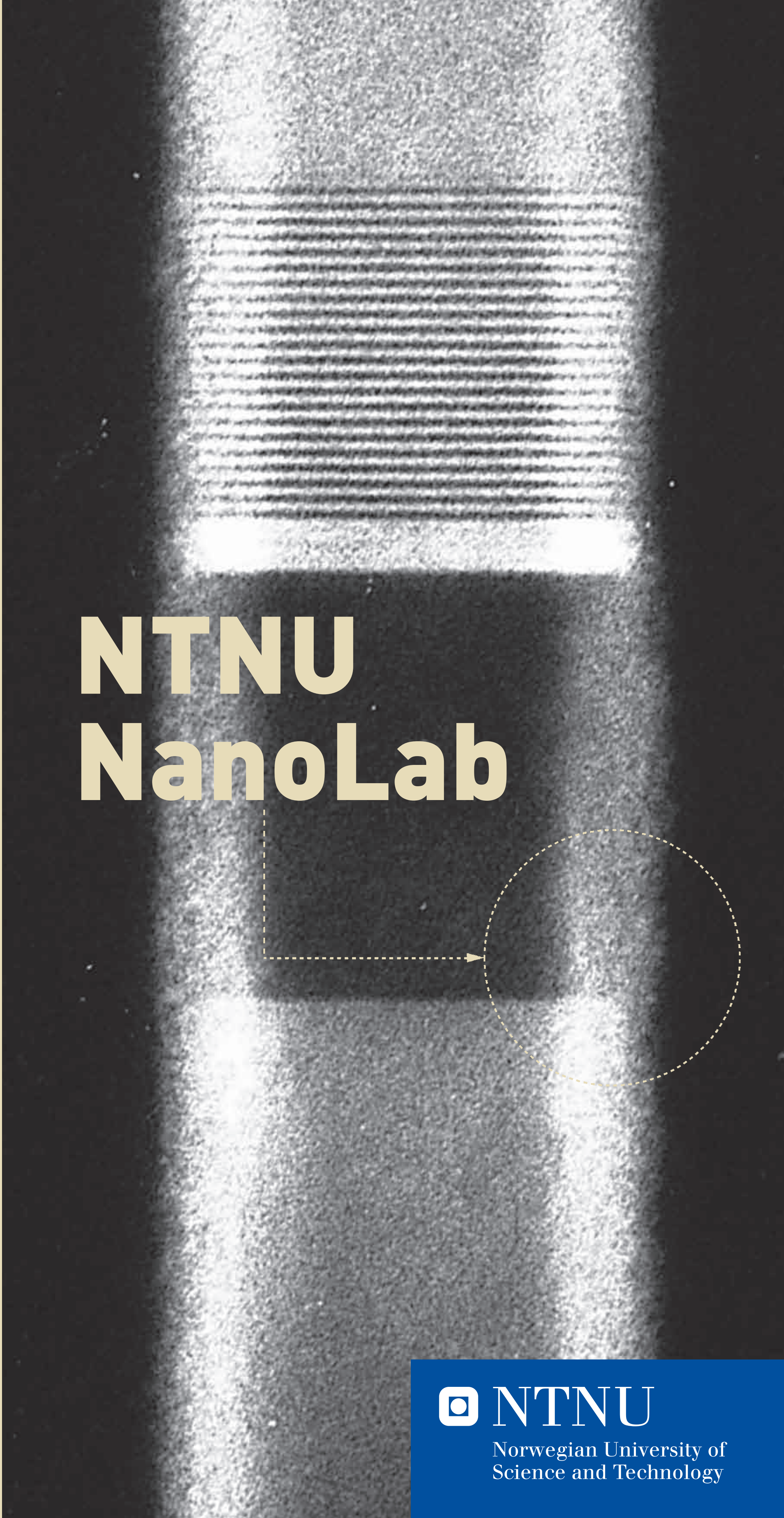
Annual Report 2008

NTNU NanoLab



NTNU
Norwegian University of
Science and Technology

About NTNU NanoLab

NTNU NanoLab was established by the Board of NTNU in 2004 as the university's coordinating initiative within nanoscience and nanotechnology. The mission given to NTNU NanoLab was to:

- coordinate nanotechnological research and capital investments at NTNU
- build, equip and operate a new state-of-the-art laboratory for nanotechnological research and education
- promote a new 5 year MSc program in nanotechnology

The initiative currently comprises departments at five faculties: The Faculty of Natural Sciences and Technology, The Faculty of Information Technology, Mathematics and Electrical Engineering, The Faculty of Engineering Science & Technology, The Faculty of Medicine and The Faculty of Arts,and is run in close cooperation with SINTEF.

Visit us at www.ntnu.no/nanolab/

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Photo front page: Dark field TEM image of GaAs nanowire with GaAsSb insert. Nanowire grown by MBE at IET (Weman, Fimland, Dheeraj). Image taken by S Grønsberg (IFY / TEM Gemini Centre). For more details see: DL Dheeraj et al., "Growth and characterization of wurzite GaAs nanowires with defect-free zinc blende GaAsSb inserts", Nano Letters, 8, 4459-4463, 2008.

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NTNU NanoLab 2004-2008

The first five years of NTNU NanoLab have resultet in the establishment of nanoscience and nanotechnology on the strategic agenda of research, higher education and innovation at NTNU. Nanotechnology is expected to contribute significantly in many areas of research and industrial applications, e.g. materials for sensor technology, materials for cleaner combustion, membranes for separation of gases, and targeting of nanomedicine for diagnostic and therapeutic applications. While still in the start-up phase, the scale of resources and scientific commitment bodes well for the ambition of developing nanotechnology at NTNU more broadly to inter-national recognition.

The first five years have been marked by design and construction of research infrastructure hiring of permanent scientific staff, as well as shifting part of the scientific profile of NTNU towards nanotechnology. A MSc degree in Engineering in Nantotechnology has been developed, and the number of applicants is promising.

In March 2005 the Board of NTNU granted 145 MNOK for the construction of a cross-disciplinary cleanroom facility. It was expected that this facility would enable NTNU to become a national centre and an international team player in nanotechnology. In 2005 the contract for construction of the first part of the integrated laboratory, the area for chemical methods, was signed. The official opening of this part of the laboratory, by Professor Astrid Lægreid, Pro Rector Research and Innovation, in March 2007 was a significant milestone. The plans for the remaining area of the 700 m^2 laboratory were finalized during the autumn of 2007. The construction of a new building, adjacent and connected to the chemical section, was started in January 2008. In May 2009, the second significant milestone will be the opening of the entire laboratory, designed to host numerous interdisciplinary research activities. The goal is to enable nanotechnological research emerging from classical disciplines such as physics, chemistry, biology and engineering disciplines such as microelectronics and materials science and engineering. The laboratory infrastructure is expected to support both basic and applied science, enabling development within areas spanning from medicine to space technology, from energy and environment to materials science, and from generic competence building to innovation. Efficient and stable operation of such an advanced facility requires a highly qualified technical staff, as well as well designed workflow. The hiring of technical staff has started, and by the end of 2008 three highly qualified engineers were employed. NTNU NanoLab also has a high awareness of HES challenges related

Thomas Tybell, director of NTNU NanoLab, Bjørn Torger Stokke, chairman of NTNU NanoLab's board, Erik Wahlstrøm, acting director of NTNU NanoLab.
Photo: Ida Hederström

to nanotechnology, e.g. exposure of various nanomaterials. A compulsory user course on HES issues has been established. The goal is to have continues focus on good laboratory practice in order for the lab to be an excellent and safe workplace for students, researchers, and technical staff.

Alongside the establishment of the research infrastructure, positioning nanotechnology on the strategic research agenda has largely contributed to the success so far. The involvement of the scientific staff has been essential in this effort. We were also happy to welcome three new faculty members to NTNU, hired specifically to strengthen the nanotechnology initiative within central fields for NTNU. Professor Helge Weman was appointed at the Department of Electronics and Telecommunications, and focuses on nanophotonics and optical devices based on nanowires. Associate professor Pawel Sikorski at the Department of Physics investigates how nanostructured materials harvested from nature can be employed in specific applications. Associate professor Fride Vullum, recently appointed at the Department of Materials Sciences and Engineering, focus her research on efficient lithium batteries and photo-voltaic materials. Furthermore, various departments at NTNU have hired new scientific staff within nanotechnology related to their scientific domain. Totally this adds up to a strong scientific environment, with essential team players in our continuous efforts towards excellence.

The NTNU NanoLab facility has been planned in a national context from start. The process profile has been developed in cooperation with SINTEF. We also enjoy collaboration with other key national stakeholders in the field. In order to be strong both nationally and internatio-nally, we are in the process of establishing a national network for micro and nano processing: Norwegian Micro and Nano Fabrication Facilities (NMNF). The participating laboratories will have complementary state-of-the-art infrastructure, providing a strong national basis for nanotechnological research. NTNU has also been awarded the role as coordinator of the new national research school "Nanotechnology for Microsystems", in which NTNU NanoLab will be a key resource.

We would especially like to highlight one event in 2006, the welcome of 30 students to the new interdisciplinary MSc in Engineering in Nanotechnology. From the start the students were introduced to current challenges and possibilities in different fields such as nanoelectronics and bionanotechnology, as well as ethical and health issues. They rapidly picked up speed, not only with the curriculum, but also with extra curricular activities such as forming a student association, Timini hosting new "classical festivities" such as the Bucky Ball. This program has established itself as a program recruiting resourceful students, and thus contribute to increase the interest for natural sciences in general. We anticipate that the graduates of this program will provide strong resources to existing and yet unborn Norwegian industry. Moreover, the new infrastructure will allow the students, at the MSc level within both nanotechnology and related topics of other study programs at NTNU, to get training on state-of-the art nanotechnological tools.

A key activity has been to promote nanotechnological activities at NTNU. To this extent, organizing the annual NTNU NanoLab Users Meeting has been an important instrument. These meetings focus on the cross-disciplinary possibilities nanotechnology can offer. In 2006, 40 researchers gathered for the first meeting, and in the following years we have enjoyed increasing attendance. A highlight of the outreach activity was the hosting the symposium 1st Nanotechnology@NTNU in conjunction with the awarding in 2008 of the first Kavli Prizes in Nanoscience. The official Kavli lecture by one of the laureates in Nanoscience, Louis E. Brus, was given at NTNU, and our symposium also hosted the other Kavli Laureate Sumio Iijima as well as other distinguished nanoscientists; Flemming Besenbacher from Aarhus University, Thomas Bjørnholm from Copenhagen University, Thomas Ebbesen from Université Louis Pasteur, Herman Gaub from Ludwig Maximilians University Munich, Hans Mooij from the Kavli Institute of Nanoscience, Delft University of Technology and Michael Roukes from the Kavli NanoScience Institute at California Institute of Technology.

The management of NTNU NanoLab gratefully acknowledge the sincere dedication and motivation shown by the various parties in their contribution to establish nanotechnology at NTNU. To some extent, a dream is in the process of coming true. The volume of the investment, the high expectations, and recognition of the broader responsibilities associated with the field are all factors indicating the commitment so far. Although significant achievements are identified, it is actually from now on that we are in position to contribute significantly to the field of nanotechnology. It has been a long and rewarding road from the publication of the report "Nanotechnology at NTNU 2003". The former rector of NTNU, Eivind Hiis Hauge will in this annual report reflect on what is realized so far and the road a head.

Finally, we strongly encourage the scientific community to take the opportunity to join in this ongoing scientific and technological journey towards excellence in nanotechnology.

Bjørn Torger Stokke
(Chairman of NTNU NanoLab)

Thomas Tybell
(Director of NTNU NanoLab)

Erik Wahlstrøm
(Acting Director of NTNU NanoLab)

Eivind Hiis Hauge wasn't quite sure what kind of offspring he would bring to life when he fostered the nanotechnology research area at NTNU. But he figures that the new kid on the block will be a healthy one! Photo: Arne Asphjekk/NTNU Info

Science for the passionate

Nano research will only succeed if we find enthusiasts who are willing to see beyond their own disciplines.

In 2002, a new rector took charge at NTNU. His name was Eivind Hiis Hauge. He was 64 years old and a professor of theoretical physics. One of his first efforts as rector was to appoint a committee. It was a highly professional committee, loaded with heavyweights, with participants from four countries and several disciplines. Their job was to discuss how the emerging field of nanotechnology should be handled at NTNU. The committee's report and recommendations came the following year. The rest, as they say, is history.

You could say Eivind Hauge is history too, in the sense that he has now joined the ranks of the emeriti and no longer has any institutional power to exercise – not for studies, strategies, committees, study programs or laboratories. But this child he helped conceive he still keeps an eye on. And if he doesn't say so himself: It is a very promising child indeed.

Why this interest in nanotechnology?

