new functionalised nanoparticles based on readily available Danish raw materials of low cost, such as clay minerals, that can be used in cement-based materials. The nanoparticles will be combined with



Jørgen Skibsted

Application of nanoparticles in modified cement may lead to new building materials with low embodied energy consumption and CO_2 emission. At iNANO solid-state NMR spectroscopy is used as one of the tools to study the interactions between such nanoparticles and cement minerals.

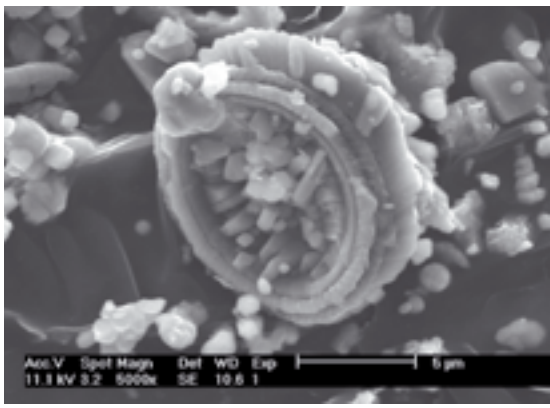
The FUTURECEM collaboration

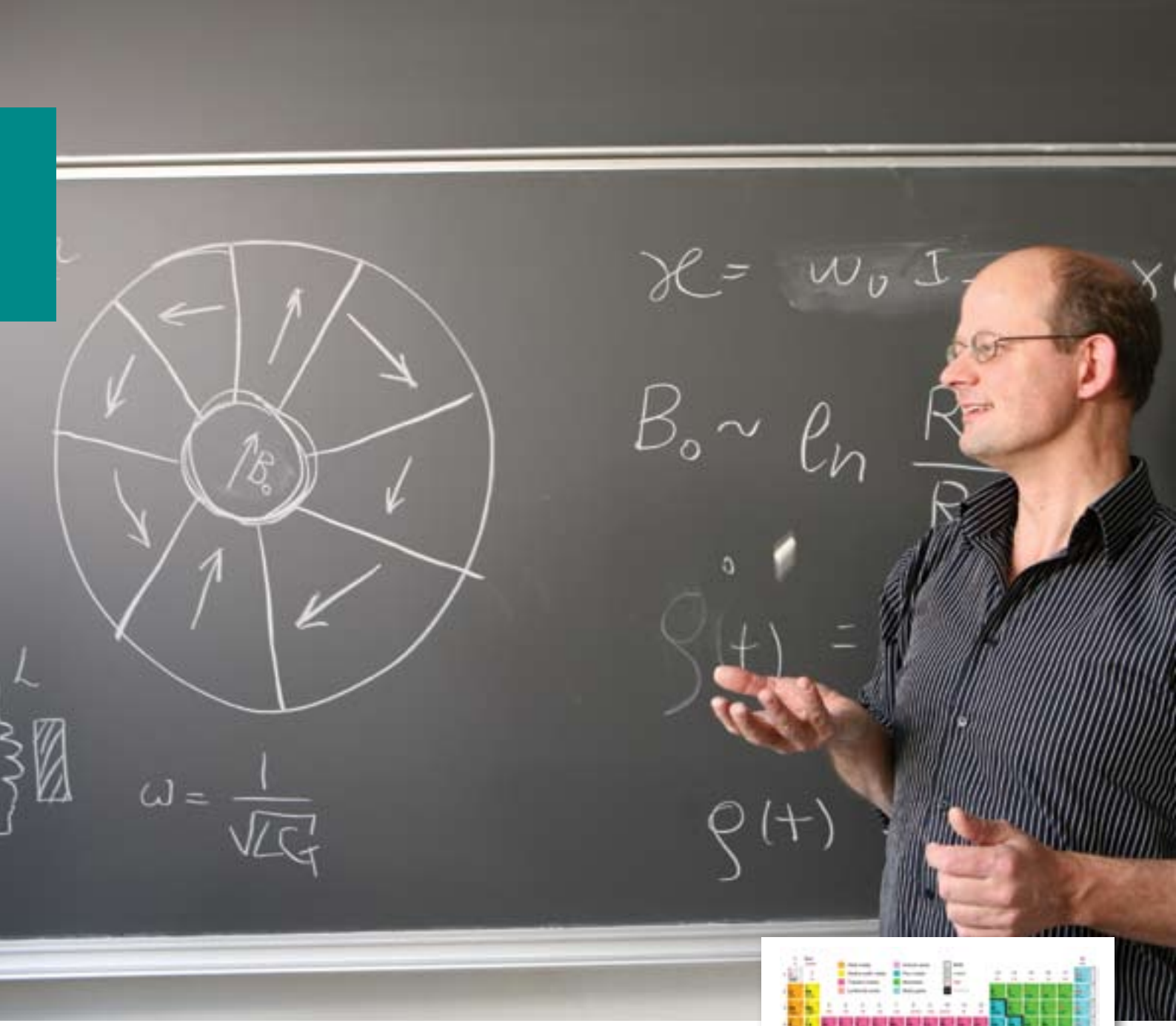
FUTURECEM is a joint collaboration between Aalborg Portland A/S, the only cement producer in Denmark, iNANO at the University of Aarhus and Aalborg University, and the Geological Survey of Denmark and Greenland (GEUS). The goal is to develop sustainable cement by application of nanoparticles. In 2006 the Danish National Advanced Technology Foundation donated DKK 10 million in support of the three-year project, and the partners contributed with DKK 10 million.

modified Portland cement that is chemically optimised towards high reactivity and compatibility with specific nano-sized additives. The goal is to develop new building materials with low embodied energy consumption and CO_2 emission, a reduced raw material consumption as well as good workability, high strength and durability. The target is to reduce the CO_2 emission by 30 per cent for cement-based materials.

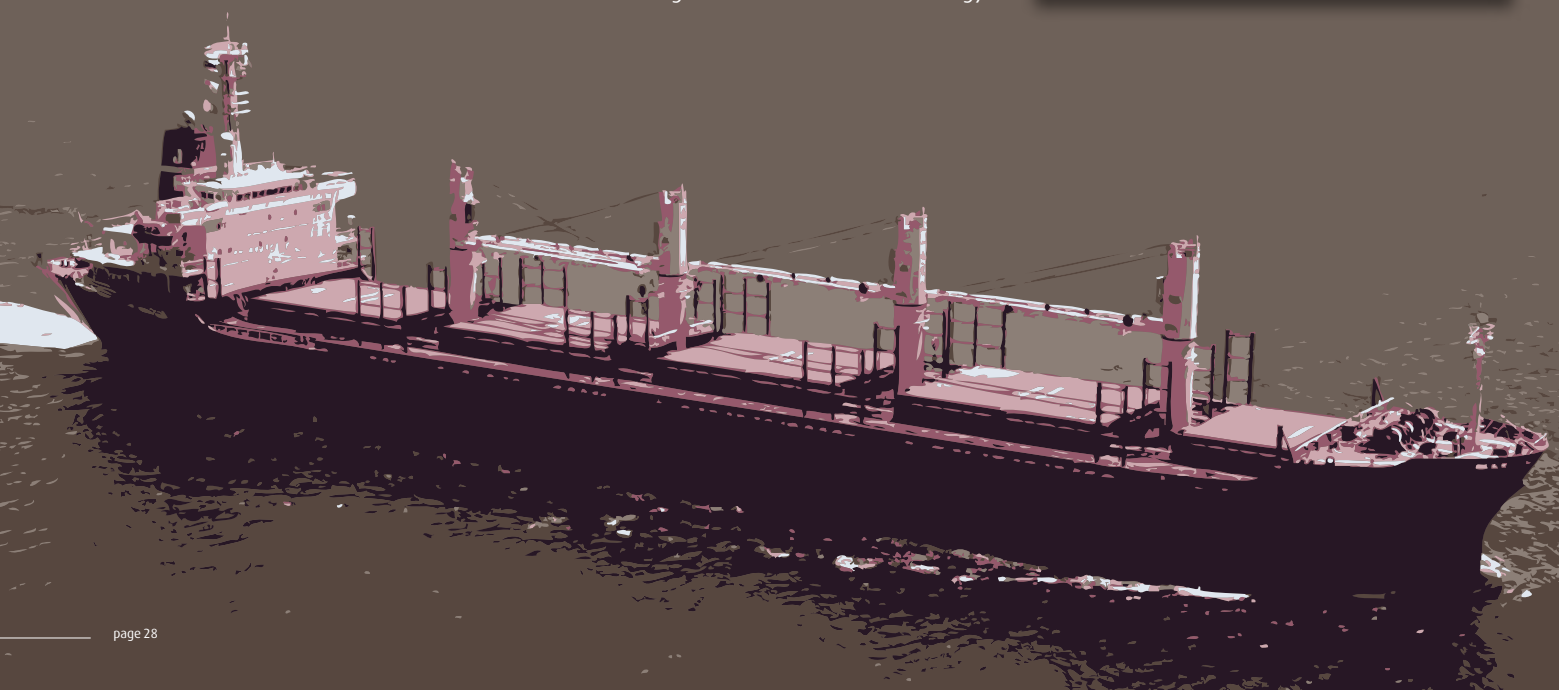
A breakthrough in the application of nanoscience in the cement industry may form the basis for an increased cement production whilst optimising the environmental performance of cement. If successful, the project is expected to have a significant commercial potential in the global cement industry. Furthermore, it will enable Aalborg Portland to introduce nanoparticles to the market as a new commercial product for the construction industry.

Chalk is a natural raw material abundant in Denmark that accounts for the main fraction of raw materials used in the manufacturing of cement.





Lab-on-a-ship equipment with integration of OnBoardNMR technology



Niels Chr. Nielsen

Real-time analysis of oil for the shipping industry

Low-quality bunker oil as fuel for ships is a big problem from a commercial and environmental point of view. The nanotech company NanoNord and iNANO set new standards for online oil quality control in the shipping business.

By Carsten Tilm, Ole Jensen, and Niels Chr. Nielsen

Improved refinery technology and increasing oil prices motivate oil companies to extract all higher grade oils such as petrol from crude oil. This causes severe problems for the shipping industry because the efficient extraction may result in low-quality bunker oil. Bunker oil is now the largest operating cost of ocean-going vessels, and degrading quality increases these expenses, the number of engine breakdowns, and the environmental pollution.

To enable measurements of oil quality during bunkering and thereby avoid the poorest oil coming onboard, NanoNord and iNANO join efforts in a high-technology project with the central theme: Real-time analysis of oil using mobile nuclear magnetic resonance (NMR) spectroscopy. The project is supported by a grant from the Danish National Advanced Technology Foundation.

The aim is to construct a portable NMR equipment – OnBoardNMR - that will be installed in NanoNord's oil analysis system, Lab-on-a-ship, also performing other physical measurements. The vision is to extend existing lab-based methods of oil analysis to on-board measurements.

OnBoardNMR

Existing on-site methods provide limited information on the chemical make-up of the oil, as the sensors focus on element analysis of particles, e.g. the contents of sulphur and vanadium. The goal of OnBoardNMR is to obtain knowledge about the chemical bindings of selected components in bunker oil in order to determine the combustion value of the oil as well as the content of, e.g., asphaltenes and aromatics.

The ratio of asphaltenes to aromatics provides important information on the stability of the oil. Bunker oil contains large densities of high molecular weight asphaltene molecules, which are insoluble in aliphatic oils and therefore prone to agglomeration and sediment formation. This may lead to blockage of tanks, pipes, filters, and centrifuge bowls, and in worst case fatal system breakdowns.

Similarly, the presence of zeolites from the catalytic oil cracking, acids from added vegetable oils, and heavy metal pollutants from lubricant oil waste dumped in the bunker oil are known to have detrimental effects on the engine system, which is why the ability to detect these elements is highly desirable.