– It was perhaps mostly due to the fact that I had changed research in the 1980s. From being involved with statistical physics I went to work on electron transport in small structures. The electrical engineering group had gotten itself a fine, expensive MBE machine (Molecular Beam Epitaxy), which could create layered structures for electronics purposes. This should be interesting stuff, and the group wanted to have physicists on the team. But the physicists were reluctant: They had enough to do with their own research, thanks. I found that quite vexing, so I said I would try. It was a demanding, but fun change. The structures were becoming smaller and smaller, and dimensions were shrinking below one micrometer, on the way down to the nanometre. In that realm quantum mechanics is needed to understand what is happening, and that makes it really interesting. It didn't go quite as hoped with the MBE project. The research labs of the National Telephone Company and The Norwegian Defence Research Establishment wanted to have their own machines, and funding for ours became difficult. But as a theorist, I was not as bothered by tight funding. I had a sabbatical year in the U.S. in 1988/89 and was a researcher in residence in Delft in 1992, and came in contact with some of the best groups in nanotechnology. Then I understood that great things were about to happen in this field, at least in electronics and physics. Later, materials and biology came into the picture.

So when in 2002 you had the power and authority, you thought ...?

– That it was wrong that the country's most prestigious technology institution didn't have a research and educational strategy for such an important area! And that the subject was so large and complex – and also so expensive experimentally – that it would never grow organically from below, as a kind of grassroots movement. In that kind of situation it is essential that the top management the initiative, put the structure and framework in place, and create opportunities. That way all the scientific enthusiasts, the guys and girls "in the trenches", could come and realize their own projects. The Research Council of Norway eventually had the idea to establish national efforts in several areas, it created major programs and wanted to have NTNU as one of the engines. That gave us the opportunity to take a chance and be on the offensive: The board went along with a commitment to nanotechnology, we set aside some funds of our own, hired competent people and initiated projects. From there, the ball began to roll -- slowly.

What kind of vision did you have at the time?

– Nothing precise. It was quite obvious that there would be important innovations in physics, chemistry, electronics, biology, materials and medicine – but no one could know precisely what. And the subjects are so intertwined: A step forward in one area can provide opportunities for breakthroughs in a completely different area. History also shows how closely the interaction has been between technological developments and basic research. Actually, it is meaningless to talk about nanoscience and nanotechnology as if they were two completely different disciplines; there is no clear distinction between them. Interaction across disciplines is also essential and has proved to be extremely fruitful. The guy who sits with his very focused basic research and the woman who dreams up the most fantastic visions – they are both needed in nanoscience. Infinite views frequently end up in ditches, but still: Without drive and enthusiasm, and without imagination, we'd never get anywhere.

What do you see as the challenges ahead?

– Some are trivial, related to equipment. We are talking about expensive and complex equipment, and you cannot hand it over to students to run it. There will certainly be a need for more technicians, among others. But the most important thing is to see scientific opportunities together, and explore them together, both researchers and students. The quality of our students is impressive, and that is obviously an inspiration for teachers. So all we need to do is to find good projects to put the students on. NTNU's nanotechnology education hasn't yet found its optimal form. With so many parties involved, it is difficult to get all the courses, laboratories and lectures to fit together. Maybe a separate program of study won't be the right way in the future? But I'm not very concerned about this, it will work out somehow.

Can NTNU's nanotechnology group be internationally cutting edge?

– Right now it's too new. But why not? It will be demanding, and it won't happen on its own -- but it can be done. The Centre for the Biology of Memory is an example. The Moser husband-and-wife team and their research didn't exactly fit into the main institutional strategies, but the management at NTNU recognized the outstanding qualities of the team, and helped provide the framework. Now the centre attracts the world's best scientists. It could happen here again, and the nano group is starting to attract some very good people in some areas. It's important that we are thinking: What can I use his expertise for?" "What can she and I do together?" That we crawl up from our own scientific hole, take a deep breath and look around us. That we make an effort to understand some of the other subjects - maybe even have a little respect for people who are not researchers.

People are pretty busy, aren't they?

– All good scientists always have too much to do! And yes, it is difficult to think in an interdisciplinary way, it is difficult to learn new dialects. So our first reaction will tend to be: "Don't come here and bother me with new opportunities!" It's important that we look up and see that it's possible to get things done when we work together. That the framework of NTNU NanoLab is now here, and that it is possible to steer work in that direction. Everything will depend on enthusiastic scientists working together and finding their niches in this incredibly diverse, global field of research: nanoscience.

Establishment of Cleanroom Facilities

The construction of the cleanroom facilities has been one of the core efforts of NTNU NanoLab since the activities started. The work sprung out of the report *Nanotechnology at NTNU* given by an advisory committee of international experts in 2003. Since then, the the planning of the cleanroom has been carried forward by three committees in conjunction with NTNU's Technical Division. As mentioned above, the first part to be built was the cleanroom area for chemical methods, which was opened for users in 2007. The planning of the larger cleanroom area has been an ongoing process since 2005 until 2008.

Great emphasis has been put on designing a flexible infrastructure that may easily be adapted to future demands. In addition to specialized equipment, the facility includes general support laboratories, offices and meeting areas. During 2008 the revised plans for the cleanroom infrastructure were finalised. The cleanroom was finished December 2008 and the complete facility will be commissioned during the spring of 2009.

A major part of the establishment of the NTNU NanoLab's infrastructure is the build up of efficient and safe routines, including a competent staff. By the end of 2008 three engineers were hired, and the work to put the laboratory into operation in a safe and knowledgably manner had been initiated.

The entire cleanroom area will cover over 700 m^2 and is designed to be GMOII: 2 compatible. The facilities will be organized in several zones equipped for various purposes:

- Area for chemical methods
- Area for physical methods
- Area for bionanotechnological methods
- Area for characterization
- Area for education

These areas will hold cleanness between class 10.000 and 100 and offer vibration free zones down to VC-E. The laboratories will be furnished with state-of-the-art equipment for nanotechnological research within prioritized areas, complementing the facilities of SINTEF's MiNaLab in Oslo.

The area designated for chemical methods has been especially equipped for structuring and characterization of nanomaterials and nanoparticles. Available processes / instrumentation include:

Chemical syntheses:

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

Nanoscale characterisation:

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

View from the cleanroom area for chemical methods. Photo: Anne Støre

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

- Thin film growth: sputter deposition, plasma enhanced chemical vapour deposition (PECVD), e-beam deposition, metallisation.

The FIB in the cleanroom area for physical methods. Photo: Ida Hederström

- Lithography methods: Dual beam focused ion beam etching system, DUV-lithography, e-beam lithography and nanoimprint lithography.
- Etching methods: wet etching, dry etching [Reactive ion etch, inductively coupled reactive ion etch (ICP-RIE), plasma etching].

During 2008 the upgraded e-beam lithography machine based on a Hitachi 4300-SE with laser interferometric stage was installed temporarily at the old cleanroom at the Department of Electronics and Telecommunications. Another important purchase has been the ICP-RIE which will be installed during spring 2009. Otherwise the main focus has been on the purchase process of a dual beam focused ion beam system, in conjunction with a high resolution SEM with STEM capabilities, which will fulfil the needs of nanostructuring, 3D slice and view as well as TEM sample preparation.

The area dedicated to bionanotechnology will incorporate tools for nanoscale fabrication based on biological methods or fabrication using biological materials. Key activities will include work on nanostructured surfaces functionalized with biological molecules for applications in sensors and devices, work on biopolymers, studies related to drug delivery and fabrication of new contrast agents for medical imaging and characterisation of single molecules and nanostructured biomaterials. The facilities will also allow work with cells and microorganisms.

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

- High resolution Scanning Electron Microscope (SEM)
- Two darkrooms for optically demanding characterisation and manipulation (combined AFM/optical microscopy, spectroscopy, optical tweezers).
- AFM suitable for wafer inspection.
- Smaller process monitoring equipment.

The area for education is separated from the research area and allows for full photolithography processing. This area will also serve experimental processing, and be equipped with:

- Maskaligner for photolithography
- Wet processing equipment
- Education STMs and AFMs

In addition to the cleanroom areas, the infrastructure includes supporting and technical facilities, laboratories for chemical and biological work, as well as offices, meeting rooms and areas for seminars. Installation of a fibre drawing tower has also been planned in conjunction with the laboratory.

The laboratories will be open to all resear-chers interested in nanotechnology, at NTNU, SINTEF and other Norwegian re-search organisations.

Study Program in Nanotechnology

A new MSc program in nanotechnology was launched in 2006.

A part of the assignment given to NTNU NanoLab in 2004 by Board of NTNU was to initiate a 5-year Master program in nanotechnology. Thus, in 2006 NTNU's master's program in nanotechnology was launched for the first time. An aim of the program was to give the students a solid broad background in the basic scien-tific fields that merge within nanotechnology. This has led to a cross disciplinary curriculum, with many different Departments and Faculties. The program appeared to be very attractive, with 1430 applicants for the 30 places offered. How is the situation now?

Professor Bjørn Erik Christensen, head of the board of Master's program in nanotechnology says it has been a challenge to put together a program consisting of so many different subjects.

– We are lucky to have so many great students that do not let themselves be frustrated by all the changes we have to make during evaluation. The students are very committed to their field of study. Their feedback has helped us develop a better program in nanotechnology, says Christensen.

One of the challenges of making this new cross disciplinary program has been that every faculty wants to have a say in how much the students should learn within the various topics included in the curriculum. Should they learn more physics? More nanoelectronics? An important challenge in making this program has been to ensure that the students learn enough within the various scientific disciplines so that they end up as highly qualified nanotechnologists.

– In addition to the courses already offered at NTNU we had to create brand new, specialized courses. When every student is to have one nanorelated course each semester whilst having the right subject combination and the correct progress, it has lead to some reorganizing. I think, however, that we have everything in place now, though we will always have to evaluate as we go along, Christensen says.

Like many others, Bjørn Erik Christensen is very happy that the cleanroom of NTNU NanoLab now is finished and ready to be used by the students of the program from the autumn of 2009. He hopes many interesting nanoprojects for students will emerge that include experimental work in the cleanroom. The "hands-on" policy of NTNU NanoLab, allowing the students to handle advanced equipment themselves will give them excellent training.

The nanotechnology students scored the highest on their exams out of all the programs at NTNU. According to Christensen, this might be because nanotechnology is the hardest program to be accepted in to. However, the nanostudents have been very efficient in creating a nice study environment, and there has been hardly any drop outs so far, says Christensen. However, he still sees challenges ahead with regards to maintaining the program's reputation and quality.

– The biggest challenge is to always offer the subjects most relevant for nanotechnologists as well as obtaining a well coordinated schedule. As some subjects have students from several different programs, it may be a challenging job for the lecturers to set up their curriculum so that everybody learns exactly what they need. We still have some work to do in this respect with the brand new courses of the program. Another challenge is that the nanostudents do not belong to one specific department. Thus, there may be a conflict of interest when the board of the program asks for the best

Bjørn Erik Christensen.

quality possible and the departments are faced with the financial costs.

Christensen is, however, not concerned that the students will suffer from the lack of a home department. In his opinion they are privileged to have the opportunity to get insight in all of these scientific areas. With all these departments involved, this might well be the largest cooperative project at NTNU right now.

Getting impulses from all these different scientific communities must be very inspiring and useful for the coming generation of nanotechnologists. With NTNU NanoLab open, the infrastructure is in place. If the cleanroom is filled with activity and the organization of the program runs smoothly, the future of this master's program looks very bright. And to students on other programs:

– You don't have to be enrolled in the master's program in nanotechnology in order to work with nanotechnology at NTNU. Several other study programs offer nano-relevant specialisations and projects that will involve work in NTNU NanoLab's cleanroom, ensures Christensen.

Marianne Sandvold is on her second year of the Master program in nanotechnology and has been elected president of the student organization Timini. They work with improving the social environment for nano students, particularly with giving new students a good welcome. Timini also acts as the student's representatives in matters regarding the study program. Marianne thinks her time so far at NTNU has met her expectations.

– Yes, I think so. At least academically. I was expecting a challenging program which would allow us to study across different scientific fields. At this point I feel that my expectations have been met. I have to admit that I was hoping for better lecturers, but that is more in general for the university, rather than specifically for the nanotechnology program, says Marianne.
There has been some discussion about the nanotechnology students not having a

Marianne Sandvold, head of Timini.
Photo: Ida Hederström

"home department" like other students at NTNU, but Marianne doesn't see this as a big problem. The only drawback is that the students don't have anyone between the head of the faculty and themselves when they want to communicate something. They do however have representatives in the study program council and so far have been able to present all their issues there. She also points out that they've had a good connection with Jo Esten Hafsmo, who is head of the Study Section at the Faculty of Natural Sciences and the voice of the nanotechnology students.

When asked what she has enjoyed the most so far in the program, Marianne has one favourite.

– It has been fun to work with nanoequipment in the course "nanoverktøy". It is quite unique that students in their second year already get to handle so advanced instruments themselves. It makes it easier for us to understand how things work which is very motivating.