Nanofood – more than tiny lunchboxes!

The term 'Nanofood' covers the area of food production using nanotechnology. Virtually every step from agricultural food cultivation, production, processing, packaging to enhancement is a potential application area for nanotechnology. The potential is thus enormous; for producers, retailers and consumers.

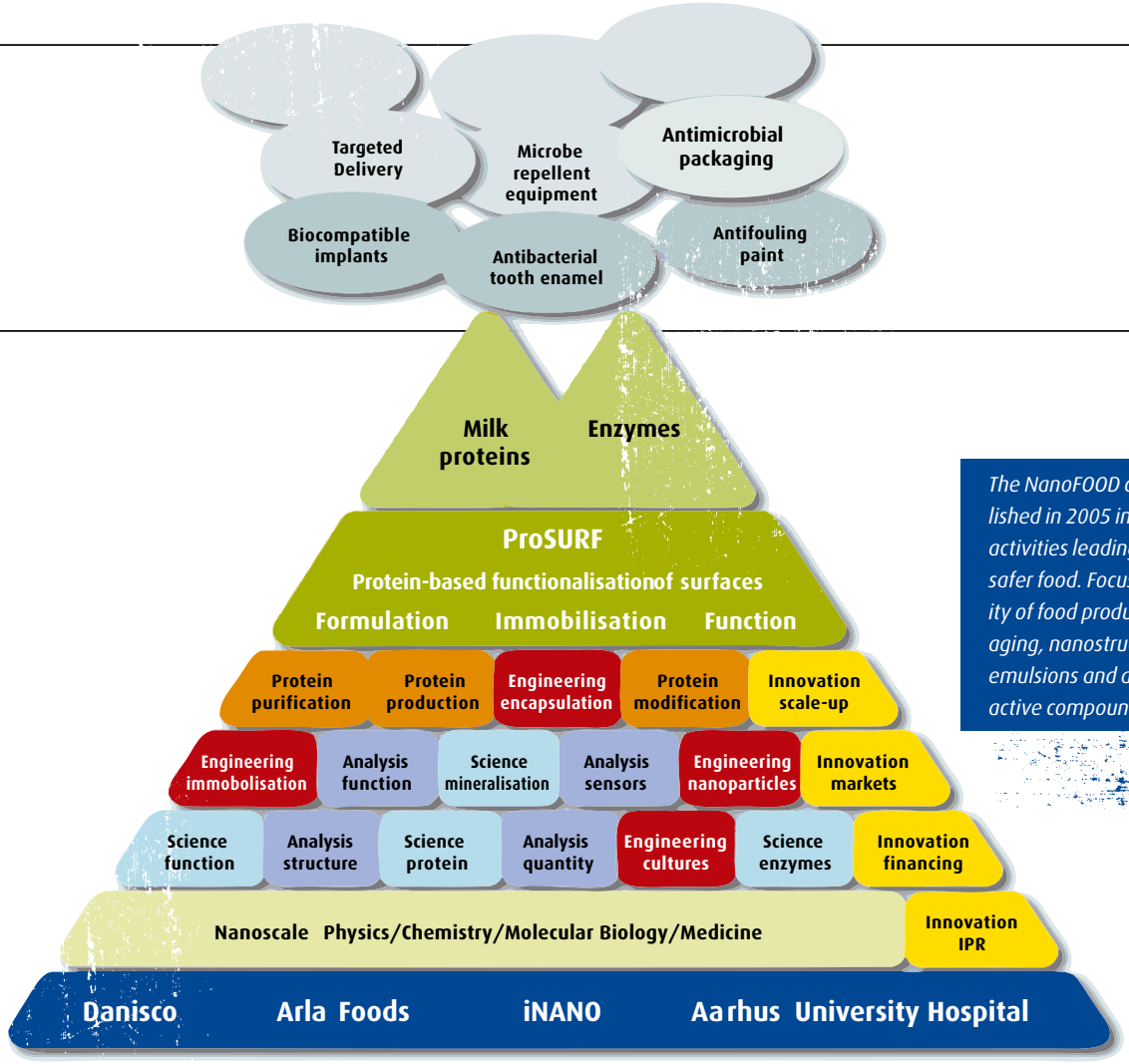
By Leif Schauser

Nanotechnology may have a tremendous impact on foods. Some applications are improved processing and packaging, enhanced flavour and nutrition, tracking of products and ingredients from farm to shelf, and monitoring of taste, ripening, and microbiological contamination. These areas are of major public and industrial interest and technical solutions require that profound insights from materials science are combined with a thorough understanding of chemical, molecular, and physical composition of foods and their nutritional effects. Hopes are high that nanotechnology can provide solutions to many of these diverse challenges.

The mission of the NanoFOOD Consortium is to apply nanotechnology to enable safe and healthy food products in the future. The first two major projects have recently been funded.

Fatty acids and health

A project called "Fatty acids in Foods: A nutrinomics approach" received three years of funding from the Directorate for Food, Fisheries and Agri Business. In total DKK 3 million was granted to interdisciplinary research involving iNANO, Aarhus University Hospital, Danisco A/S and Arla Foods. A plethora of dietary fatty acids are known to be major risk modulators of cardiovascular dis-



The NanoFOOD consortium was established in 2005 in order to strengthen activities leading to healthier and safer food. Focus areas are traceability of food products, biosensors, packaging, nanostructured surfaces, nanoemulsions and designed release of active compounds.

eases, diabetes and obesity, and the project aims to investigate how a broad range of these fatty acids affect the human proteome of selected cell lines. The first goal is to identify specific biomarkers for fatty acid response. The relevance of these biomarkers will then be demonstrated through intervention studies of fatty acids in humans.

Surfaces with enzymatic activity

In 2006 the ProSURF project, running from 2007 to 2011, received DKK 15 million from the Danish National Advanced Technology Foundation. The project involves two industrial partners, Arla Foods and Danisco A/S, and the iNANO Center at the University of Aarhus. ProSURF focuses on the characterization and exploitation of proteins immobilised on surfaces.

Immobilization strategies need to be developed to ensure the surface attachment of functional proteins in order to modify surface properties to include enzymatic activity. Such enzymatic surfaces have huge potential in many applications including food production, health care and environmental control.

Non-toxic antifouling

An example of the latter is the development of substitutes for the ecotoxic tributyltin antifouling paint used on ships. This paint must be phased out by 2008, and the race is on to find effective and environmentally friendly alternatives.
As part of the ProSURF project, scientists will develop surfaces and paint formulations with antifouling properties. Apart from marine vessels, such surfaces and paint may find application in food production and hospitals.

The approach is to engineer surfaces with antifouling effects against a wide range of organisms by immobilising enzymes that either degrade key components of biofilm or have toxic effects on the fouling organisms. The hope is that such properties will inhibit bacterial adhesion and growth. Long-term functionality and sustained release of active compounds are key goals.

White and clean teeth

Another focus area of the ProSURF project is dental health care. Additives for toothpastes with improved antibacterial and tooth whitening properties will be developed. The approach is based on nanoparticle formulations of enzymes and a milk protein called osteopontin. This protein associates with teeth and appears to bind and change the bacteria present there, which may aid in maintaining a healthy bacterial flora. Many current types of toothpaste boast teeth whitening effects. In this project tooth whitening enzymes within nanoparticles will be guided to the tooth enamel and the bacteria by the milk protein, leading to improved whitening effects. Different formulations of milk protein and enzyme carrying nanoparticles might well be ingredients in future nanotoothpastes.

Improved implants

Inflammation, tissue compatibility and infections arising from medical implants are major complications encountered in biomedical engineering. ProSURF will address these problems by designing improved materials for medical implants. Again, osteopontin is envisaged to play a central role. Osteopontin is a key component of bone and will be used to steer the recruitment, adhesion and differentiation of bone cells, which will speed up the integration of implants. Furthermore, antibacterial enzymes immobilized on the implant surface could minimize complications due to infections.

Together these bold projects demonstrate the importance of interdisciplinary research to be able to address the challenges of applying nanotechnology in foods, medico technology, and environmental protection.

iNANO and industry

At the inauguration of the iNANO center in 2002, it was decided to establish an iNANO board with representatives from the main stakeholders: Danish industry, deans from the Science and Health Faculties at the University of Aarhus and the dean from the Faculty of Engineering, Science and Medicine at Aalborg University. From the outset the message was clear; the success of iNANO should be evaluated on the basis of iNANO's mission statements.

As chairman of the iNANO board I am pleased to note that in 2006 iNANO successfully met our ambitious expectations within all three key areas: education, research, and innovation, including collaboration with industry. We have witnessed continuous growth in the number of collaborative projects with industrial partners, and we expect this development to accelerate even further when the new iNANO house is ready in 2011.

It has been satisfactory to note that the government has decided to increase the overall research budget significantly from 2007 and onwards. However, in contrast to other countries no initiatives such as a focused and dedicated Danish Nanotechnology Initiative that would specifically strengthen the Danish effort in nanoscience and nanotechnology have been launched. The government has left it to the universities to prioritise nanoscience and nanotechnology – a surprising and disappointing decision based on the widespread expectation that nanotechnology will lead the next industrial revolution. Can Denmark really afford to run the risk of being technologically surpassed by other countries when this expectation materialises, now that many other countries with whom we normally collaborate and compete have invested in the nano area at government level? Moreover, I have to reiterate a statement from last year's report: Too much valuable research time is spent on writing numerous applications for programmes with limited funding potential. The funding bodies need to realise this, and as a consequence, they must establish programmes with a larger funding potential and long-term commitment.

Finally, I wish to congratulate iNANO´s management and dedicated staff on the excellent results and progress during 2006, express my full support to the visionary ideas behind iNANO and to thank my colleagues on the iNANO board for their valuable inputs, continued interest and dedication. I look forward to continue our work in 2007 with great expectations of another grand year.

Hans Jørgen Pedersen
CEO of Danfoss Bionics A/S
Chairman of the iNANO board

Collaborators

Industrial Partners

Aalborg Portland A/S, Denmark
AarhusKarlshman A/S, Denmark
Arla Foods amba, Denmark
Bioneer A/S, Denmark
Capres A/S, Denmark
Carlsberg Research Center, Denmark
CemeCon Scandinavia A/S, Denmark
CeNTect Gmbh, Germany
Chew Tech I/S, Denmark
Coloplast Research A/S, Denmark
Crystal Fibre A/S, Denmark
Danfoss A/S, Denmark
Danfoss Bionics A/S, Denmark
Danisco A/S, Denmark
Danish Crown amba, Denmark
Danish Technological Institute, Denmark
Dantherm A/S, Denmark
Delta, Denmark
Exiqon A/S, Denmark
Fibertex A/S, Denmark
GPV Group, Denmark
Grundfos A/S, Denmark
H2 Logic ApS, Denmark
Haldor Topsøe A/S, Denmark
IBSEN A/S, Denmark
Ignis Photonyx A/S, Norway
Image Metrology A/S, Denmark
Interuniversitair Micro-electronica Centrum vzw, Belgium
IRD Fuels cells A/S, Denmark
Lundbeck A/S, Denmark
Nanon A/S, Denmark
NanoNord A/S, Denmark
NKT Research & Innovation A/S, Denmark
Novozymes A/S, Denmark
OFS Fitel Denmark A/S, Denmark
Oticon A/S, Denmark
Pipeline Biotech A/S, Denmark
Rho-BeSt Coating plc, Austria
SCF Technologies A/S, Denmark
Sintex A/S, Denmark
SPECS, Germany
Stryker, Denmark
Systematic Software Engineering A/S, Denmark
Unisense A/S, Denmark
Veeco, USA
Versamatrix A/S, Denmark
Vipergen, Denmark
Zgene A/S, Denmark