Marianne really likes her study program, both the curriculum and the social side of it. In her first year, she was a bit disappointed by some of the lecturers. She felt that the lecturers were teaching because they had to, not because they wanted to. But now, in her second year, the lecturers have improved. She feels that the introduction course to nanotechnology also needs improvement. It is supposed to work as a motivation and give an insight to what's ahead. However, the course has no clear curriculum and she thinks there really should be a visit to the laboratory involved.

Since the Master program in nanotechnology was established in 2006, the students have to be active in evaluations and give a lot of feedback to the Board for the study program. Marianne explains that there have been many changes along the way.

– There have been many discussions and many things have been changed. Subjects have been merged, and later separated again, upon the student's request. Some subjects could maybe be placed differently, but we understand that this is a new program that has to go through some changes before settling properly. Another area of improvement is the information given to second year students regarding their choice of specialization for the following three years. A better job should be done on informing about this in the future, says Marianne.

The students are very enthusiastic about the new NanoLab. They've had access to two labs at the existing cleanroom, but this will be something totally different. During their fourth year, the students will be allowed inside the NanoLab, something they are looking forward to. Marianne finds it exciting that NTNU has put so much effort into this program and nanotechnology in general.
It is nice to see that this actually happened instead of remaining as another idea on paper.

As a second year student, Marianne is now glad to see that she is working on more subjects related to nanotechnology, and she has great expectations for the last three years of her study program.

– I expect the program to narrow down as I proceed to the third year. I am now in my fourth semester and I have more and more nano related subjects and I hope even more are ahead. I also hope that the industry opens its eyes to nanotechnology and come to visit us at NTNU. There is a job to be done in marketing the new opportunities, because nanotechnology is relevant for many areas of the industry. That is what makes nanotechnology so exciting, that the field is so wide. But I think people will notice the nanotechnologists here at NTNU, especially when we graduate and start working. That is still in the future, says Marianne Sandvold, head of Timini.

Student activities; Eirik Timo Bøe Vilpponen becomes acquainted with the teaching STEM in the cleanroom. Photo: Roya Deghan.

Strategic Positions

NTNU NanoLab is strongly committed to its founding vision of opening nanotechnology to cross disciplinary research at NTNU. In 2003 an advisory committee of international experts recommended four broad areas of research as particularly relevant:

- nanostructured materials
- bionanotechnology
- nanoelectronics, photonics and magnetism
- nanotechnology for energy and the environment

In 2004 the board of NTNU allocated three academic positions as a strategic means to promote the research activity within the three first of these four areas. How is progress? We have asked the staff members hired for this purpose to tell us more.

Associate professor Fride Vullum

Fride Vullum has her Ph.D from Tulsa University (USA). Why Tulsa? Well, they rewarded her performance in long distance running with scholarships and she was fascinated by their research on nano materials. She joined NTNU as a post doc. late 2005, and was offered a position as associate professor at the Department of Materials Science and Engineering in September 2008. Drawing on her past experience, she has initiated research on lithium batteries and solar cells. Noting that these are areas of strong commercial interest and considerable research internationally, she explains her approach:

Associate professor Fride Vullum. Photo: Ida Hederström

– Lithium batteries consist basically of three parts: the anode, the cathode and the electrolyte. Much research is focused on improving the characteristics of each of these components. I believe we have our best chances with a total system approach. In other words, we will consider how the potential of nanotechnology can be exploited to optimize the characteristics of the components to give over all better batteries.

This sounds like a good idea. But isn't it rather obvious? Isn't that what everybody would be doing?

– The goal may be simply stated, but reaching it is actually far from trivial. It requires the combined efforts from several areas of detailed study. For example, in the design of cathodes, you obviously wish to improve the mobility of Li-ions and reduce diffusion length. In practice there could be trade-offs here, in particular when other characteristics such as storage capacity and safety are taken into account. This is just one example. In fact, there are many options and choices required when you start analysing the complete battery in real detail. And then there is always the challenge of finding solutions that can be produced industrially at realistic prices. I think the state-of-the-art is now such that the time is right for organized efforts at the total system level.

Solar cells based on silicon would seem to be another well established area of research. How can NTNU NanoLab expect to raise its head in the crowd?

– The point here is that we are not starting from scratch. Research on silicon is a well established area at our university. NTNU NanoLab offers an expansion of this activity into a broader choice of processing techniques. As an example, I am looking forward to see what we can achieve using chemical vapour deposition (CVD) to synthesize new materials for third generation photovoltaics in addition to thin film deposition on conventional silicon wafers to improve the efficiency of light conversion.

Fride has clear ambitions. How does she view the realism of her aims in view of the recourses at NTNU NanoLab?

– The laboratory has reached a high standard in instrumentation and professional skills. It remains to be seen if we manage to keep the level of funding sufficient to fill some remaining holes, and maintain state-of-the-art standard over time. The research we are initiating now will surely produce some interesting publications, but establishing NTNU NanoLab more broadly as a research centre at international level will depend on the quality of our work and the support for the laboratory in the long run, I think.

In the long run . . . With a half-marathon at 1hr 16 min Fride knows all about the importance of concentration of effort and consistency of purpose.

Associate Professor Pawel Sikorski

Pawel Sikorski has been involved in the NTNU NanoLab project since 2005. He arrived at NTNU in 2002, having completed his PhD in physics at University of Bristol, UK, in 2001, and graduated from Wroclaw University of Technology, Poland, in 1998. At NTNU he works with both physics and bionanotechnology, and at times he feels

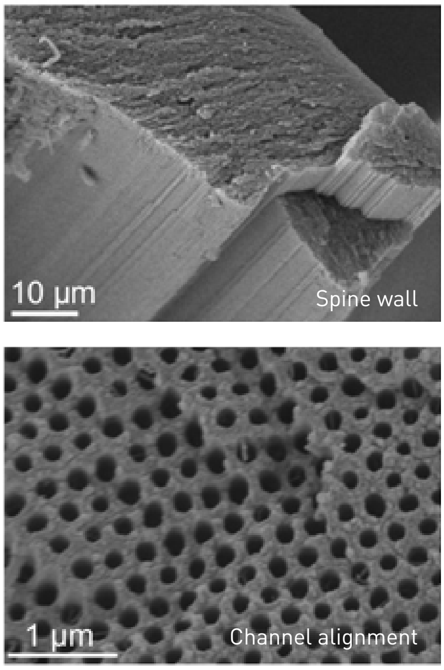
Associate professor Pawel Sikorski. Photo: Ida Hederström torn between these two fields. But that just reflects the broad cross-disciplinary nature of nanotechnology:

– The new thing about nanotechnology is that on nm-scale the traditional borders between the different research disciplines fade. Nanotechnology is a science that crosses the borders of many other sciences, including physics, chemistry, biology and biotech-nology,and material science. This is mirrored in the curriculum for the of NTNU's master in nanotechnology study program (MTNANO). We can achieve a lot, if we combine challenges from, for example medical field, with the nanotechnology insights from the physical and engineering sciences here at Gløshaugen. It is exciting and challenging.

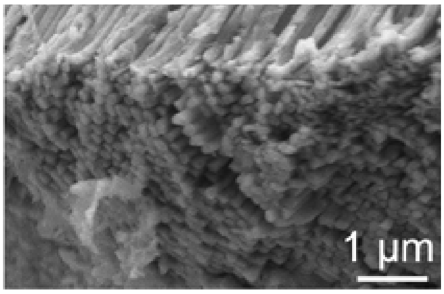
Pawel's own work is a good example – combining inspiration from nature with the resources of NTNU NanoLab to produce nanowires. These "wires" are 150 nm in diameter and can be up to 1 cm long. The fabrication process is based on using biological templates (template is a kind of "mould") harvested from a sea worm called

Sea Mouse and colours produced by its nanostructured spines and hairs.
Photo: Florian Mumm

Sea Mouse. This animal is covered with spines and hairs, each of them having a very special internal structure. They contains thousands of nanochannels ordered in a in a densely packed array, extending the length of the spine/hair. The service to the Sea Mouse of this structure is that the spines refract light in rainbow-like beauty. The service to Pawel is that the structure can be used as a template for production of nanowires. The trick is to fill the channels with organic or inorganic material, from which he would like to make nanowires. The next step is to dissolve and remove the material of the template. If all goes well he is then left with a fair supply of nanowires.



High magnification SEM micrographs showing a dense array of nanochannels.
Photo: Florian Mumm



ZnO nanowires.
Photo: Florian Mumm

Sure enough, all does not go well easily, but Pawel is optimistic:

– Our results are encouraging, and the perspectives are open ended. The nearest applications of nanowires are in electronics. I think we can achieve a lot by using or imitating biological systems in our production of such components. But that is only one aspect. In fact, plants and animals consist to a great extent of nanostructured materials, and I am very confident that in a fusion of medical and biological research with physics at the nano level we find opportunities beyond our present imagination. NTNU NanoLab will be a key resource for this type of cross-disciplinary research.

From the visionary clouds Pawel sees some down to earth challenges:

– We face on one hand the need to engage in a broad cooperation, not only within NTNU but also including SINTEF and industry. The students will get valuable experiences by working with projects within different industries, and this also shortens the way from our research to industrial applications. Personally, I have fruitful cooperation with research groups in UK, Finland and Japan, and will seek to broaden the international framework of our scientific cooperation.

While stressing the need for broad cooperation, Pawel also thinks it will be important to concentrate the efforts:

– Nanotechnology is a demanding field of research. NTNU NanoLab will offer a very powerful infrastructure with first class instrumentation and a highly qualified staff. This allows the scientists to spend more time doing research. But if we shall gain international recognition, we cannot cover everything. If we can keep NTNU NanoLab up to date, and if we are able to agree upon a few niches we can put our combined efforts into I am certain that we will succeed! It is an exiting time. The train is leaving now, he says.

Pawel Sikorski hopes that more researchers at NTNU will get on board the train and he is excited to see what discoveries will be made. And he is sure that amazing discoveries will follow.

Professor Helge Weman

Helge Weman came from the Swiss Federal Institute of Technology in Lausanne (EPFL) to NTNU in September 2005 and brought many years' experience from research in nanotechnology within photonics and electrooptics with him. Together with Prof. Bjørn-Ove Fimland he uses the MBE (Molecular Beam Epitaxy) machine at the Department of Electronics and Telecommunications to produce free standing nanowires with carefully controlled parameters. Helge explains:

– The nanowires are typically 10-100 nm in diameter, and several micrometers long (Figure 1a). We can control the composition and crystalline structure both axially (Figure 2) and radially (Figure 1b). Or I should say, we are learning to control the parameters more and more accurately to produce nanowires with the desired characteristics.

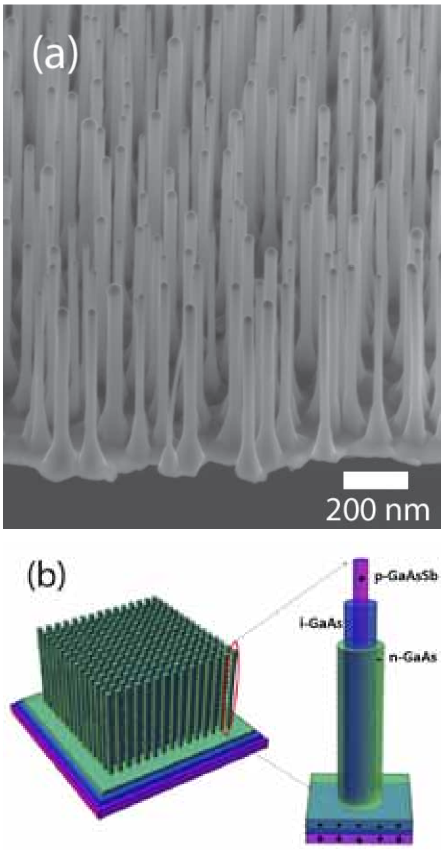


Figure 1 (a) SEM image of GaAs based core-shell nanowires grown by MBE at NTNU. (b) Schematic diagram of a radial p-i-n junction designed for a new nanowire solar cell project.

And where does the desire come from?

– I produce nanowires to demonstrate in practice the characteristics that calculations from quantum mechanics predict in theory. The better we do this, the better we can produce components for practical applications. The linkage to theory is essential. Without theoretical guidance there are too many possibilities. We can now also measure the electro-optical properties of individual nanowires in a new nanophotonics lab I have set up at NTNU, which together with structural characterization at the atomic level gives the necessary feedback for the growth. Basically I work with gallium arsenide (GaAs) and additions of other elements to demonstrate for example quantum mechanical effects by measuring the light from a nanowire with a single quantum dot inside (Figure 2b). Basic research, in other words.

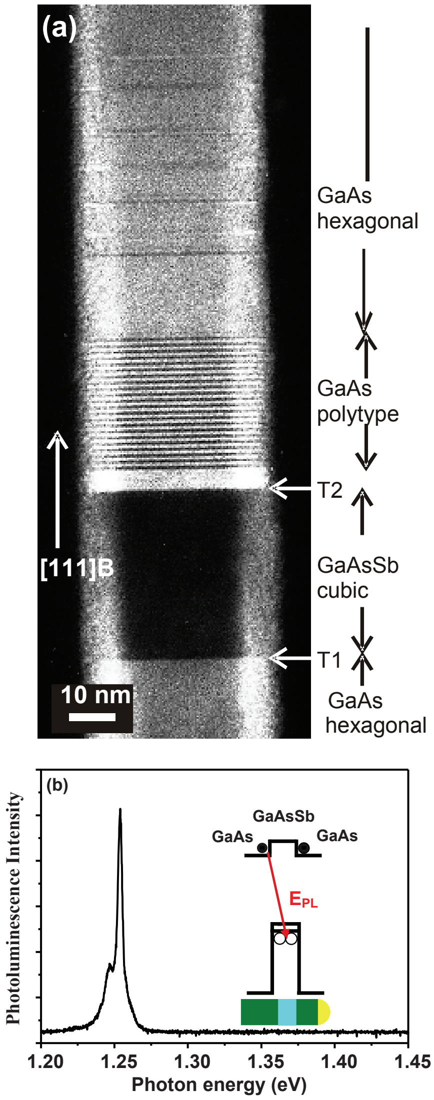


Figure 2 (a) Dark field TEM image of a GaAs/GaAsSb nanowire quantum dot. It is revealing a cubic phase GaAsSb quantum dot inserted between GaAs barriers of different hexagonal polytype crystal phases. (b) Micro-photoluminescence from a single GaAsSb nanowire quantum dot. For more details see: D.L. Dheeraj et al., Nano Letters 8, 4459 (2008).

But you see practical applications on the horizon?

– The early applications will be in micro- and opto-electronics where we shall see nano scale components perform with far better performance and less energy than present designs. Improved lasers, solar cells, various sensors are also foreseeable. And then there are some more exotic possibilities. Single photon emitters for example, a light source with controlled emission of quantum bits - that could enable quantum -communication and -computing in the future, and in the mean time, a nice gift to researchers in quantum optics.

Changing the subject. You have experience from first class nanotechnology laboratories in several countries. What do you think about the potential for success at NanoLab?

– After a start–up period with the usual challenges, NTNU NanoLab now has instrumentation and staff at an international level. The important thing as we move on is of course that we must keep the lab at this advanced level. We must also develop a strong culture of documentation so that scientists can save time by learning from the practical experience of others. Taking the most out of a central resource like NTNU NanoLab, requires a bit more collective effort than the traditionally individualistic university approach, says Weman.

And do you see the cooperative spirit developing? – and more broadly, the attitude to nanotechnology?

– We used to be a limited group of specialists centred on the technology itself.

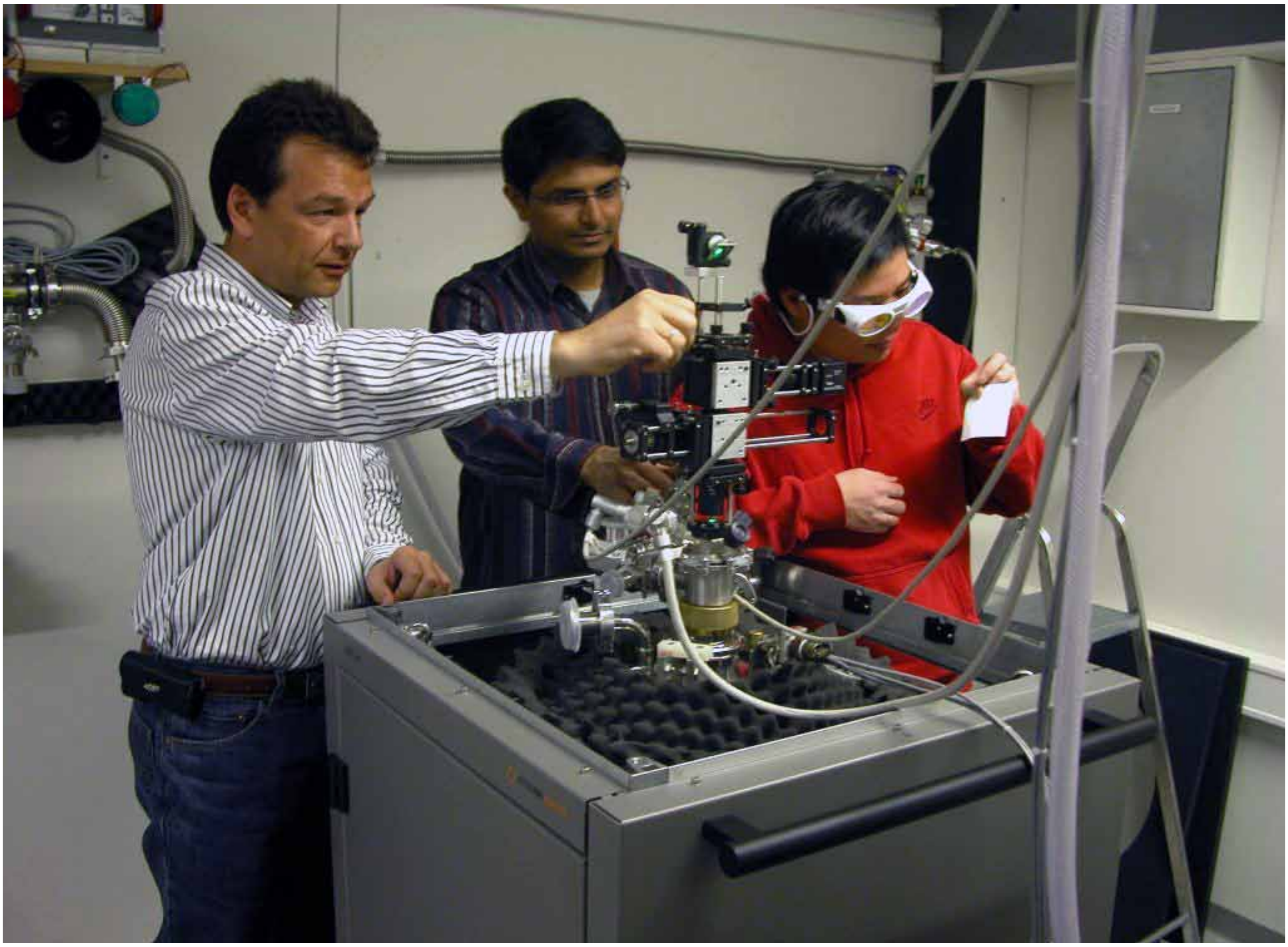


Figure 3: Professor Helge Weman (left), PhD student Fervin Moses (middle) and post doc Thang Ba Hoang (right) in the new cryogenic "nanophotonics" lab at the Department of Electronics and Telecommunications. In this lab light can be measured from single nanoparticles down to low temperatures (-271 Celsius), time-resolved (pico seconds), and at high magnetic fields (11 Tesla). Photo: Hailong Zhou

Now there is a growing "awakening" that nanotechnology will affect research and have applications across the spectrum from biology and medicine to electronics and mechanical engineering. "Cross-disciplinary" is moving from a vision to reality. People show an interest in wanting to meet now. Through students and researchers there will be a lot of cooperative work done across the different subjects. Eventually I believe we must specialize in a few niches to produce top international scientific research here at NTNU NanoLab. From a broad base we should be able to make the right choices as we move on.

Helge Weman is well established internationally. He has his PhD from University of Linköping, 1988 followed by post doctor research at University of California, Santa Barbara. From 1994 he was invited professor at NTT Optoelectronics Lab, Japan. He then held a position as project leader on optoelectronic quantum wire components at Swiss Federal Institute of Technology (EPFL), Lausanne, 1996-2005. He is clear on the international perspective of his efforts:

– Close international contacts are always essential in advanced research. A personal network is indispensable, and formal arrangements can be very useful to secure resources. I am pleased that we have been invited to join a consortium of some of the most successful research groups on nanowires in Europe to apply for an EU research grant. It is a step in the right direction for NTNU NanoLab, says Helge Weman.

Highlights

Nanostructured Ferroelectric Materials

Perovskite oxides are an important group of ceramic materials with the common formula ABO_3. Several perovskites such as $PbTiO_3$ and $KNbO_3$ are ferroelectric, meaning that they exhibit a spontaneous electric polarization that can be switched by an external electric field. Other perovskites are multiferroic, meaning that they exhibit both ferroelectric and ferromagnetic properties. $BiFeO_3$ is a multiferroic material which has gained huge interest in the recent years because of its ferroelectric and antiferromagnetic behaviour.

In the drive to miniaturize electronic components, sensors and other devices, nanostructuring of materials become increasingly more important. Nanostructures of ferroelectric materials are used in a variety of applications such as non-volatile ferroelectric random access memory, nanoelectromechanical systems, nanoscale capacitors, advanced sensors, energy-harvesting devices, photonic crystals and in photocatalysis. For such applications to become wide-spread in the future, it is desirable to fabricate the nanostructures by cost-effective and large-area methods. This favours chemical bottom-up methods in contrast to physical top-down methods such as lithography. So although controlling the growth of such nanostructures is a challenging task it has a high potential for future use.

The Inorganic Materials and Ceramics Research Group at the Department of Materials Science and Engineering, headed by Professor Mari-Ann Einarsrud and Professor Tor Grande, has studied the growth and properties of nanostructures of ferroelectric perovskites since 2003. The main efforts have been in synthesizing one-dimensional nanostructures of $PbTiO_3$ and $KNbO_3$, and in studying finite size effects in $BiFeO_3$. The PhD students Per Martin Rørvik and Sverre Magnus Selbach, and post doc Guozhong Wang have been the main contributors to this work.

For controlled growth of $PbTiO_3$ nanorods, we have developed a hydrothermal synthesis method to grow nanorods on $SrTiO_3$ substrates. Hydrothermal synthesis is a relatively simple method to obtain crystalline material at much lower temperatures compared to other synthesis methods. In the synthesis procedure an amorphous $PbTiO_3$ precursor was mixed with a surfactant and heat treated at 180 °C in the presence of a single-crystal $SrTiO_3$ substrate. Hierarchical nanostructures of $PbTiO_3$ nanorods were obtained by controlling the synthesis parameters (Figure 1). The anisometric growth of the nanorods is proposed to occur by self-assembly of cube-shaped or facetted nanocrystals.

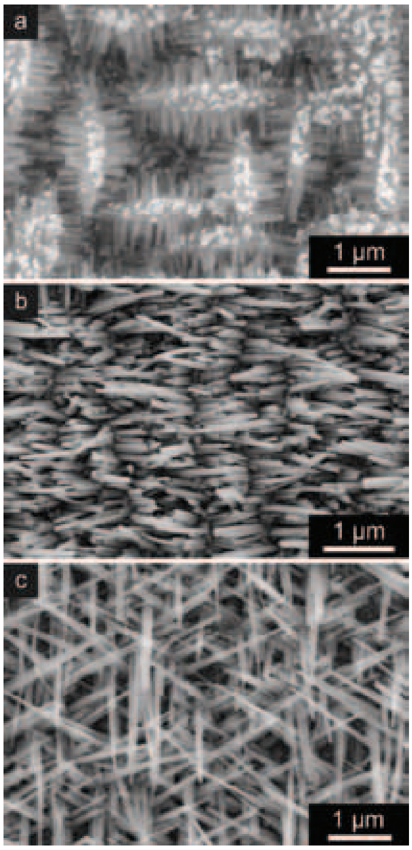


Figure 1. SEM images of $PbTiO_3$ nanostructures grown on single-crystal $SrTiO_3$ substrates by a hydrothermal method. Growth on three different substrate orientations is shown: (a) (100)-oriented substrate, (b) (110)-oriented substrate, and (c) (111)-oriented substrate.

The domain configuration of these $PbTiO_3$ nanorods has been studied by transmission electron microscopy (TEM) and piezoresponse force microscopy (PFM) in collaboration with the TEM group at the Department of Physics (Professor Randi Holmestad) and the Oxide Electronics group at the Department of Electronics and Telecommunications (Professor Thomas Tybell). The as-synthesized nanorods were shown to have the polarization direction in the longitudinal direction. After annealing the nanorods above the Curie temperature (490 °C) the crystallographic orientation changed and the polarization was found along the radial direction. A hysteresis curve measured by PFM is shown in Figure 2, demonstrating the ferroelectric nature of the nanorods.