Academic Partners

Advanced Photon Source, Chicago, USA
Arizona State University, Arizona, USA
Centre National de la Recherche Scientifique, Toulouse, France
Centro Atomico Bariloche, San Carlos de Bariloche, Argentina
Chalmers University of Technology, Göteburg, Sweden
Danish Cancer Society, Copenhagen, Denmark
Danish Institute for Fishery Research, Copenhagen, Denmark
Danish Institute for Food and Veterinary Research, Aarhus, Denmark
Danish Institute of Agricultural Science, Foulum, Denmark
Danish Meat Research Institute, Slagelse, Denmark
Department of Chemistry, Lehigh University, Pennsylvania, USA
Donostia International Physics Center, Donostia/ San Sebastian, Spain
Duke University, North Carolina, USA
Eidgenoesische Technische Hochschule Zürich, Zürich, Swizerland
Florida Atlantic University, Florida, USA
Forschungszentrum Karlsruhe GmbH, Karlsruhe, Germany
Freie Universität Berlin, Berlin, Germany
Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany
German Aerospace, Cologne, Germany
Hasylab, Hamburg, Germany
ICGEB, Trieste, Italy
IGH, Montpellier, France
Imperial College London, London, Great Britain
Institut Andre Lwoff, Villejuif, France
Institut Cochin, Paris, France
Institute for Solid State Research, Dresden, Germany
Institute for Solid State Research, Jülich, Germany
Institute of Bioorganic Chemistry, Polish Academy of Sciences, Poznan, Poland
Instituto per la Sintesi Organica e la Fotoreattività, Consiglio Nazionale delle Ricerche, Bologna, Italy
International Business Machines Corporation, Zurich Research Laboratory, Zurich, Swizerland
Jet Propulsion Laboratory, Pasadena, USA
Karolinska Institutet, Stockholm, Sweden
Lawrence Berkeley National Laboratory, Berkeley, USA
Lund University, Lund, Sweden
Max-Planck-Gesellschaft zur Förderung der Wissenschaften, Stuttgart, Germany
Max-Planck-Institute for Infection Biology, Berlin, Germany
Max-Planck-Institute of Molecular Cell Biology and Genetics, Dresden, Germany
MESA+ Research Center, Enschede, Netherlands
National Environmental Research Institute, Silkeborg / Roskilde, Denmark
NCCR, Basel, Swizerland
Oak Ridge National Laboratory, Oak Ridge, USA
Poul Scherrer Institute, Villigen, Switzerland
Risø, Roskilde, Denmark
Ruprecht-Karls-Universität, Heidelberg, Germany
Sincrotrone Trieste, Trieste, Italy
Technical University Delft, Delft, Holland
Technical University of Denmark, Kgs. Lyngby, Denmark
The WARK Institute, Mawson Lakes, Australia
Universidad Autónoma de Madrid, Madrid, Spain
Universitaet Basel, Basel, Swizerland
Universität Hannover, Hannover, Germany
Universität Osnabrück, Osnabrück, Germany
Universite de Bordeaux, Bordeaux, France
Université du Québec, Montreal, Canada
University of Nagoya, Nagoya, Japan
University of Amsterdam, Amsterdam, Netherlands
University of Birmingham, Birmingham, England
University of California, Santa Barbara, USA
University of Cambridge, Cambridge, England
University of Cardiff, Cardiff, UK
University of Copenhagen, Copenhagen, Denmark
University of Glasgow, Glasgow, Scotland
University of Milan, Milan, Italy
University of New Hampshire, Durham, USA
University of New South Wales, Singapore
University of New South Wales, Sydney, Australia
University of Parma, Parma, Italy
University of Rennes, Rennes, France
University of Rome “La Sapienza”, Rome, Italy
University of Southern Denmark, Odense, Denmark
University of Stockholm, Stockholm, Sweden
University of Sydney, Australia
University of Tennesse, Knoxville, USA
University of Tsukuba, Tsukuba, Japan
University of Turin, Torino, Italy
University of Uppsala, Uppsala, Sweden
University of Washington, Seattle, USA
University of Western Australia, Perth, Australia
VTT Technical Research Centre of Finland, Espoo, Finland
Westfälische Wilhelms-Universität, Münster, Germany

PhD Theses

Almtoft, Klaus Pagh, Structural characterization of nanocrystalline thin films grown by magnetron sputtering

Andersen, Ebbe Sloth, The structure, function and evolution of HIV-1 RNA – interdisciplinary studies combining bioinformatics, biochemistry and biophysics

Andersen, Thomas V., Applications of nonlinear optics and optical fibers

Bech, Lone, Experimental studies of model systems with relevance to heterogeneous catalysis

Beermann, Jonas, Nonlinear far- and near-field scanning optical microscopy of nanostructures

Clò, Emiliano, Synthesis of novel two-photon singlet oxygen sensitizers and development of DNA-programmed "on-off" switchable singlet oxygen sensitizers

Christensen, Mogens, The structure, function and evolution of HIV-1 RNA

Dong, Mingdong, Scanning probe microscopy studies of biomolecules on surfaces

Hansen, Michael Ryan, Structural investigations of heterogeneous alumina-boria catalysts by solid-state NMR spectroscopy and DFT calculations of electric-field gradients

Hundahl, Christian, Neuroglobin and cytoglobin, their functional characteristics and expression in the mammalian central nervous system

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Pedersen, Jesper S., In vitro studies of amyloid-like protein fibrils using glucagons as model system

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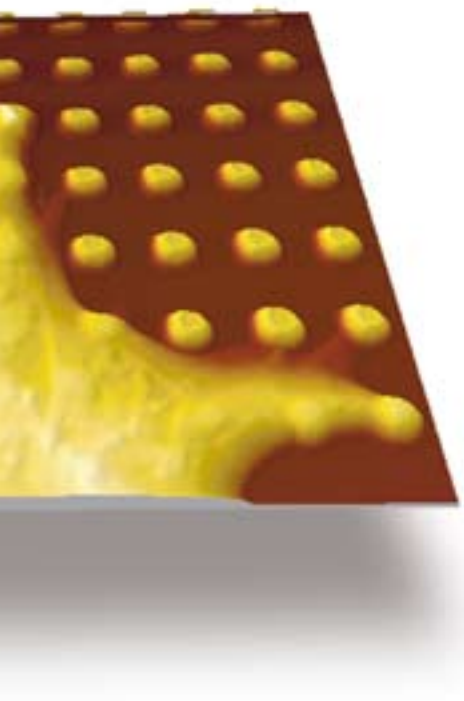

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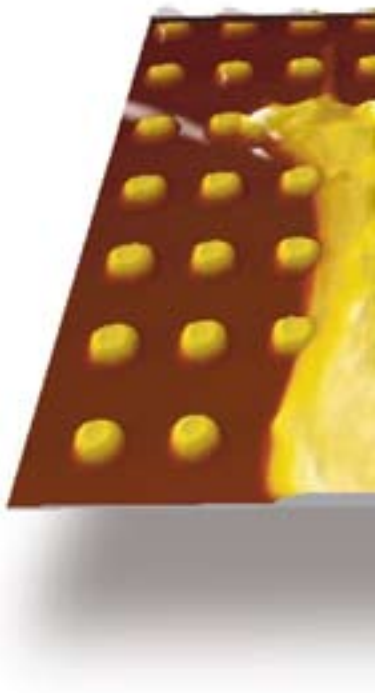

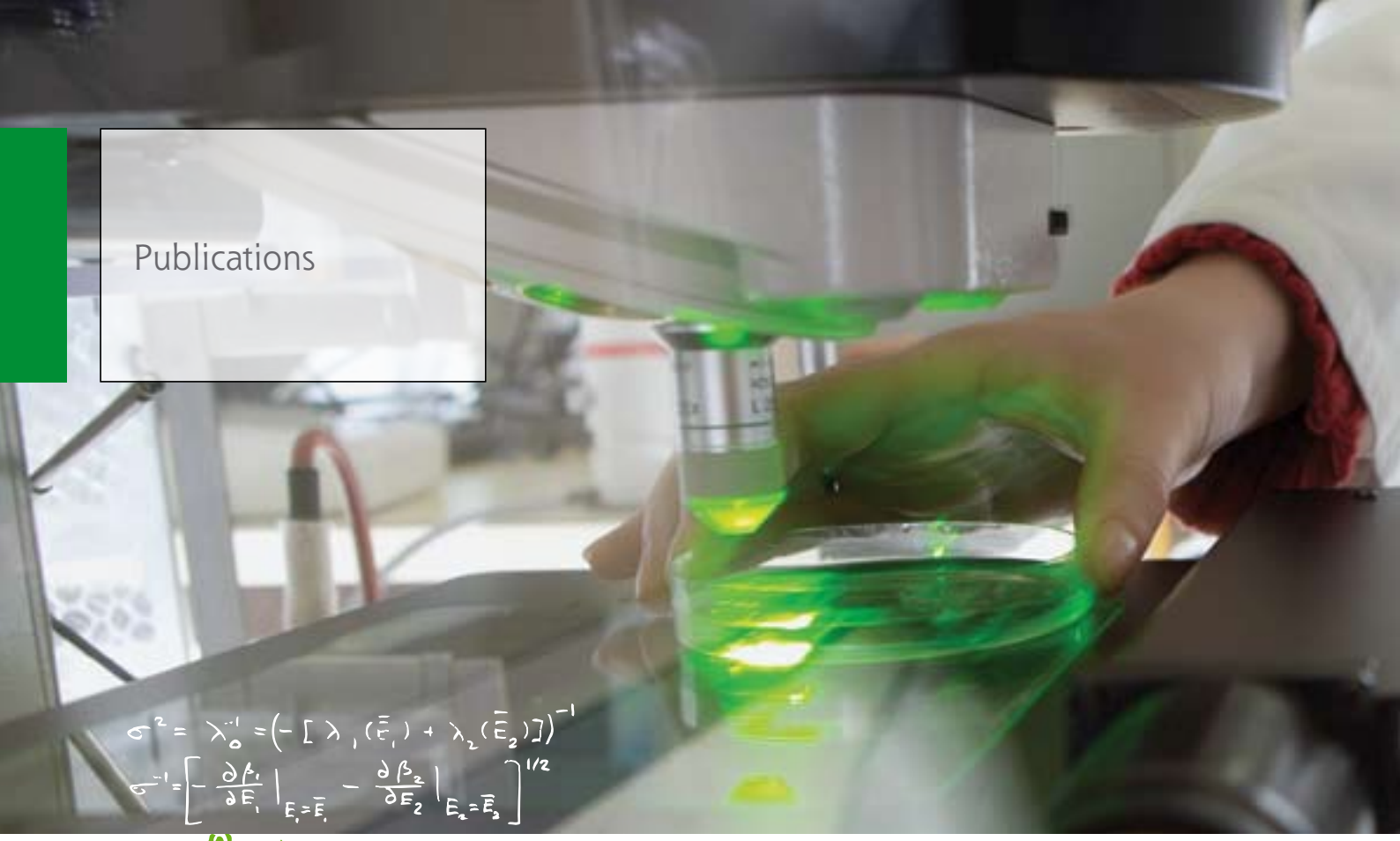

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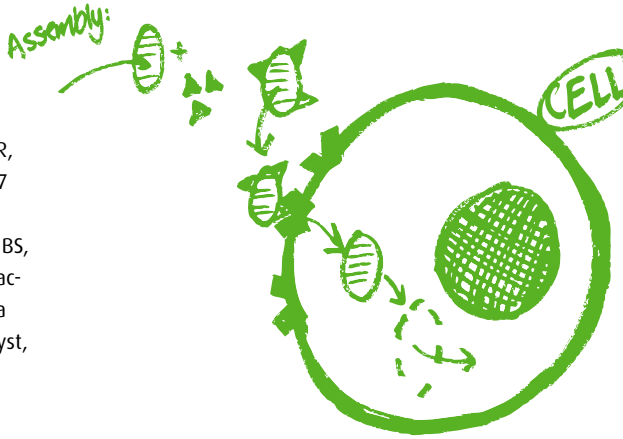

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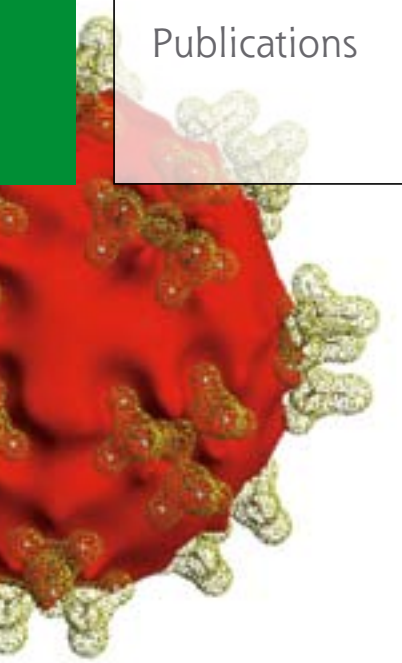

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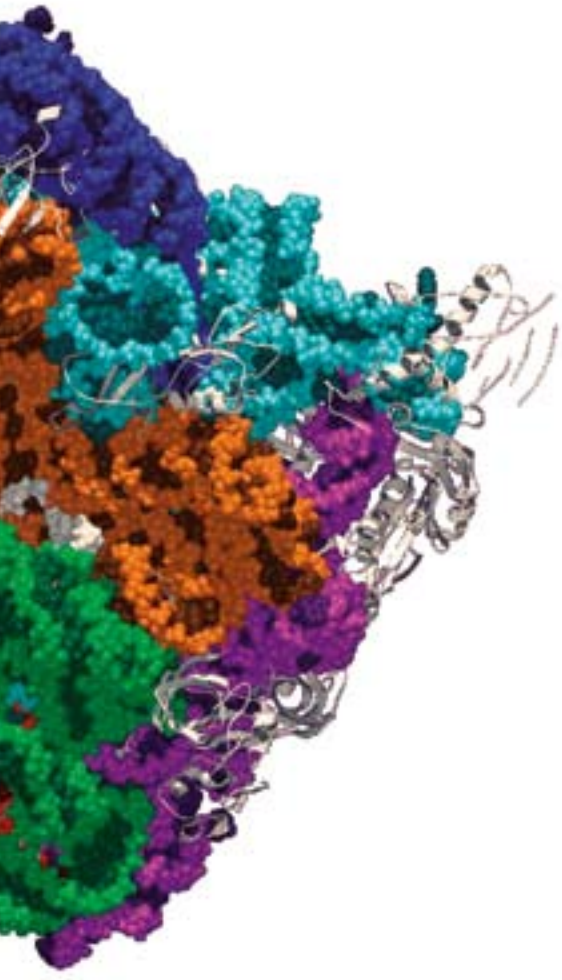

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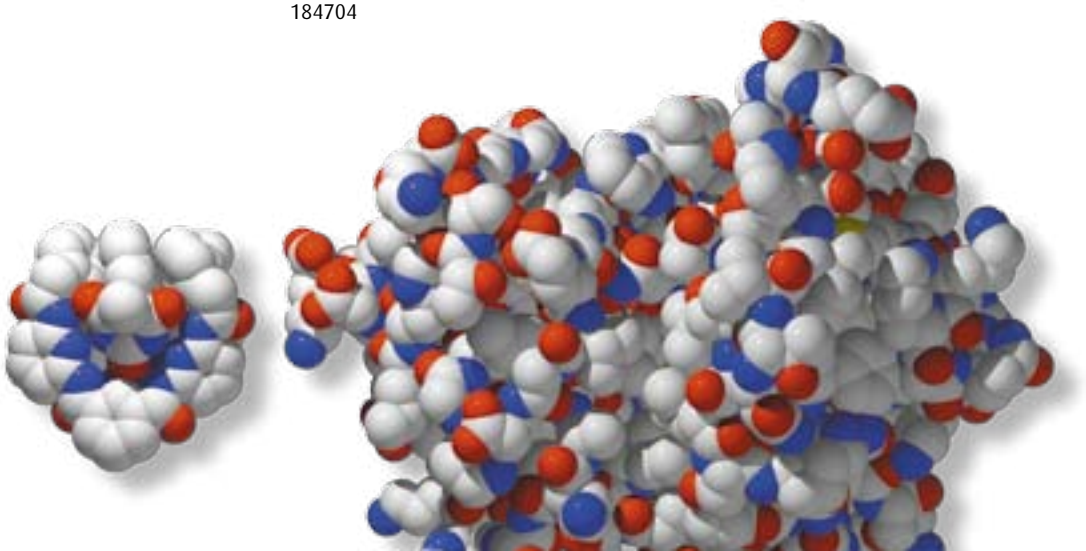

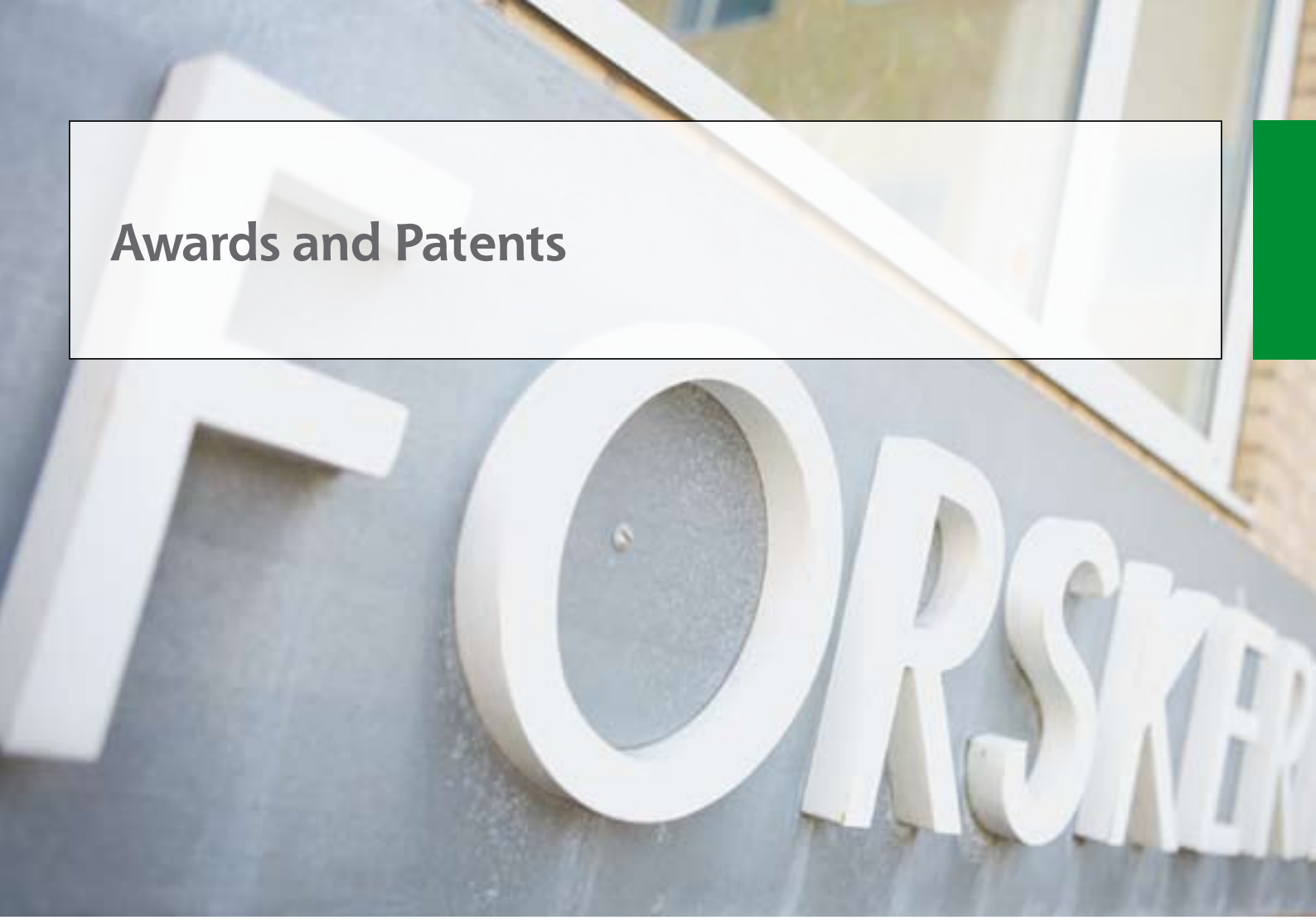

Awards and Patents

Awards

Flemming Besenbacher, Grundfosprisen 2006

Bjørk Hammer, Hede Nielsen Prisen

Niels Chr. Nielsen, Ib Henriksens Forskerpris

Poul Nissen, Hede Nielsen Prisen

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Patents

P. R. Ogilby, J. Arnbjerg, A. Jiménez-Banzo, M. J. Paterson, S. Nonell, J. I. Borrell, C. Teixido, O. Christiansen, Use of porphycene derivatives in two-photon photodynamic therapy, patent no. P200603192, filed in Spain

B.B. Iversen, A. Bentien, S. Johnsen, G.K.H. Madsen, F. Steglich, Use of thermoelectric materials for low temperature thermoelectric purposes, application no. P16340EP00

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K.A. Howard, J. Kjems, X. Liu, F. Besenbacher, Delivery of siRNA, patent no. 60/819.209

B.B. Iversen, M. Christensen, B. Lundtoft, D. Platzek, Improved p-type thermoelectric materials, a process for their manufacture and uses thereof, US60/686,240

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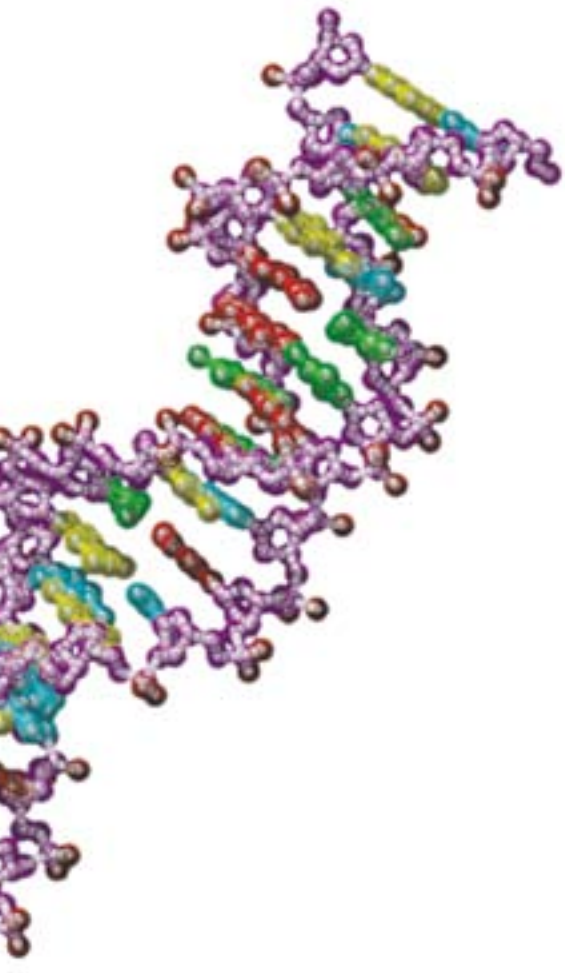
J. Skibsted, H.J. Jakobsen, H. Lindgreen, M.R. Geiker, H. Stang, H. Krøyer, Suspension of clays in water for addition to e.g. concrete, application no. PA 2006 01416