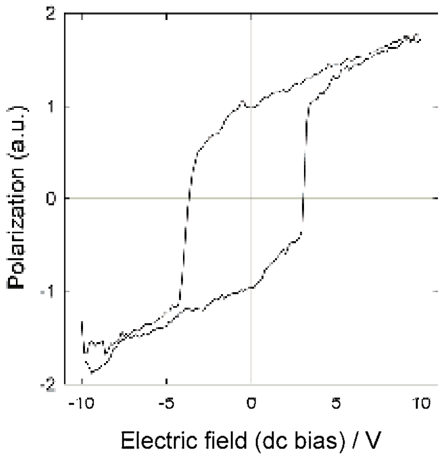


Figure 2. Hysteresis curve measured by PFM on a single $PbTiO_3$ nanorod.

A template-assisted method has been developed for the preparation of $PbTiO_3$ nanotubes, using porous alumina membranes as templates in which a Pb-Ti sol was infiltrated. After subsequent drying and annealing, and removal of the template by immersion in NaOH, $PbTiO_3$ nanotubes were obtained (Figure 3). The template-assisted method is an easy method to obtain nanotubes of perovskite oxides, but necessitates high-temperature treatment to crystallize the material and typically produces polycrystalline tubes.

Our group has also developed a hydrothermal method for synthesizing orthorhombic single-crystalline $KNbO_3$ nanorods, by reacting Nb_2O_5 in a KOH solution, using a surfactant as structure-directing agent. High-quality $KNbO_3$ nanorods were only obtained in a narrow window of synthesis parameters. The phase transition temperatures for the orthorhombic to tetragonal and tetragonal to cubic transitions of the nanorods were significantly lower than that of the bulk $KNbO_3$ materials, reflecting a finite size or disorder effect.

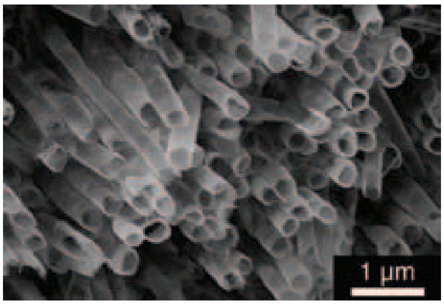


Figure 3. SEM image of $PbTiO_3$ nanotubes made by a template-assisted method.

A detailed study on the strong size-dependent properties of the multiferroic compound $BiFeO_3$ has been conducted using X-ray diffraction and differential scanning calorimetry. Nanoparticles with mean diameters of 11 - 86 nm were made by calcining a polymeric $BiFeO_3$ precursor at various temperatures. When the nanoparticle size decreased, the polar distortion of the unit cell decreased, the polar displacements of Bi^{3+} and Fe^{3+} relative to the oxygen sublattice increased, and the Néel temperature (the onset of antiferromagnetic ordering) decreased (Figure 4). The combination of increasing polar displacements of cations and decreasing unit cell distortions sheds light on the microscopic origin of finite size effects in ferroelectric nanoparticles. Ferroelectricity disappears at small dimensions due to loss of cooperative ordering of cation displacements, but polar displacements on a local scale prevail. The origin of finite size effects is decoupling of ferroelectric moments, hence ferroelectricity is lost through disordering rather than a displacive process. The decrease in the Néel temperature can be rationalized from decreasing Fe-O-Fe angle due to increasing displacements of Fe, and increasing Fe-O bond lengths. Both microscopic structural changes leads to decreasing overlap of Fe 3d eg and O 2p orbitals, and antiferromagnetic ordering vanishes at lower temperatures. Combined with recent observations of increased magnetization of nanoparticles, these are promising results with respect to the possibility of making small multiferroic nanostructures for technological applications.

These basic research studies have shown the ability of relatively simple chemical methods to synthesize nanoparticles and hierarchical nanostructures of a technologically important group of ceramic materials. We have also shown that the properties of the nanostructured materials differ from their bulk counterparts, which is important in applications. A list of publications can be found at the group's homepage (http://www.material.ntnu.no/ceramics/publications).

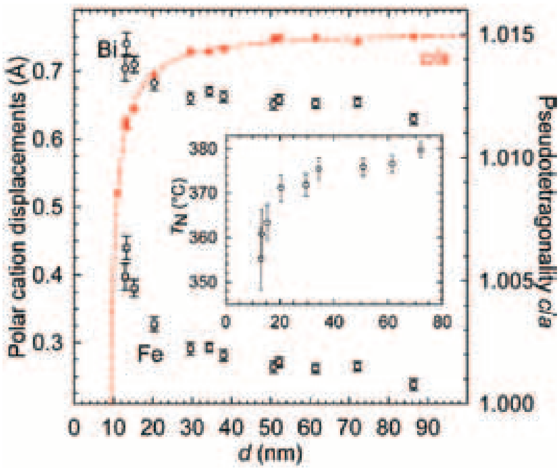


Figure 4. Size-dependent properties of $BiFeO_3$ nanoparticles as function of the nanoparticle diameter (d). Pseudotetragonality c/a (in red) is a measure of the unit cell distortion along the polar direction c. Polar displacements of Bi and Fe along the c-axis are the origin of ferroelectric polarization in $BiFeO_3$. Inset: The antiferromagnetic ordering temperature T_N.

Synthesis and Applications of Carbon Nanotube Based Composites

Building nanoarchitectures by controlling atomic assembly to manipulate material properties has opened great opportunities for fabrication of novel structured materials with improved material properties and stabilities. Nanomaterials with well controlled nano-structures/-architecture have become increasingly important for catalysis and they are expected to play a key role in the development of new and renewable energy, such as catalysis for biomass conversion, electrochemical energy storage and conversion (lithium-based batteries, supercapacitors and fuel cells). The presence of organized nanostructures is also critical factor for novel solar cells. In recent years a range of novel nanostructured catalytic materials have been developed in the Catalysis group at the Department of Chemical Engineering. These materials are now beginning to be investigated for the application within the following areas of new and renewable energy:

- Hierarchically organized carbon nanotubes (CNTs) and nanofibers (CNFs) have been prepared by CVD methods. These CNTs and CNFs have provided superior activity and stability of an array of metals (Pt, Pd, Au, Ni, Co and their alloy nanoparticles) and metal/oxides (Pt/CeO_2, Au/TiO_2 nanoparticles) utilized in many different reactions. An efficient preparation method has been developed to deposit nanoparticles on CNTs and CNFs with high dispersion and good stability. The CNTs and CNFs can also be used as catalyst supports for applications within hydrogen storage in organic hydrides and as electrodes in fuel cells and other electrocatalytic devices.

- Carpets or arrays of vertically aligned CNTs and CNFs on different substrates have been prepared by plasma enhanced CVD and catalytic CVD. The focus has been on development of a scalable method for synthesis of aligned CNTs on different metal foils such as Ti, stainless steel, Cu, as well as graphite foils, carbon papers, carbon felts and metal wires. The CNTs and CNFs have also coated with TiO_2 and gold nanoparticles by a colloid method in order to tune the properties and stabilities of the composites. The properties of the hierarchically structured composites can be tuned at nano and macro scales, which provide new and excellent opportunities for improving existing processes and new applications.

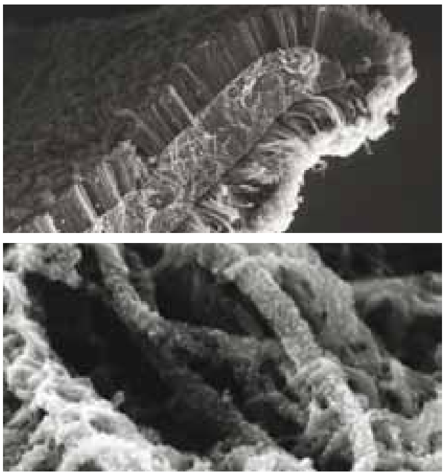


Fig 1. Aligned carbon nanotubes on Ti metal foils (top) PANI/aligned CNT composites.

- Thin CNT films coated with conductive polymers have been synthesized as supercapacitors, batteries and organic-inorganic hybrid solar cells. A scalable method of in-situ polymerization has been developed to deposit a thin layer of CNTs on the conductive polymer. A new concept of nanoelectrode array has been developed with a conductive polymer as outer tube and CNTs as the inner tube. These structures significantly increase the surface area per volume and the stability of the polymer as well as reduce the transportation paths of ions and charges. These CNT based composites have shown an excellent supercapacitive performance.

- CNFs with different graphite sheet orientations relative to the fiber axis as a platform for rational design of nanocatalysts, has for a long time been one of the main research areas in Catalysis group. A better understanding of the relationship between the nanostructures and catalyst properties has been gained by detailed characterization and molecular dynamic simulations in cooperation with the Departments of Physics and Chemistry, respectively. It has bee shown that the surface chemistry, surface wet properties and surface charge can be controlled by the graphite sheet orientation of the CNFs. The platelet structure has thus been identified as a superior catalysis support in many catalyst systems.

Rational design based on a better understanding and controlled synthesis of nanostuctured materials is becoming an important research topic in the Catalysis group. Nanoparticles of nanostructured CO_2 solid acceptors, Ni nanoparticles for hydrogen production from steam reforming catalysts or sorption enhanced reforming of natural gas and biomass derived oils and synthesis gas, as well as gas cleaning process, Co nanoparticles for F-T reactions, Au/TiO_2 for CO oxidation, Pt nanoparticles for propane dehydrogenation, Pt and Pt bimetallic nanoparticles as fuel cell catalysts are the examples.

Nanosized Ceramic Powders by Spray Pyrolysis

Ceramic materials are widely used for many different types of applications. In particular there are substantial developments of multicomponent functional oxide ceramics. The functional properties of these materials are typically related to electronic and ionic (protons or oxygen ions) conductivity relevant for the development of solid oxide fuel cells and dense permeable membranes as well as materials for information and communication technology such as ferro- and piezoelectric materials. Materials with tailored catalytic properties are also important in a number of industries. These material systems all have in common that they are high performance oxide ceramics with rather complex compositions.

Ceramic materials are generally prepared by a high temperature firing of a powder compacted with the desired shape and geometry. The main challenge for the preparation of this group of materials is hence the provision of high quality ceramic powder with uniform properties. A high quality ceramic powder is defined by a small particle size (sub micron or nanosized), narrow particle size distribution, low degree of agglomeration, high purity and high phase purity. Hence high quality sub-micron powders are attractive in the development of ceramic materials.

The traditional route to multicomponent ceramic powders is solid state reaction between binary oxides. However, this route gives a coarse powder often containing impurites in the form of unreacted material or impurities introduced during the necessary milling to reduce the particle size. Therefore, wet chemistry has shown to be

Professor Mari-Ann Einarsrud and MSc student Jon Strand in front of the spray pyrolysis equipment. Photo: Ida Hederström an excellent strategy to prepare high quality ceramic powders of sub micron size. By this synthesis approach, the precursor for the material is a homogeneously mixed salt solution containing the cations to build up the material. The transformation from the solution to the ceramic material can proceed through several different routes like sol-gel, precipitation, spray drying, glycine nitrate and spray pyrolysis.

The Inorganic Materials and Ceramics Research group at the Department of Materials Science and Engineering, represented by Professors Mari-Ann Einarsrud, Tor Grande and Kjell Wiik, has since early 1990's developed several wet chemical synthesis routes to high quality ceramic powders. This powder processing has been the basis for development of a large research activity on ceramic materials for energy technology applications and for information and communication technology. To produce sufficient amounts of high quality ceramic powders, the spray pyrolysis route has been developed since 2004 and a pilot scale laboratory being able to produce up to 10 kg of powders per day has been constructed. The pilot plant has been financed by the Research Council of Norway and is one of only a few production facilities in Europe. The production unit has the capacity to provide our own research group with sufficient amounts of high quality powders but also our collaborating partners.
The principle for the spray pyrolysis is the atomization of a precursor solution into a furnace where drying and calcination of the droplets/particles are occurring as shown in the schematic illustration in Figure 1.
A photo of the spray pyrolysis equipment is provided in Figure 2. The aqueous precursor solutions are formed from water soluble salts e.g. nitrates and contain the cations to build up the material in the correct stoichiometry. To obtain the same stoichiometry and homogeneity in the powders as in the solution, the use of complexing agents like EDTA and malic acid is necessary for some compositions. The atomized droplets less than 50 µm in size dry to form egg-shell-like agglomerates as shown in Figure 2. These agglomerates are further calcined and milled to obtain submicron or nanosized powder with a low degree of agglomeration. During the calcination, traces of nitrates, etc are decomposed and traces of organic complexing agents are burned off. A free-flowing powder of high quality is obtained as can be seen from the SEM image in Figure 2. The powders show excellent sintering properties resulting in well defined microstructures in the submicron range as can be seen from the micrograph of a sample sintered by hot pressing included in Figure 2.

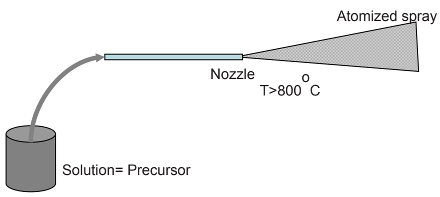


Figure 1. Schematic drawing of the spray pyrolysis process.