K. Søballe, M. Ulrich Vinter, B. Elmengaard, C. Stengaard, Inventor Bioimplant for treatment of critical tissue defects, patent no. PA 2006 00928

Invited Talks



Peter Andreasen, Proteolytic enzymes and their inhibitors in cancer growth, invasion, and metastasis, School of Stomatology, Capital Medical University, Beijing, China

Peter Andreasen, Proteolytic enzymes and their inhibitors in cancer growth, invasion, and metastasis, College of Stomatology, Tianjin Medical University, Tianjin, China

Peter Andreasen, Proteolytic enzymes and their inhibitors in cancer growth, invasion, and metastasis, the Affiliated Stomatological Hospital, Fujian Medical University, Fouzhou, China

Peter Andreasen, Proteolytic enzymes and their inhibitors in cancer growth, invasion, and metastasis, School of Dentistry, Changsha Medical University, Changsha, China

Peter Balling, NORSOLA Conference, Copenhagen, Denmark

Peter Balling, Mikro- og nanoaktiviteter i Danmark, ATV-Semapp, Fredericia, Denmark

Flemming Besenbacher, Dynamics and self-assembly of organic molecules on surfaces revealed by high-resolution, fast-scanning STM, VIII Annual Linz Winter Workshop, Linz, Austria

Flemming Besenbacher, Nanotechnology will lead to the next industrial revolution, Rotary Århus, Aarhus, Denmark

Flemming Besenbacher, Dansk Selskab for Medicinsk Fysiks Symposium 2006, Denmark

Flemming Besenbacher, Dynamics of nanostructures on surfaces revealed by high-resolution, fast-scanning STM, IWTF2, Prague, Czech Republic

Flemming Besenbacher, Dynamics of nanoclusters and surfaces revealed by fast-scanning STM, SONS Summerschool, Pisa, Italy

Flemming Besenbacher, Nanostructures on surfaces revealed by high-resolution, fast-scanning STM, Nanosea, Aix-en-Provence, France

Flemming Besenbacher, Dynamics of nanostructures on surfaces revealed by high-resolution, fast-scanning STM, NANO9 meets STM'06, Basel, Switzerland

Flemming Besenbacher, Biosurface science: from the nanometer to the micrometer length scale, Biointerfaces, Göteborg, Sweden

Flemming Besenbacher, Organic molecules on surfaces studied by high resolution STM: dynamics, chirality and self-assembly, TNT2006, Grenoble, France

Flemming Besenbacher, Dynamics of nanostructures on surfaces revealed by high-resolution, fast-scanning STM, ACS National Fall Meeting, San Francisco, USA

Flemming Besenbacher, Dynamics of nanostructures on surfaces revealed by high-resolution, fast-scanning STM, NanoMesh Workshop, Braunwald, Switzerland

Flemming Besenbacher, Dynamics and self-

assembly of organic molecules on surfaces revealed by high-resolution, fast-scanning STM, 10th ISSP International Symposium on Nanoscience at Surfaces, University of Tokyo, Tokyo, Japan

Flemming Besenbacher, The impact of nanoscience hetergenerous catalysis in the 21st centrury, European Forum on Nanosciences, Bruxelles, Belgium

Flemming Besenbacher, Introduktion til nanoteknologi, basis for den næste industrielle revolution, Ikast Folkeuniversitet, Ikast, Denmark

Flemming Besenbacher, Introduktion til nanovidenskab og nanoteknologi, Folkeuniversitetet, Aarhus, Denmark

Flemming Besenbacher, Introduktion til nanovidenskab og nanoteknolgi, AU-HIH, Aarhus, Denmark

Henrik Birkedal, Biological and bioinspired polymer-based materials: inspiration from invertebrates, 2nd STIPOMAT workshop, Seggau, Austria

Niels E. Christensen, Theory of optical properties of solids including e-h correlations, Leibniz Institute, IFW, Dresden, Germany

Niels E. Christensen, Ab initio calculations of optical properties including e-h correlations, "Nano Talk", University of Aalborg, Aalborg, Denmark

Niels E. Christensen, Ab initio calculations of electronic, structural, and optical properties in solids under pressure, Frontiers in High Pressure Research, Ein-Guedi, Israel

Niels E. Christensen, Free excitons in AlN under pressure, High Pressure in Semiconductor Physics (HPSP-XII), Barcelona, Spain

Niels E. Christensen, Theory of optical properties of solids including e-h correlations, 5-th Workshop on Computational Chemistry and Molecular Spectroscopy, Punta de Tralca, Chile

Lars Diekhöner, A close view of electrons at surfaces: electronic states, magnetism and correlation effects, Center for Individual Nanoparticle Functionallity, Technical University of Denmark, Kgs. Lyngby, Denmark

Angela Fago, Hemoglobin as a nitrite reductase: a vasodilation study, University of Parma, Parma, Italy

Angela Fago, International visions on blood substitutes. Hemoglobin-based oxygen carriers: from chemistry to clinic, Parma, Italy

Angela Fago, Oxygen binding (and other reactions) in an ancestral vertebrate globin, 14th International Conference on Dioxygen Binding and Sensing Proteins, Napoli, Italy

Angela Fago, NO-vel reactions in hemoglobin: a role in vasodilation?, 1st International Congress of Respiratory Biology (ICRB), Bonn, Germany

Angela Fago, Hemoglobin as a (glutathione-dependent?) nitrite reductase: a vasodilation study, What's new in oxygen binding heme proteins and red blood cell physiology, Aarhus, Denmark

Morten Foss, Biocompatibility of topographically structured tantalum, Frontiers meeting, Sicily, Italy

Morten Foss, Proteins and cells on biocompatible materials, Bioneer, Hørsholm, Denmark

Morten Foss, Proteins and cells on topographically structured tantalum, Aalborg University, Aalborg, Denmark

Morten Foss, QCM-D studies of protein adsorption and cell attachment/spreading on tantalum, QCM-D World Conference, Boston, USA

Bjørk Hammer, Catalysis at oxide/metal/gas three-phase boundaries - a DFT study, Kloster Irsee, Irsee, Germany

Bjørk Hammer, Catalysis at the oxide/metal interface perimeter, Inorganic Oxides: Surfaces and Interfaces, Technical University of Vienna, Vienna, Austria

Bjørk Hammer, Density functional theory of enantioselective reactions at kinked and chirally modified metal surfaces, San Francisco, USA

Philip Hofmann, Electron-phonon coupling on surfaces, Universität Zürich, Zürich, Switzerland

Philip Hofmann, Electron-phonon coupling on surfaces, Workshop on quantum properties in low dimensions, Å, Norway

Invited Talks

Philip Hofmann, Electron-phonon coupling, 13th International Conference on Solid Films and Surfaces, San Carlos de Bariloche, Argentina

Bo Brummerstedt Iversen, AxZn4-xSb3-yBy - a promising thermoelectric material?, International Symposium on Solid State Chemistry, Cracow, Poland

Bo Brummerstedt Iversen, Charge density studies of metal organic framework structures, Kemisk Forenings årsmøde, Odense, Denmark

Bo Brummerstedt Iversen, Nanomaterials, Ungdommens Naturvidenskabelige Forening, Aarhus, Denmark

Hans Jørgen Jakobsen, Crystal structure and transformation reactions of ammonium oxo- and thiomolybdates characterized by 14N and 33S MAS NMR spectroscopy, 48th Rocky Mountain Conference on Analytical Chemistry - NMR, Breckenridge, Colorado, USA

Hans Jørgen Jakobsen, Advancements in natural abundance solid-state 14N and 33S MAS NMR with applications to inorganic/organic materials, 35th Southeastern Magnetic Resonance Conference, Gainesville, Florida, USA

Torben R. Jensen, Reversibel faststofbrintlagring, Årets Brintdag, Danish Hydrogen Association, HIRC, Herning, Denmark

Torben R. Jensen, Hydrogen-samfundet - et mere miljøvenligt energisystem, Tønder Gymnasium og HF, Tønder, Denmark

Torben R. Jensen, Hydrogen-samfundet - et mere miljøvenligt energisystem, Herning Amtsgymnasium, Herning, Denmark

Torben R. Jensen, Nano-teknologi og udvikling af et nyt energi-system, Forskningens Døgn, Grundfos, Bjerringbro, Denmark

Peter Kingshott, Natural and synthetic surfaces for minimising, bioadhesion, surface analysis06, AVS New Mexico Chapter Annual Meeting, Albuquerque, USA

Jørgen Kjems, RNAi, Clinical Medicine, AU annual meeting, Vejle, Denmark

Jørgen Kjems, Genesilencing using polymeric nanocarrier systems, Nordita Conference, Copenhagen, Denmark

Jørgen Kjems, Chemical design of small interfering RNA (siRNA) and improved polymeric delivery systems, EURO TIDES, Hamburg, Germany

Jørgen Kjems, Small interfering RNA delivery and gene silencing using polymeric nanocarrier systems, European Society for Gene Theray Annual meeting, Athens, Greece

Jørgen Kjems, siRNA delivery, RIGHT general assembly meeting, Paris, France

Jørgen Kjems, Novel strageties for siRNA design and delivery, RIGHT Symposium: RNA in vivo, Paris, France

Jørgen Kjems, siRNA delivery and gene silencing using polymeric nanocarrier systems, GSF, Workshop on RNAi in vivo technologies, Munich, Germany

Jørgen Kjems, Bionanotechnology, Forskningens dag, Aarhus, Denmark

Jørgen Kjems, Biotechnology, Nanoethic Workshop, Aarhus, Denmark

Jørgen Kjems, An electric bio-sensing platform using micro-cantilevers, Workshop on Nanomechanical sensors, Copenhagen, Denmark

Jørgen Kjems, RNAi and siRNA delivery, DFU PhD course on Drug Delivery, Copenhagen, Denmark

Jørgen Kjems, Posttranscriptional gene regulation in HIV-1, Hidden HIV meeting, Amsterdam, the Netherlands

Jørgen Kjems, Regulation of HIV-RNA splicing, EURASNET meeting, Barcelona, Spain

Jørgen Kjems, Gene silencing using polymeric nanocarrier systems, "Fuge" RNA workshop, Tromsø, Norway

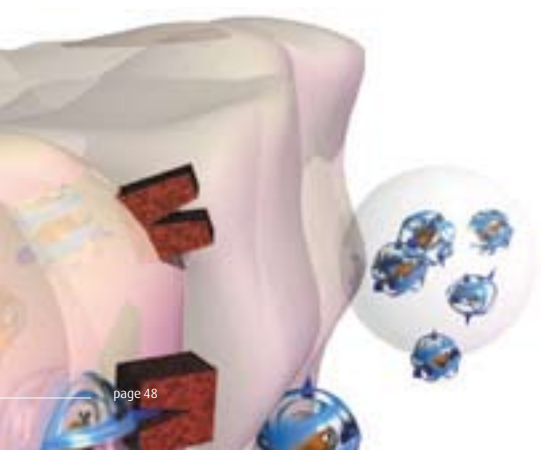
Martin Kristensen, Photonic crystals and quantum dots: towards integrated optics for advanced ultra-fast all-optical signal processing, ECOC'06, Cannes, France

Martin Kristensen, Advanced design and optimization techniques for photonic crystal devices, LEOS-2006 conference, Montreal, Canada

Martin Kristensen, Multiphoton processes in silicon nano-optics, the Nonlinear Workshop, Sydney, Australia

Kim Lambertsen Larsen, Visioner for anvendelsen af cyclodextriner i forebyggelse af biofilm, BioMed 2006, Taastrup, Denmark

Kim Lambertsen Larsen, Introduction to cyclodextrins, DTI, Taastrup, Denmark



Kim Lambertsen Larsen, Controlled release from hydrogels, DTI, Taastrup, Denmark

Kim Lambertsen Larsen, Introduction to cyclodextrins, Fertin Pharma, Vejle, Denmark

Kim Lambertsen Larsen, Controlled release from hydrogels, Fertin Pharma, Vejle, Denmark

Kim Lambertsen Larsen, Unusual cyclodextrins and unusual guest molecules: large-ring cyclodextrins and formulation of peptides and proteins with cyclodextrins, Laboratoire de recherche sur les polymeres, CNRS, Thais, France

Jeppe Vang Lauritsen, Defect and Adsorbate Identification on TiO2(110) with nc-AFM, 9th Noncontact AFM Conference, Sapporo, Japan

Jeppe Vang Lauritsen, Atom-resolved Scanning Probe Microscopy Studies relevant to Catalysis, University of Osnabrück, Department of Physics, Osnabrück, Germany

René Trolle Linderoth, Dynamics, reactions and chirality of organic molecules on surfaces, SONS Workshop – Functional Molecular Nanostructures, Kloster Irsee, Germany

René Trolle Linderoth, Organic molecules on surfaces studied by STM: dynamics, chirallity and organisation, Spanish Molecular Electronics Symposium, San Sebastian, Spain

René Trolle Linderoth, Large organic molecules on surfaces studied by STM: dynamics, chirality and organization, International Symposium: Complex Molecular Architectures on Surfaces, Bonn, Germany

René Trolle Linderoth, Large organic molecules on surfaces studied by STM: dynamics, chirality and organization, Annual Meeting of the Danish Physical Society, Hotel Nyborg Strand, Nyborg, Denmark

Erik Lægsgaard, SPM - scanning probe microscopy, Syddansk Universitet, Sønderborg, Denmark

Erik Lægsgaard, Ending the never-ending story of decaying men and alpha particles, University of Bergen, Bergen, Norway

Rikke Louise Meyer, Nanoteknologi i fødevareproduktion, succesfuld samspil mellem fødevare-, emballage-, og udstyrserhvervet, Videnscenter for Fødevareudvikling, Bredsten, Denmark

Niels Chr. Nielsen, Composite dipolar recoupling: anisotropy compensated coherence transfer in solid-state NMR, The 47th Experimental NMR Conference (ENC), Asilomar,California, USA

Niels Chr. Nielsen, Recoupling techniques, European School on Solid-State NMR, Brueckentinsee, Germany

Niels Chr. Nielsen, Simulation of MAS and oriented-sample NMR spectra and design of NMR pulse sequences using SIMPSON, European School on Solid-State NMR, Brueckentinsee, Germany

Niels Chr. Nielsen, Structure and membrane bound conformation of bacteriorhodopsin studied by oriented-sample solid-state NMR spectroscopy, 12th International Conference on Retinal Proteins, Awaji Island, Yumebutai, Japan

Niels Chr. Nielsen, Novel approaches for design of biological solid-state NMR experiments & oriented-sample studies of membrane proteins, 2006 Symposium of the Danish Instrument Center for NMR Spectroscopy of Biological Macromolecules, Copenhagen, Denmark

Niels Chr. Nielsen, Optimal control in solid-state NMR, The Principles and Applications of Control in quantum systems (PRAQSYS 2006), Harvard University, Cambridge, MA, USA

Niels Chr. Nielsen, Solid-state NMR and insoluble proteins, Université Mediteranee, Marseilles, France

Niels Chr. Nielsen, Novel solid-state NMR experiments developed using optimal control theory, Current Trends in Solid State NMR Methodology and Practice, National Chemistry Laboratory, Pune, India

Niels Chr. Nielsen, Solid-state NMR of oriented membrane proteins – approaches for non-perfectly aligned large membrane proteins, Current Trends in Solid State NMR Methodology and Practice, National Chemistry Laboratory, Pune, India

Poul Nissen, Structure and function of P-type ATPase pumps, P-type ATPase cation pumps in cell membranes, Ramon Serrano, XIV International Workshop on Plant Membrane Biology, Valencia, Spain

Poul Nissen, Rational approaches in structure determination of membrane proteins, Membrane proteins studied by X-ray crystallography, MRC-LMB, MRC-LMB seminar series, Cambridge, UK

Poul Nissen, Structure and function of P-type ATPase cation pumps, MRC Dunn Human Nutrition Unit, Dunn seminar series, Cambridge, UK

Poul Nissen, Structure and function of membrane proteins, Membrane proteins in cell biology, physiology and medicine, Annual meeting of the Danish Society for Biochemistry and Molecular Biology, Helnæs, Denmark

Poul Nissen, Rational approaches in structure determination of membrane proteins, American Crystallographic Association, ACA2006, Honolulu, USA

Poul Nissen, Pumps and circumstances in translation, translation and membrane proteins, Workshop on Biostructural Chemistry, Spetses, Greece

Poul Nissen, Ca2+-ATPase: nucleotide-bound forms, membrane proteins, cation pumps, structure and function, Gordon Research Conferences, Protons and Membrane Reactions, Ventura, CA, USA

Poul Nissen, The cation pumps - structure, function and regulation, how is energy transformed into a vectorial transport process across the membrane?, Knud Lind Larsen Symposiet 2006, Organic Chemistry at the Interface to Biology, Copenhagen, Denmark

Poul Nissen, Structure and function of the calcium pump, patrick cramer, gene center seminar series, Munich, Germany

Jeppe Olsen, Bridging the gap between multiconfigurational perturbation and coupled cluster methods, International Conference on computational methods in sciences and engineering (ICCMSE), Chania, Greece

Daniel Erik Otzen, Fibrillation of the peptide hormone glucagon: structural and energetic polymorphism is modulated by environmental conditions as well as mutagenesis, EMBO Workshop on Amyloid Formation, Florence, Italy

Daniel Erik Otzen, Folding and stability of a minimal heme-binding protein, COST Meeting on Protein-lipid interactions, Murcia, Spain

Daniel Erik Otzen, Protein aggregation and fibrillation: nature's use and abuse of the social side of protein folding, Ankara University, Ankara, Turkey

Finn Skou Pedersen, A tumor suppressor function for NFATc3 in T cell lymphomagenesis by murine leukemia virus, the17th International Workshop on Retroviral Pathogenesis, Saint-Malo, France

Finn Skou Pedersen, Fusiogenic envelope proteins of endogenous and exogenous retroviruses, Conference on cell fusion, epigenetics, and cancer, Söderköping, Sweden

Invited Talks

Finn Skou Pedersen, The variable loops of the polytropic SU define a surface that allows functional interaction with more than one receptor, the 2006 International Workshop on Retroviral Pathogenesis, Palm Springs, USA

Finn Skou Pedersen, Lymphomagenesis by murine leukemia viruses, Dept. of Pathology, University of Würzburg, Würzburg, Germany

Jan Skov Pedersen, Form factors of complex particles derived by use of monte carlo simulations, XIII International Conference on Small-angle Scattering, Kyoto, Japan

Jan Skov Pedersen, Structure and interactions of PEO-containing block copolymers micelles by small-angle scattering, International Small-Angle Scattering Workshop, Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research. Dubna, Russia

Jan Skov Pedersen, Recent applications of solution SAXS in structural biology at the University of Aarhus, SAXS on Nanosystems – Science and Technology (10 years Austrian SAXS-beamline), Trieste, Italy

Jan Skov Pedersen, Scanning SAXS of bone structure on a laboratory based instrument From Diffraction to Imaging. International Symposium on Scanning Microbeam Small- and Wide-Angle Scattering of Hierarchically Structured Materials, BESSY (Berlin/Adlershof), Germany

Birgit Schiøtt, Ligand binding in the human serotonin transporter, Lundbeck, Copenhagen, Denmark

Jørgen Skibsted, Characterization of guest-ions in cementitious materials by solid-state NMR, 2nd Open Meeting NANOCEM, Copenhagen, Denmark

Jørgen Skibsted, Structural investigations of Portland cement components, hydration and effects of admixtures by solid-state NMR spectroscopy, 16th IBAUSIL – Internationale Baustofftagung, Weimar, Germany

Troels Skrydstrup, EU COST meeting (D28), Santorini, Greece

Henrik Stapelfeldt, Alignment of molecules by strong laser pulses, Max Planck Institute, Garching, Germany

Henrik Stapelfeldt, Alignment of molecules by strong laser pulses, Kansas State University, Manhattan, KS, USA

Henrik Stapelfeldt, Aligning molecules with long or short laser pulses - or both, Dynamic Imaging Conference, London, UK

Henrik Stapelfeldt, Aligning molecules with long or short laser pulses - or both, MOLEC, Levico, Italy

Henrik Stapelfeldt, Aligning molecules using laser pulses, DESY, Hamburg, Germany

Duncan Sutherland, Optimised LSPR nanostructures for biosensing, ACS March 2006, Atlanta, USA

Duncan Sutherland, Artificial nanostructured biointerfaces, University of South Denmark, Odense, Denmark

Duncan Sutherland, Nanotechnology: education and training in the future, workshop on nanotechnology in education and business, Heerlen, The Netherlands

Duncan Sutherland, Artificial nanostructured biointerfaces, Max Planck Institute for Solid State Research, Stuttgart, Germany

Duncan Sutherland, Localised surface plasmon resonance based biosensors, IMEC, Leuven, Belgium

Duncan Sutherland, Surface nanostructures to control proteins and cells, TNT 2006, Grenoble, France

Duncan Sutherland, Biomaterials, tissue engineering and stem cell therapy, NanoEthics Network, Aarhus, Denmark

Duncan Sutherland, Nanoparticle shape as a route to optimized localised surface plasmon resonance biosensors, EU Workshop on Physics of Sensors and Detection Systems, Ispra, Italy

Duncan Sutherland, Artificial nanostructured biointerfaces, Frontiers meeting, Sicily, Italy

Carsten Svaneborg, Microscopic deformations, macroscopic stresses, and primitive paths in polymer networks, Leeds, UK

Kjeld Søballe, Treatment of osteoarthritis – surgery and osteoarthritis, Forskningsseminar, Gigtforeningen, Skælskør, Denmark

Kjeld Søballe, A mechanobiological model of periprosthetic tissue healing, World Congress of Biomechanics, Munich, Germany

Kjeld Søballe, Forskning inden for ortopædkirurgien, Jydsk Medicinsk Selskab, Aarhus, Denmark

Kjeld Søballe, Ganz osteotomi, 53rd Congress of the Nordic Orthopaedic Federation, Oslo, Norway

Kjeld Søballe, Overview of surgical treatment options, 13th EFORT Instructional Course, Zürich, Switzerland

Kjeld Søballe, The effect of hydroxyapite coating, Total hip replacement in congenitally dislocated hips, Revision of the femoral component using extended trochanteric osteotomy, V International Course in Arthroplasties, Barcelona, Spain

Thomas Vosegaard, Efficient sampling of multidimensional NMR experiments, 9eme Réunion de Travail RMN du Solide, la Baume, France

Thomas Vosegaard, SIMPSON simulations, Advanced European Solid-State NMR School on Biological Solids, Brückentinsee, Germany

Leif Østergaard, Stroke imaging: predicting tissue outcome, 12th Kuopio Bio-NMR Workshop, Kuopio, Finland

Leif Østergaard, Cerebral blood flow and perfusion imaging, International Symposium and Training Academy, German Stroke Competence Network, Berlin, Germany

Leif Østergaard, Cross-disciplinary research and neuroimaging at the Danish National Research Foundation's Center of Functionally Integrative Neuroscience (CFIN), Aarhus, Denmark, Nordic Network on Imaging in Medicine and Biology, Turku, Finland

Leif Østergaard, Prediction of stroke damage using MRI, nordic network on imaging in medicine and biology, Turku, Finland

Leif Østergaard, Implementing MRI based selection criteria for thrombolysis in acute stroke within the 3 hour window: efficacy over a 2 year period, Joint World Congress on Stroke 2006, Cape Town, South Africa