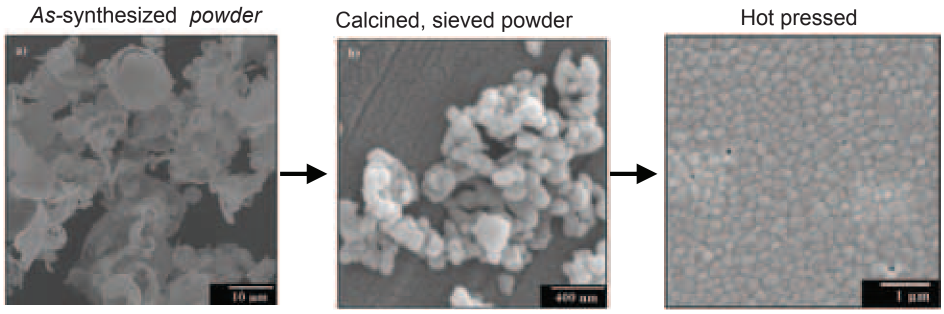


Figure 2. As-synthesized egg-shell-like agglomerates, calcined and sieved sub 200 nm powder and hot-pressed ceramics of $LaNbO_4$.

Since the establishment of the spray pyrolysis laboratory we have produced a wide variety of different material compositions and the method has demonstrated its versatility producing high purity, homogeneous powders with particle size down to 10 nm.

A spin-off company, CerPoTech AS, was established October 2007 aiming at the production of multi component ceramic oxide powders by spray pyrolysis for the growing international research and development market. The establishment of the company has been strongly assisted and supported by The Technology Transfer Office at NTNU.

Spintronics and Nanotechnology

Nanoscience offers theoretical physicists an intriguing field where there is a need to explain how materials behave at a small scale, because this behaviour is so dramatically different from what is found at a macroscopic scale. Exploiting nanoscale properties of materials can lead to new technological breakthroughs, particularly in computing and miniaturization. NTNU Professor Arne Brataas and his Condensed Matter Physics Research Group have been pursuing a number of theoretical investigations in the areas of AC magnetoelectronics and spintronics, DC transport in ferromagnetics including domain wall resistance, mesoscopic superconducting ferromagnetic systems and graphene.

The graphene work was of particular note in 2008, when a team of experimental physicists confirmed theoretical predictions made by the Brataas group in 2006. Graphene is a layer of carbon that is just one atom thick, with a honeycomb or chicken wire structure. The substance was only created in 2004. Both graphene and carbon nanotubes are thought to be good candidates as components for a spintronic device, which uses an electron's spin to transmit or encode information.

A carbon nanotube enables the orbital state of electrons, which are coupled to an electron's spin, to be separated into those that circle the tube in a clockwise direction and those that circle in an anticlockwise direction. This binary relationship can carry information, much the way that today's computer chips carry information in the on- or off-position of their switches. Carbon has two other properties that make it a particularly good candidate for transmitting spintronic signals. The first is that the nucleus is very small, reducing electronic spin-orbit interactions, which means that the spintronic signal should be stable. The second is that carbon nuclei themselves have no nuclear spin, which would otherwise interfere with the spin signal and cause it to decay.

But while spin-orbit interactions in carbon nanotubes were generally expected to be weak, the Brataas group predicted in 2006 that there would in fact be interactions between the spin and orbit of electrons in curved structures such as nanotubes. This is what the team of experimental physicists publishing in Nature in 2008 confirmed, when they showed that the interaction between an electron's spin and its orbital motion is actually strong.

Professor Arne Brataas, Department of Physics, Photo: Synnøve Ressem/NTNU Info

In evaluating the finding, Brataas writes in Nature that the effect found could be seen as ruling out carbon nanotubes as a substance for spintronics devices – but in fact the opposite is true. Instead, Brataas says, "this effect could be exploited to allow electron spin to be manipulated by electrical means alone, a long sought capability that would open the door to many more spintronics applications."

A second effort of note concerns the group's studies of magnetization relaxation, which is of interest because it determines the magnetization dynamics and noise in magnetic memory devices. In a publication in Physical Review Letters, the group offered an alternative formulation of Gilbert damping, which helps describe magnetization relaxation, which could help lead to a better understanding of dissipation in magnetic systems.

Glucose Sensitive Nanosensors

The biopolymer physics activity at Biophysics and Medical Technology, Department of Physics, NTNU is led by prof. Bjørn Torger Stokke, and currently includes post docs Marit Sletmoen, Gjertrud Maurstad, Dionne C.G. Klein, Katarzyna Maria Psonka-Antonczyk and PhD student Sven Tierney. During the academic year 2008/09 we also enjoyed the visit of Makoto Takemasa, affiliated with one of our long term collaborating groups in Japan (Sakai). The group collaborates locally with the Norwegian Biopolymer Laboratory. Other local partners include the Medical Faculty and the Department of Chemical Engineering. Our research is focused on mesoscale structure formation and interactions between and within biological macromolecules and their components, and how this relates to the structure-function relationship of biopolymers. The classes of biological macromolecules studied are foremost various polysaccharides. The hierarchical assembly of (bio) polymer materials and their interactions underpin normal biological function, but are also crucial for numerous technological applications. Current research activities are focused on structures and mechanisms of polyelectrolyte complexes, multilayer structures, gelation and interactions. Specific biopolymers include alginates, chitosans, xanthan, (1,3)-β-D-glucans, DNA, tailor made samples within these macromolecular families, and other biopolymers. In addition, there is considerable focus on development of techniques for characterization, modelling of the data, and the migration of the techniques to related areas of biological polymers. Specific tools implemented locally for this research include atomic force microscopy, dynamic force spectroscopy, high resolution interferometry and rheology.

The current research on biopolymer complex formation includes polycation-induced condensation of DNA as a possible first step in the preparation of a therapeutic gene delivery vector. The focus of this research is two-fold: i) investigating the use of chitosans for compaction of DNA for gene delivery, and ii) investigating in general the influence of macromolecular properties and preparation conditions on the structure formation of condensing semiflexible biopolymers. Figure 1 shows a gallery of 150 nm large toroidal structures being a preferable state adopted by DNA-chitosan complexes following the electrostatic driven complexation between these oppositely charged polyelectrolytes.

The single-molecular interaction studies were initially undertaken to elucidate the mode of action of the mannuronan C-5 epimerase when catalyzing the conversion

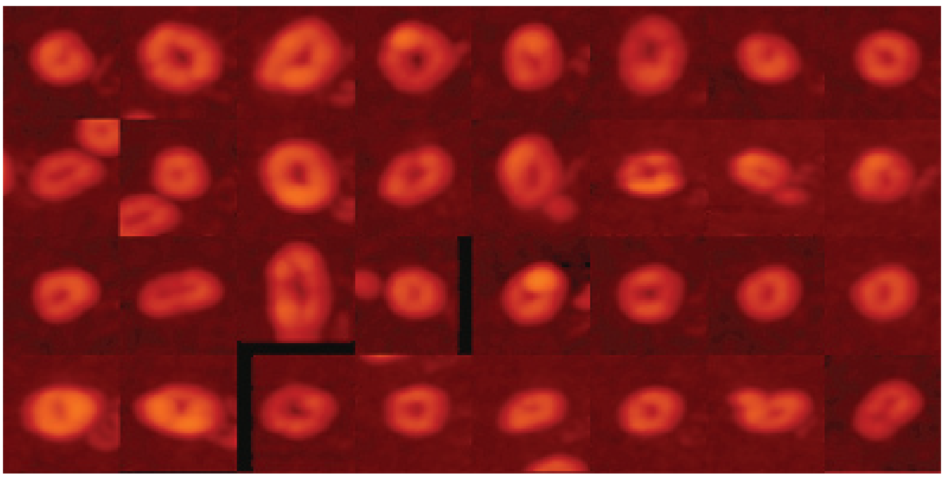


Figure 1. Ensemble of toroidal DNA-chitosan complexes characterized by atomic force microscopy. Data generated by S. Danielsen

of the mannuronic acid to its C-5 epimer, guluronic acid, at the polymer level. The determined interaction strengths in the range from 30 to 300 pN and its dependence on the force loading rate led to the conclusion of a processive mode of action. Such single-molecule interactions are currently adopted as a means for characterization of other molecular pairs, e.g., selected part of immunlogical signalling cascades (toll-like receptor 9 (TLR9)), mucin – lectin interactions, DNA-repair enzymes and selected high molecular weight polysaccharides forming physical gels.

In this context, we have recently developed a line of research for technological utilization of molecular interactions in biological sensing. In addition to tailoring hydrogel materials to act as biological signal transducers, this line of research takes advantage of a high resolution (2 nanometer) interferometric technique for characterisation of the optical length of responsive gels. This technology, providing a 100 fold improved resolution compared to diffraction limited optical imaging, is currently being applied for characterisation of bioresponsive hydrogel materials aimed at sensor development. The hemispherical hydrogel of 50-60 µm radius manufactured at the end of an optical fiber makes up a Fabry-Perot cavity for high resolution interferometric detection of the optical length. The interference of light guided by the optical fiber and reflected at the fiber-gel and gel-solution interfaces enables detection of the optical path length within the gel and thus, the swelling degree of the gel (Figure 2a). Both the amplitude and phase of the interference wave reflected back through the optical fiber contains signatures that can be used to deduce changes of the optical properties of the responsive hydrogel material. However, the phase represents the highest resolution information. The function of the miniaturized bioresponsive hydrogel material is both to embed specific biological recognition events and to transduce this to changes of the hydrogel that can be read by the interferometric platform. The small size of the sensing hydrogel supports rapid changes of the hydrogel material, that together with the high resolution of interferometric readout

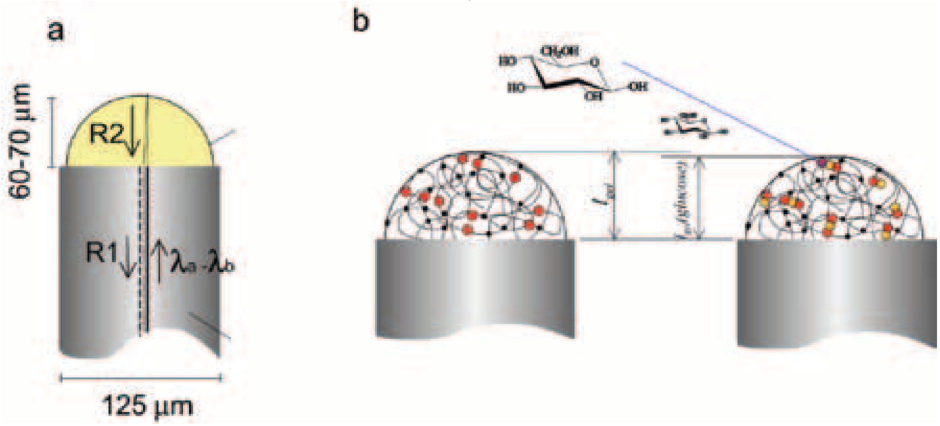


Figure 2. Schematic illustration of the principle for determination of changes in the optical length of a hemispherical biosensisitive hydrogel attached to the end of an optical fiber (a), and glucose induced cross linking between glucose-recognizing groups integrated in the hydrogel network (b) . Incident light directed through an optical fiber reflected at the fiber-gel and gel-solution interfaces, R1 and R2, yields a reflected interference wave with phase depending on the optical path length depending on the hydrogel swelling. The hemispheral hydrogel at fiber optical end has a length of the order 60 – 70 µm (a). Copyright: B.T. Stokke

platform (2 nanometer) yields potential for rapid and sensitive monitoring various components.
The technique has been applied to characterize various developed hydrogel matrices in order to explore the potential resolution and to demonstrate biospecific sensing transduction. Polycationic hydrogels with various charge densities integrated on this technological platform display changes in the equilibrium optical length upon changes in ionic strength of the immersing solution of the polyelectrolyte gels. Step changes in the ionic strength of the solution induced swelling with time constants in the order 2 seconds. This is consistent with literature data for diffusion of the polymer network being the rate limiting process for hydrogels of the actual size. The experimentally established uncertainty in the determination of the optical length of the hydrogel was 2 nanometers. This is about 100x better than determination of swelling based on diffracted limited optical microscopy, and such a high resolution supports development of various biological sensing schemes at high resolution.

A glucose sensor has been realized on this platform by utilizing the glucose sensing functionality of boronic acid moieties incorporated into the hydrogel matrix (Figure 2).