Leif Østergaard, Brain perfusion MR in dementia, Karolinska Sjukhuset, Huddinge, Sweden

Leif Østergaard, Perfusion imaging, European Society for Magnetic Resonance in Medicine and Biology (ESMRMB) School of MRI, Heidelberg, Germany

Leif Østergaard, Cellulær og molekylær MR imaging med målrettede nano-partikler, Forskningens Dag, Aarhus, Denmark

Leif Østergaard, Perfusion imaging, European Society for Magnetic Resonance in Medicine and Biology (ESMRMB), MR Lectures on Perfusion and Flow, Copenhagen, Denmark

Leif Østergaard, Brain MRI: anatomy, landmarks and territories, European Society for Magnetic Resonance in Medicine and Biology (ESMRMB) Annual Meeting, Warszawa, Poland

Leif Østergaard, Tissue characterization: perfusion MRI in stroke, European Society for Neuroradiology (ESNR), Geneva, Switzerland

Leif Østergaard, Stroke imaging, symposium arranged by Schering AG, European Society for Neuroradiology (ESNR), Geneva, Switzerland

Leif Østergaard, Basics of diffusion and perfusion MRI, International Summer School on MRI and MRS, Poiana Brasov, Romania

Leif Østergaard, Clinical applications of diffusion and perfusion MRI, International Summer School on MRI and MRS, Poiana Brasov, Romania

Leif Østergaard, Perfusion imaging, International Society for Magnetic Resonance in Medicine (ISMRM) 14th Annual Meeting, Seattle, USA

Leif Østergaard, Theory of MR perfusion measurements, International Society for Magnetic Resonance in Medicine (ISMRM) 14th Annual Meeting, Seattle, USA

Leif Østergaard, The physiological significance of the Tmax parameter in bolus tracking MRI, International Society for Magnetic Resonance in Medicine (ISMRM) 14th Annual Meeting, Seattle, USA

Leif Østergaard, Tracking vascular supply using bolus tracking MRI, International Society for Magnetic Resonance in Medicine (ISMRM) 14th Annual Meeting, Seattle, USA

Leif Østergaard, Musik og hjernen, Dansk Psykiatrisk Selskabs Årsmøde, Nyborg, Denmark

Leif Østergaard, Perfusion and diffusion MRI in stroke: predictive models

Leif Østergaard, Diffusion and perfusion MR imaging of the brain: imaging techniques, protocols and post-processing, European Congress of Radiology, Vienna, Austria

Leif Østergaard, Assessing tissue viability by MRI and neuroinformatics, BrainStorm 2006, Aarhus, Denmark

Colloquia

iNANO Annual Meeting 2006

January 18, Professor David N. Reinhoudt, "Writing with molecules on molecular printboards", University of Twente

January 18, Dr. King Li "Nanotechnology for vascular targeted imaging and therapeutics: A paradigm for personalized medicine" Associate Director, NIH Clinical Center

January 18, Professor Jackie Y. Ying, "Research in Bioengineering and Nanotechnology" Executive Director of Institute of Bioengineering and Nanotechnology, Agency for Science, Technology and Research (A*STAR)

January 18, Professor Sumio Lijima, "Science and Nanotechnology of Nano-Carbon Materials", Mejio University of Materials Science & Engineering, Director, Research Center for Advanced Carbon Materials A/AIST"

January 18, Professor Cees Dekker, "Nanoscience from carbon nanotubes to single-molecule biophysics", Delft University of Technology, Kalvi Institute of NanoScience

iNANO colloquia, Aarhus

January 27, Professor Dick Heinegård, Dept. of Experimental Medical Science, Lund University, Sweden, "Role of extracellular matrix proteins in tissue homeostasis"

February 10, Professor Lone Gram, Danish Institute for Fisheries Research, Dept. of Seafood Research, DTU, Denmark, "Bacteria sticking to surfaces - a problem and an advantage"

February 24, Dr. Thomas A. Jung, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute, Switzerland, "Molecular and supramolecular self assembly @ surfaces: phenomena of condensed matter physics projected into 2 dimensions"

March 3, Professor Paul J.A. Borm, Centre of Expertise in Life Sciences, Zuyd University, the Netherlands, "Worldwide activities on the toxicology of Nanomaterials"

March 10, Associate Professor, Vladimir Zachar, Laboratory for Stem Cell Research, Aalborg University, Denmark, "Control of stem cell fate by oxygen"

March 17, Professor Franz Himpsel, Dept. of Physics, University of Wisconsin Madison, USA, "What is special about Nanoscience and Nanotechnology?"

March 24, Associate Professor Esben Skipper Sørensen, Dept. of Molecular Biology, University of Aarhus, Denmark, "Bioactive milk proteins"

March 31, Professor Vinod Subramaniam, Biophysical Engineering, University of Twente, the Netherlands, "Nanoscale characterisation of protein aggregation"

April 21, Professor Mary Wirth, Dept. of Chemistry, University of Arizona, USA, "Single-molecule probing of binding to G-protein coupled receptors"

April 28, Dr. Fabio Biscarini, Institute for Nanostructured Materials Studies - CNR, Bologna Division, Bologna, Italy, "Nanotechnology of multifunctional materials: bottom-up fabrication, organic transistors, bio-organic functional systems"

May 5, Professor Ian Hamley, Physical School of Chemistry, University of Reading, Reading, United Kingdom, "Hierarchical Order in Block Copolymers containing Liquid Crystal or Peptide Units"

May 19, Dr. Per Morgen, Physics Department, University of Southern Denmark, Odense, Denmark, "What happens to the properties of thin films when they become very thin?"

June 9, Frederik Höök, Lund University, Lund, Sweden, "Nanoscale Sensor Templates Functionalized for Studies of Lipid-Membrane-Mediated Biorecognition reactions"

September 1, Professor Allan S. Hoffman, Dept. of Bioengineering, University of Washington, USA, "Origins and Principles of Non-fouling Surfaces"

September 15, Professor Insung S. Choi, Department of Chemistry, KAIST, Korea, "Biosurface Organic Chemistry for Nanotechnology"

September 22, Vice President Karl Sanford, Danisco, "A roadmap for High Performance Protein Polymers with a Bias toward Nano applications"

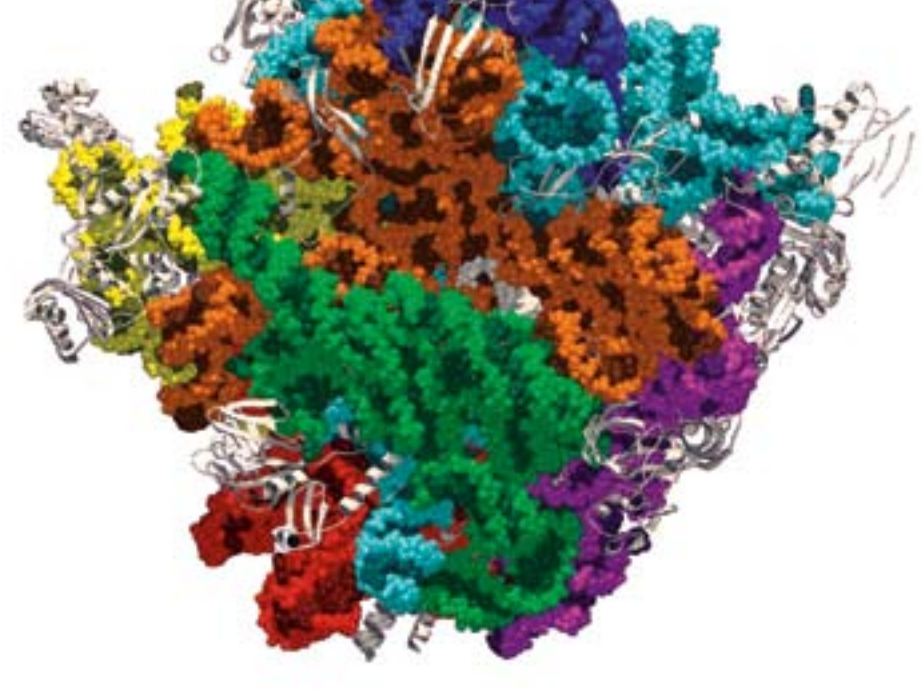
September 29, Professor Norm Dovichi, Dept. of Chemistry, University of Washington, Seattle, USA, "Chemical Cytometry for prognosis of Barrett's Esophagus"

October 6, Professor Julius Vancso, MESA+ Institute for Nanotechnology, Enschede, the Netherlands, "Interrogating Macromolecules on the Nanoscale?"

October 13, Professor Sven Lidin, Organisk kemi, Stockholm University, "4:3 or not 4:3, that is the question"

October 20, Dr. Andriy Mokhir, Anorganisch Chemisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany, "Autocatalytic reactions for analysis of nucleic acids"

October 27, Dr. Mario Ruben, Forschungszentrum Karlsruhe, Institut für Nanotechnologie, Karlsruhe,



Germany, "Surface-assisted Self-Assembly and Coordination Chemistry"

November 10, Professor Søren Molin, Infection Microbiology Group, BioCentrum-DTU, Technical University of Denmark, Copenhagen, Denmark, "Chronic Lung Infections: Structure, Function and Development of Microbial Populations and Interactions with the Host"

November 24, Professor Gary Drobny, Department of Chemistry, University of Washington, Seattle, USA, "Solid State NMR Studies of Biomaterials: The Structure of a Surfaced-Adsorbed Protein"

December 1, Professor Richard Edward Palmer, Nanoscale Physics Research Laboratory, University of Birmingham, Birmingham, England, "Organising Atoms, Clusters and Proteins on Surfaces"

December 8, Professor Anja Boisen, MIC - Department of Micro and Nanotechnology, Technical University of Denmark, Kgs. Lyngby, Denmark, "Nanomechanical sensors for label free detection, drug delivery and microexplosions"

iNANO specialized colloquia, Aarhus

January 12, Professor Peter Agre, University School of Medicine, Duke University, Durham, USA, "Aquaporin water channels – from atomic structure to clinical medicine"

January 19, Professor Hans W. Spiess, Max Planck Institute for Polymer Research, Mainz, Germany, "Advanced solid-state NMR methods for determining structure and dynamics of functional materials"

January 19, Dr. Janeck James Scott-Fordsmand, Dept. of Terrestrial Ecology, National Environmental Research Institute, Denmark, "Ecotoxicology of nanotechnological products"

January 30, Lucica Barbes, Dept. of Chemistry, Ovidius University, Romania, "Alternative anti-fouling systems"

February 1, Professor Ole G. Mouritsen, Center for Biomembrane Physics, Physics Department, University of Southern Denmark, "The physics of cholesterol"

February 15, Mats Eriksson, Spectral Solutions, Lidingö, Sweden

March 8, Dr. Ali Tinazli, Institute of Biochemistry, Johann W. Goethe University, Frankfurt, Germany

March 23, Professor Peter G. W. Gettins, Director of Center for Structural Biology, Dept. of Chemistry & Molecular Genetics, University of Illinois, USA, "Proteinase inhibition by serpins"

March 27, Dr. Jamie Diaz, "Transport of bacteria through natural porous media. Application in the field of soil bioremediation"

March 27, Associate Professor Kim Lambertsen Larsen, Section of Chemistry, Aalborg University, Denmark, "General overview of cyclodextrins and their applications"

April 4, Managing Director Kenneth P. Morse, MIT Entrepreneurship Center, MA, USA, "Building an entrepreneurial ecosystem: commercializing intellectual property developed in universities"

April 18, Dr. Ronnie Nielsen, Aalborg University, Denmark, "Oriented and non oriented Teflon substrates were used to sandwich and isothermally crystallize poly(butylene adipate)"

April 24, Lindsay R. Merte, University of Washington, USA, "More than the sum of its parts: how microscopy and spectroscopy combined can yield a more complete picture in surface research"