The interaction between glucose and boronic acid changes the driving forces for gel swelling. The glucose selectivity relative to other carbohydrates was tuned by additionally incorporating a tertiary amine into the responsive hydrogel matrix. The properties of the responsive hydrogel as a glucose sensor were determined in more detail with respect to swelling kinetics and equilibrium swelling degree. The results showed that there was a good degree of reversibility, both for equilibrium swelling and swelling kinetics. The mechanism for the glucose induced response of the fabricated hydrogels involved glucose mediated cross linking to boronic acid sensing groups attached to topologically different network chains. Fabricated hydrogel sensors with slight differences in size yielded an overlapping relative response, indicating an excellent degree of sensor reproducibility. The sensor proved to be temperature dependent. By increasing the temperature from 25°C to 37°C, the swelling was about fourfold more rapid, and a concomitant decrease in equilibrium swelling was seen. The obtained results indicate that the sensor developed may be a candidate for continuous monitoring of glucose in blood.

Some preliminary results on oligonucleotide functionalized hydrogels supporting various biodetection schemes have also been realized. The results show that a wide array of bioresponsive hydogels can be manufactured at the end of the optical fiber for high resolution readout of specific signals, thus supporting development of biosensors.

MR and Ultrasound Research in Bionanotechnology and Nanomedicine

Molecular imaging using MR and ultrasound makes analysis and monitoring of biomolecular processes in normal and sick tissues of intact organisms possible without invasive operations. These techniques often make use of nanostructured "smart contrast agents" (often called "nanoparticles for imaging"). These are complex molecular structures containing several elements with different functions. Examples of such functions are:

- target specific, that may be a ligand for receptor binding in the diseased tissue (cancer cells, Alzheimer plaques etc.)
- measurement of relevant biological parameters from physiology (oxygen tension, pH, temperature etc.), moelcular biology (ion channel activity etc.) and epigenetics (RNA expression etc.)
- therapeutic drug that may be activated non-invasively during the imaging session

The MR and ultrasound research groups at NTNU and SINTEF have defined a strategy to establish a complete research line for synthesis, validation, in-vivo testing, development of methodology and evaluation of the feasibility of such nanoparticles for imaging. Today's research activity is mainly concentrated around preclinical studies of animal models of diseases and transgenic mice in order to survey in-vivo effects of gene modifications, as well as monitoring the effect of new treatments. The future goal is to be able to transfer the best ideas into clinical use, and opening up for industrial opportunities. This research is an important part of the Trondheim activities in the FUGE technology platform NorMIC (the Norwegian molecular imaging consortium).

The bionano-imaging activity at NTNU is also a part of the new Centre for Research-based Innovation (CRI) called MI Lab (Medical Imaging Laboratory for Innovative Future Healthcare), which was awarded to the MR and Ultrasound groups at NTNU in 2007 by the Norwegian Research Council. Being one of only three CRIs within biomedicine and health in Norway, it is a token of the high level research carried out in these scientific groups. MI Lab is lead by Professor Olav Haraldseth, who is also NTNU's official contact towards the European Technology Platform (ETP) in Nanomedicine.

One of the ongoing projects within bionano-imaging in Trondheim focuses on the use of MRI for tracking of iron-labelled cells. Cells with therapeutic effects can be implanted into the brain after injury, and the migration of the cells, as well as the therapeutic effects of the cells, can be monitored with MRI (Figure 1). This activity is partly a collaboration with professor Joel Glover at the Centre for research-based Innovation CAST (Cancer Stem Cell Innovation Centre) in Oslo.

Another ongoing project is the use of manganese-releasing MR contrast agents for monitoring cell activity in the brain and heart. Manganese is a calcium analogue. Thus, uptake and accumulation of manganese in the cells can constitute an indirect measure of the activity of the calcium channels in cell membranes. The calcium channel activity is the most important biomolecular indicator of cell activity in the brain and heart. Additionally, manganese is taken up by neurons and transported specifically along axonal pathways. We have used this technique to study central nervous system injury and repair after treatment (Figure 2) and cardiac cell function after ischemia (Figure 3). Research scientist Christian Brekken has, in collaboration with Professor Gudmund Sjåk-Bræk and Yrr Mørch at the Department of Biotechnology, developed an alginate-based capsule with manganese incorporated in the structure, allowing controlled release of manganese for optimized delivery to brain and heart tissues.

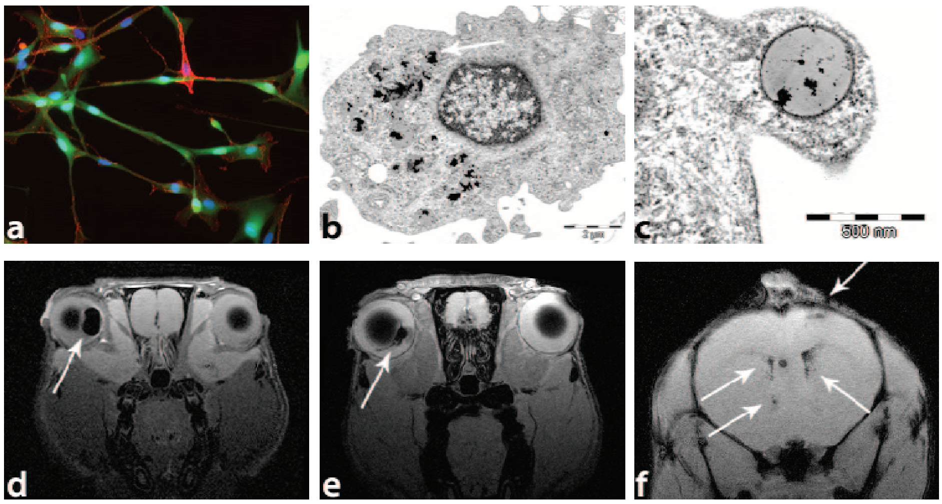


Figure 1: Iron-labelled cells for MRI. Several cells can be used for this purpose. Olfactory ensheating cells (a) are known to have stem cell like properties, and can stimulate to regeneration after axonal injury in the central nervous system. They have fluorescent properties so that they can be studied in a fluorescent microscope (a). For the cells to be visible with MRI, cells are co-incubated with micron sized iron particles. In an electron microscope, the particles can be seen as grey bobbles within the cell, and the iron as black dots (b, arrow and c). Immediately after injection into the corpus vitreum of the eye, the area where the particles are located appear dark on MRI, as seen in the left eye (arrows) after injection of iron-particles only (d) as well as after injection of iron-labelled olfactory ensheating cells (e). After implantation, the iron-labelled cells might migrate to other parts of the brain, and the migration can be monitored with MRI (f). Here, iron-labelled adipocytic stem cells migrate from the injection site (top arrow) and along the ventricles in the brain (arrows). Unpublished results, courtesy Ioanna Sandvig, MI Lab and Marte Thuen, NorMIC Trondheim.

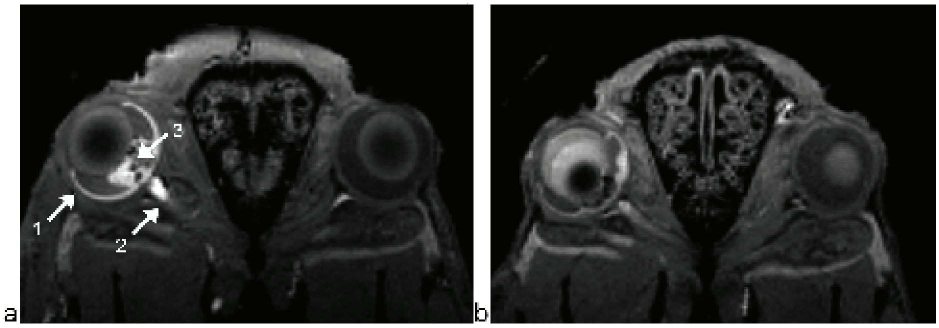


Figure 2. Manganese uptake in the retina (1) of a rat eye, and transport along the optic nerve to the site of an experimentally induced nerve injury (2) in the acute phase (a). Implantation of a peripheral nerve graft (3) causes a tendency to nerve regeneration 3 weeks later (b), due to release of growth factors from the nerve graft.
From Marte Thuen M, Brekken C et al. J Magn Reson Imag 2009;29:39-51

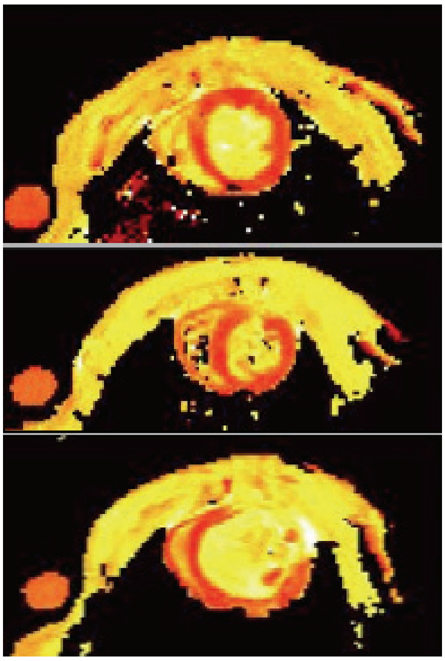


Figure 3. The upper image is a rat heart with no infarction, the middle image is a rat heart with a small infarct, and the lower image is a rat heart with a relatively large infarct. The red ring shows uptake of manganese as marker of active calcium channels and normal cardiac cell function and the broken part of the rings show the part of the cardiac wall without normal cell function.
Unpublished results, courtesy John Georg Seland and Morten Bruvold.

A third ongoing project makes use of a combination of contrast agents and theranostics with ultrasound. In this concept the therapeutic molecule is encapsulated in an air bubble attached to a ligand designed for targeting a specific receptor, eg in cancer cells. Ultrasound can then be used for ensuring drug delivery mainly to the desired cells by first detecting that the air bubbles are in the diseased tissue and then releasing the drug by breaking the air bubbles applying ultrasound waves of another frequency. An important reason enabling this research to take place at NTNU is the development of a new ultrasound imaging method (SURF) by Professor Bjørn Angelsen's group. This method increases the sensitivity and the specificity of the detection of the gas bubbles compared to conventional methods. The SURF method is achieved by processing the received signals from the transmitted dual frequency band pulse complexes with overlapping high frequency (4-40MHz) and low frequency (0.5-3MHz) pulses. The transmitted high frequency pulses are used for image reconstruction, whereas the transmitted low frequency pulses are used to manipulate the scattering properties of the contrast agent. This new ultrasound technology requires new instrumentation and through combined effort from NTNU, SINTEF and St. Olav's Hospital. A first prototype SURF scanner is now ready for initial clinical evaluation (Figure 4). With this technology, there is also a potential for differentiating free circulating gas bubbles from gas bubbles attached to given receptors. Together with SINTEF, projects are initiated for development of nanoparticles that both can be detected by ultrasound SURF technology and that have potential to be used as drug carriers. The SINTEF Health research director Toril Nagelhus Hernes is an active participant in the European Technology Platform (ETP) in Nanomedicine.

Figure 4. First prototype SURF scanner now ready for testing. Photo Rune Hansen.

Molecular Machines Repairing Our Genome: Target for Nanomedicine

Genomes are chemically unstable and tend to decay due to various hydrolytic reactions, environmental chemicals and radiation. In spite of such events, genomes of all organisms are largely kept intact by a variety of molecular machines that carry out different DNA transactions. These sense and signal DNA damage, temporarily arrest replication and transcription of damaged cells to allow time for recovery, and restore DNA by DNA repair processes. Cells suffering damage that can not be repaired are normally eliminated by programd cell death (apoptosis).

Deficient DNA repair causes cancer and premature aging. But in addition, one of the other major defence mechanisms, the immune system, depends on several DNA repair proteins to be functional. Consequently, DNA repair deficiency is also frequently associated with immune deficiency. DNA repair takes place by several mechanisms, the choice of which depends on type damage, type of cell and cell cycle status. Generally, DNA must be repaired prior to replication to prevent mutations, but in addition DNA damage may be cytotoxic by blocking transcription, and must therefore be repaired in non-proliferating cells as well. The efficacy of anticancer treatment may therefore be modulated by targeting DNA repair and associated processes, such as cell cycle control. The significance of DNA repair is schematically outlined in Figure 1. Understanding genome maintenance is fundamental to unraveling mechanisms of cancer development, but in addition it has wider implications:

- Mutations caused by unrepaired DNA damage are fundamental to cancer development.
- In transformed and malignant cells higher expression of DNA repair pathways may give the cells a growth- and survival advantage.
- Unbalanced expression of repair proteins may cause accumulation of repair intermediates and may promote illegitimate recombination (promote genome instability).
- DNA repair pathways and associated processes are targets for diagnosis and (selective) treatment.
- Expression profiling may guide therapy and predict prognosis.
- Single nucleotide analysis may identify individuals at risk for certain forms of cancer.