April 24, Professor Moustapha Kassem, Medical Biotechnology Center, SDU, Denmark, "Stem cells: from basic biology to potential clinical applications"

May 2, Associate Professor Anders Kristensen, Dept. of Micro and Nanotechnology, DTU, Denmark, "Nanoimprint lithography"

May 3, Christian Joachim, Director de Recherche, CEMES, Centre National de la Recherche Scientifique, Toulouse, France, "Towards unimolecular machines"

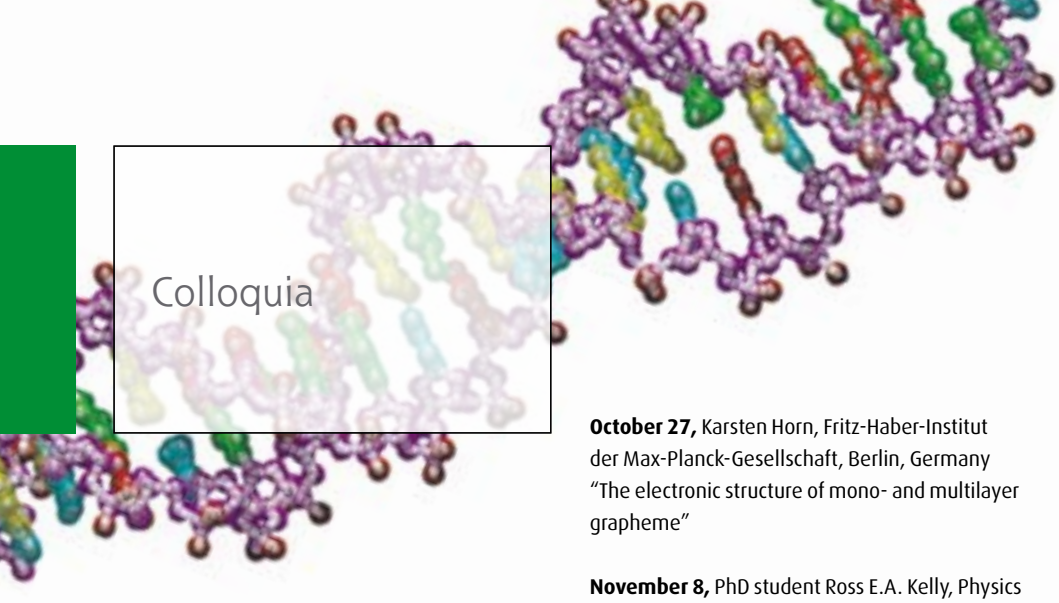
May 9, Kresten Lindorff-Larsen, Dept. of Chemistry, Institute of Molecular Biology and Physiology, University of Copenhagen, Denmark, "Combining NMR and computer simulations to study protein dynamics"

May 23, Dr. Vadim Sumbayev, iNANO, University of Aarhus and Ranvoer Lutzen Kragh, Aalborg University, Denmark, "Biosensors for environmental endocrine disruptors based on conformational changes of oestrogen receptors"

May 24, Dr. Hao Yan, Dept. of Chemistry and Biochemistry, Arizona State University, USA, "DNA-based self-assembly of hierarchical nanostructures"

June 14, Dinshaw Patel, Sloan-Kettering Institute NY, USA, "Small RNAs: mediators of gene regulation, catalysis and silencing"

June 16, Fabrice Gourbilleau, Laboratoire de Structure des Interfaces et Fonctionnalités des Couches Minces - SIFCOM/CNRS, Caen, France, "Optical properties of undoped and rare earth-doped Si-SiO2 layers grown by reactive magnetron sputtering"



Colloquia

June 19, Dr. Brian Julsgaard, "Rare-earth-ion-doped crystals for quantum information processing"

June 20, Dr. Nina Skivesen, Interdisciplinary Nanoscience Center, University of Aarhus, Denmark, "Metal-clad Waveguide Sensors"

June 29, Dr. Ayyoob Arpanaei, Center for Microbial Biotechnology, BioCentrum-DTU, Copenhagen, Denmark, " Obstructing/enhancing DNA binding to chromatography supports"

July 24, Dr. Tamer Uyar, Research Associate, Macromolecular Science & Engineering Department, Case Western Reserve University, Cleveland, Ohio, USA, "Nano-stucturing of polymers with cyclodextrins and development of polybenzoxazines and their application as high performance composite materials"

September 4, Professor Hans Griesser, Ian Wark Research Institute, University of South Australia, Adelaide, Australia, "Designed bio-interfaces for antibacterial coatings and diagnostics"

September 12, Chanyong Hwang, Korea Research Institute of Standards and Science, Daejon, Korea, "Nano magnetism with different magnetic characteristics from bulk"

September 21, Dr. Cyril Aymonier, Institut de Chimie de la Matière Condensée de Bordeaux (ICMCB), France, "Supercritical fluids for the design of nanomaterials. Application to the nanostructuration of the surface or volume of materials"

October 4, Professor Helmut Zacharias, Physikalisches Institut, Westfällische Wilhelms-Universität, Münster, Germany, "Dynamics of associative desorption of hydrogen from metal surfaces"

October 17, Miao Yu, Dept. of Physics, University of Warwick, UK, "Structural investigation of alkylthiolates and atomic sulfur on Au(111) and Ag(111)"

October 27, Karsten Horn, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany "The electronic structure of mono- and multilayer grapheme"

November 8, PhD student Ross E.A. Kelly, Physics Department, King's College London, London, UK, "Modelling DNA base superstructures observed on the Au(111) surface with ab initio DFT methods"

November 8, Professor J. Herbert Waite, Molecular Cellular and Development Biology, Dept. of Chemistry, University of California, Santa Barbara, USA, "From the intertidal shore to medical implants: translating marine adhesion"

November 23, Dr. Francis Taulelle, Institut Lavoisier, Université de Versailles Saint Quentin en Yvelines, Versailles, France, "Developments in NMR crystallography, from principles to applications"

November 30, Associate professor Manos Mavrikakis, Dept. of Chemical and Biological Engineering, University of Wisconsin-Madison, Madison, USA, "Bimetallic and ternary alloys for improved catalysis"

December 4, PhD student Prasenjit Ghosh, Theoretical Science Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore, India, "Lifting of Ir(100) reconstruction by CO adsorption: an ab initio study"

December 6, Dr. Thilo Glätzel, Institute of Physics, University of Basel, Basel, Switzerland, "Kelvin probe force microscopy"

December 8, Dr. Steven De Feyter, Katholieke Universiteit Leuven, Dept. of Chemistry, Leuven, Belgium, "Self-assembly on surfaces, from structure to function: scanning probe microscopy reveals"

December 14, Dr. C. Julian Chen, Scanning Probe Methods Group, Institute for Applied Physics, Hamburg University, Hamburg, Germany, "New concepts in STM and AFM instrumentation"

December 18, Adjunct professor Henrik J. Andersen, Faculty of Science, University of Aarhus, Denmark, "Bionano for food - or how small makes a difference"

iNANO colloquia, Aalborg

February 15, Professor Niels E. Christensen, Dept. of Physics and Astronomy, University of Aarhus, Denmark, "Ab initio calculations of optical properties including e-h correlations"

March 1, Professor Ole G. Mouritsen, Physics Dept., University of Southern Denmark, "Lipid-based nano-technologies in drug delivery"

March 15, Jens Chr. Christensen, Aalborg University, Denmark, "Holographic interferometry"

March 29, Associate Professor Peter Balling, Dept. of Physics and Astronomy, University of Aarhus, Denmark, "Micro- and nano-machining with ultrashort laser pulses"

April 5, Dr. Stefan Maier, Dept. of Physics, University of Bath, Bath, UK, "Plasmonics throughout the electromagnetic spectrum"

April 19, Professor Robert Feidenhans'l, Niels Bohr Institute, University of Copenhagen, Denmark, "X-ray tools in nanoscience"

May 10, Professor, Jens Onsgaard, Dept. of Physics and Nanotechnology, Aalborg University, Denmark, "Photoelectron spectroscopy studies of metal surfaces, interfaces and nanometer thin films"

October 11, Senior Scientist Luise Theil Kuhn, Risø, Denmark, "Magnetic states in Fe nanoparticles imaged by off-axis electron holography"

October 25, Postdoc Anders Mikkelsen, Synchrotron Radiation Research, Lund University, Sweden, "Tailoring the growth of semiconductor nanowires"

November 8, Professor Steven Blair, Dept. of Electrical and Computer Engineering, University of Utah, Salt Lake City, USA: "Nonlinear optics and molecular detection in sub-wavelength metal apertures"

November 22, Professor Ryszard Pyrz, Institute for Mechanical Engineering, Aalborg University, Denmark, "The concept of strain tensor at atomic level"

December 6, Professor Kjeld Pedersen, Institute of Physics, Aalborg University, Denmark, "Quantum well states in thin metal films"

December 20, Senior Scientist Morten Foss, iNANO, University of Aarhus, Denmark, "Proteins and cells on topographically structured tantalum"

Staff

Appointments of staff associated with iNANO in 2006

Brian Bech Nielsen was appointed
Vice-director of iNANO

Duncan Sutherland was appointed
Associate Professor at iNANO

Peter Kingshott was appointed
Senior Scientist at iNANO

Poul Nissen was appointed
Professor at Department of Molecular Biology

Trolle R. Linderoth was appointed
Associate Professor at Department of Physics and Astronomy

Esben Skipper Sørensen was appointed
Associate Professor at Department of Molecular Biology

Senior Staff

Andreasen, Peter, AU
Autrup, Herman, AU
Balling, Peter, AU
Besenbacher, Flemming, AU
Birkedal, Henrik, AU
Bozhevolnyi, Sergey, AAU
Bünger, Cody E., AU
Bøttiger, Jørgen, AU
Baatrup, Erik, AU
Christensen, Niels Egede, AU
Diekhöner, Lars, AAU
Duch, Mogens, AU
Daasbjerg, Kim, AU
Enghild, Jan Johannes, AU
Fago, Angela, AU
Foss, Morten, AU
Gothelf, Kurt Vestager, AU
Hammer, Bjørk, AU
Hofmann, Philip, AU
Iversen, Bo Brummerstedt, AU
Jakobsen, Hans Jørgen, AU
Jensen, Jan Egebjerg, AU
Jensen, Torben René, AU
Keiding, Søren, AU
Kingshott, Peter, AU
Kjems, Jørgen, AU
Knudsen, Charlotte Rohde, AU
Kristensen, Martin, AU
Larsen, Arne Nylandsted, AU
Larsen, Kim Lambertsen, AAU
Lauritsen, Jeppe Vang, AU
Linderoth, René Trolle, AU
Lægsgaard, Erik, AU
Malmendal, Anders, AU
Meyer, Rikke Louise, AU
Nielsen, Brian Bech, AU
Nielsen, Niels Chr., AU
Nielsen, Per Halkjær, AAU
Nissen, Poul, AU
Ogilby, Peter Remsen, AU
Olsen, Jeppe, AU
Otzen, Daniel, AAU
Pedersen, Finn Skou, AU
Pedersen, Jan Skov, AU
Pedersen, Kjeld, AAU
Pedersen, Thomas Garm, AAU
Pyrz, Ryszard, AAU
Revsbech, Niels Peter, AU
Schiøtt, Birgit, AU
Sigsgaard, Torben, AU
Skibsted, Jørgen, AU
Skrydstrup, Troels, AU
Stapelfeldt, Henrik, AU
Stensgaard, Ivan, AU
Sutherland, Duncan, AU
Svaneborg, Carsten, AU
Søballe, Kjeld, AU
Søgaard, Erik G., AAU
Sørensen, Esben Skipper, AU
Sørensen, Jens Lykke, AU
Vorup-Jensen, Thomas, AU
Vosegaard, Thomas, AU
Østergaard, Leif, AU

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