Although DNA repair pathways generally prevent cancer, enhanced expression of DNA repair genes may supply mutated cells en route to cancer and established cancer cells with selective growth- and survival advantages. Proteins in pathways involved in DNA damage sensing, signalling and repair are therefore promising drug targets. Expression profiling of genes involved in genomic stability in a broader sense will give more accurate diagnosis and may make possible personalised therapies and more accurate prognosis. Single nucleotide polymorphisms (SNPs) are common and are considered as "normal variation". However, it is now known that some common SNPs may predispose to different types of cancer, including lung cancer. Depending on type of lesion, DNA repair mainly takes place by five different excision repair mechanisms. These are base excision repair (BER), nucleotide excision repair (NER), mismatch repair (MMR), homologous recombination (HR) and non-homologous end joining (NHEJ). These are all multiprotein machines that carry out repair in a multistep mechanism. After removal of the damage they all, except NHEJ, use information in the complementary strand to insert the correct nucleotides, thus restoring DNA. In these mechanisms, the damaged nucleotide is not actually repaired, but rather removed and replaced by a new nucleotide. These ancient processes (all more than a billion years old) actually mimics modern "indirect" repair of instruments and machines: Remove malfunctional part and replace it by a new one. However, nature has also developed direct repair mechanisms, in which a damaged base is de facto repaired rather than replaced. This mechanism removes aberrant methyl-, ethyl- and etheno-groups from DNA bases, leaving a repaired normal base. The remarkable enzymes recognizing and repairing such minor lesions are either methyltransferases or oxidative demethylases that are highly selective for their substrates. They are small single subunit proteins present in bacteria and eukaryotes. While ancient in evolution, oxidative demethylases are the most recently identified addition to the repair crew. The E. coli AlkB protein and human homologues, e.g. $hABH_1$, $hABH_2$ and $hABH_3$, remove methyl groups in certain positions in DNA bases, and for some of them also in RNA. Some also remove ethyl- and etheno-adducts. These proteins belong to a large family of 2-oxoglutarate (2OG), Fe(II) and O_2 –dependent hydroxylases that are involved in very diverse processes, from biosynthesis of antibiotics to repair of DNA. In DNA repair, the hydroxylated methyl group is unstable and falls off as formaldehyde. These enzymes have a rather similar catalytic groove into which the substrate, e.g. a flipped out, methylated DNA-base,

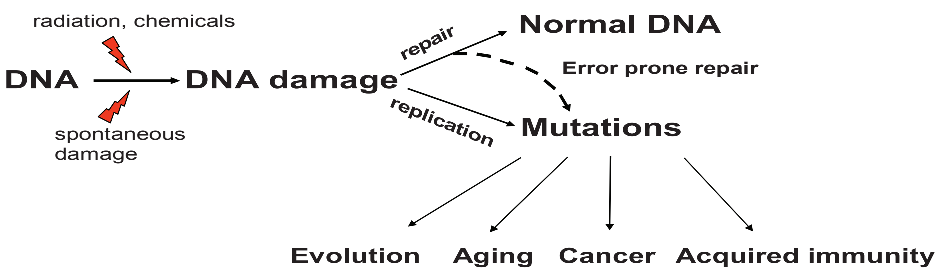


Figure 1: DNA repair prior to replication prevents mutations and cytotoxicity from DNA damage. Defective DNA repair is also associated with ageing. In adaptive immunity several DNA repair

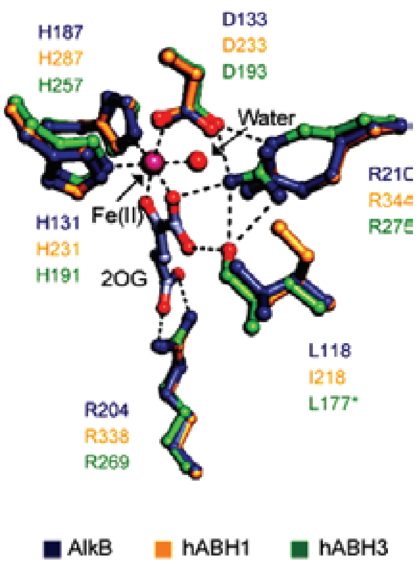


Figure 2: Close-up view of the modeled active site of hABH$_1$ (orange) superimposed onto hABH$_3$ (green) and AlkB (blue). The active iron ion and the co-factor 2OG is coordinated by conserved residues in the common beta jelly roll fold for this class of hydroxylases. The partly oxidized Leu177 found in the endogenous expressed hABH$_3$ is denoted with an asterisk.

is inserted and hydroxylated. In figure 2, the structure of hABH$_1$ has been modelled (Westbye et al., 2008), based upon known structures of hABH$_3$ (Sundheim et al., 2006) and AlkB. (Yu et al., 2006). In the AlkB subfamily, the substrate specificity is determined by a flexible protein fold apparently specific for each of the AlkB family members (Yang et al., 2008 and Sundheim et al., 2008), see comparison in Figure 3 (from Sundheim et al., 2008). This substrate specificity subdomain also determines single strand-versus double strand specificity. Thus, hABH$_3$ is essentially specific for single stranded DNA and RNA, while hABH$_2$ prefers double stranded DNA, but does not exclude single stranded DNA.

These remarkable direct repair enzymes are molecular machines that correct damage induced by environmental mutagens, such as tobacco-specific nitrosoamines, as well as endogenous metabolites, such as S-adenosylmethionine. They are potential drug targets that may be inhibited, thus enhancing the effects of alkylating cytostatics. Design of selective inhibitors requires detailed molecular understanding of the mechanism of catalysis.

The presented project has been carried out by post doctor Ottar Sundheim, Professor Geir Slupphaug and Professor Hans E. Krokan in the DNA Repair Group at the Department of Cancer Research and Molecular Medicine at NTNU.

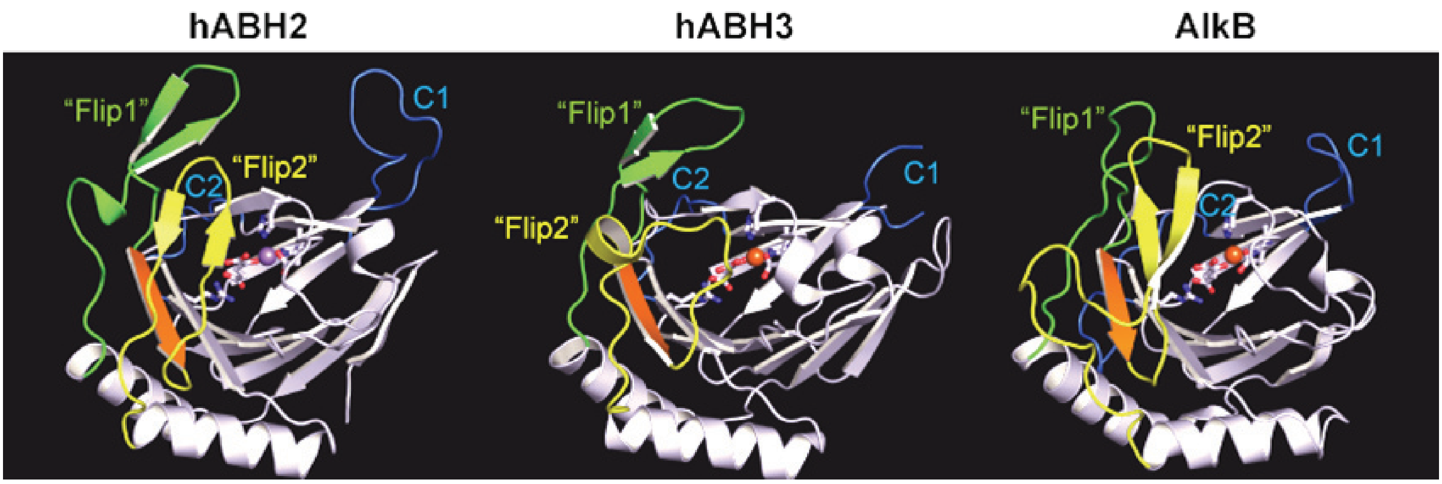


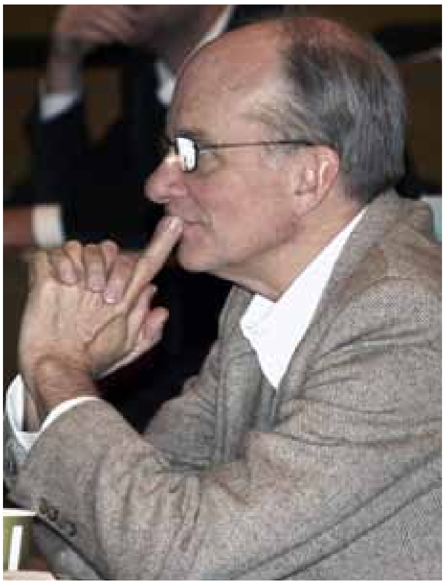
Figure 3: Cartoon presentation of the overall structure of hABH$_2$, hABH$_3$, and AlkB. The conserved beta jelly roll fold of Fe(II)/2OG dependent dioxygenases are shown in grey. The primary and secondary structure of surrounding loop segments (in colour) determine the substrate specificity of this class of repair enzymes.

Meetings and Seminars

Kavli Prize Lectures at NTNU

The Kavli Prizes were awarded for the first time in Oslo on the 9th of September 2008. His Royal Highness Crown Prince Haakon led the presentation of the international research prizes to seven of the world's most prominent scientists in astrophysics, nanoscience and neuroscience. The prizes in nanoscience were given to Louis E. Brus, Columbia University, USA and prof. Sumio Iijima, Meijo-university, Japan. In connection with the Kavli Prize award ceremony three of the laureates, Louis E. Brus, Sten Grillner, Karolinska Institutionen, Sweden and Pasko Rakic, Yale University School of Medicine, USA (both neuroscience) gave their official lectures at NTNU on the 11th of September.

Prof. Louis E. Brus' lecture was entitled: Semiconductor Nanocrystals. In addition to presenting his brilliant scientific achievements he gave the audience a vivid impression of the struggles and joys of performing practical research.



Kavli Laurate prof. Louis Brus. Photo: Ida Hederström.

Invited speakers at the symposium 1st Nanotechnology@ntnu. From the right: prof. Thomas Bjørnholm, prof. Hans Mooij, prof. Flemming Besenbacher, prof. Herman Gaub, prof. Michael Roukes and prof. Kavli Laurate, Sumio Iijima. Prof. Thomas Ebbesen was not present when the picture was taken.Photo: Ida Hederström.

1st Nanotechnology@NTNU

In conjunction with the Kavli Prize Lectures given in Trondheim, NTNU NanoLab arranged an international symposium, 1st Nanotechnology@NTNU. The symposium lasted for one and a half day, opening after lunch on the same day as the Kavli Prize Lectures were given. A number of foreign speakers had been invited to give lectures on this occasion among them the Kavli laureate Sumio Iijima. In addition, selected speakers from NTNU and SINTEF participated in the program;

- Sumio Iijima; Meijo-university; *Latest Study on Nano-Carbon Materials by High Resolution Electron Microscopy.*
- Michael Roukes, Kavli NanoScience Institute at California Institute of Technology.
- Flemming Besenbacher, Aarhus University; *Catalytic Model Systems and Surface Reactivity Studied at the Atomic Scale by High-Resolution Fast-Scanning STM.*
- T.W. Ebbesen; Light and Metal: *Surface Plasmon Devices and Circuitry.*
- Magnus Rønning, Dept. of Chemical Engineering, NTNU; *Nanostructured materials in environmental catalysis.*
- Zhiliang Zhang, NTNU Nanomechanical Lab, NTNU; *Nanomechanics of Polymer Particles.*
- Hans Mooij, Kavli Institute of Nanoscience, Delft University of Technology; *Quantum computation with nanocircuits.*
- Arne Brataas, Dept. of Physics, NTNU; *Magnetoelectronics Spin Transfer Torque, Dissipation, and Noise.*
- Hermann E. Gaub, Ludwig Maximiliians University Munich; *Single Molecule Force Spectroscopy: Access to Novel Functions of Biomolecules.*
- Marit Sletmoen, Dept of Physics, NTNU; *Probing Molecular Interactions Involving Polysaccharides – a Single Molecule Approach.*
- Thomas Bjørnholm, Copenhagen University; *Single Molecule Science.*
- De Chen, Dept. of Chemical Engineering, NTNU; *Engineering of metal nanoparticles on carbon nanofibers.*
- Randi Holmestad, Dept. of Physics, NTNU; *Scanning transmission electron micros-*

copy – Studying materials with a nanometre electron probe.
- Monika Pilz, SINTEF Materials and Chemistry, Oslo; *Nanosized inorganic-organic hybrid polymers for coating and packaging applications.*

In addition 22 posters were presented on the symposium, which gathered 133 participants.

3rd NTNU NanoLab User Meeting

The 3rd NTNU NanoLab User Meeting was arranged as a one-day seminar at the Radisson SAS Royal Garden Hotel in Trondheim, on the 6th of March 2008. The meeting was opened by the director of NTNU NanoLab, Professor Thomas Tybell who focused on the purpose of the meeting; namely to display the ongoing research activities within nanotechnology at NTNU and promote cross-disciplinary cooperation.

Photo: Ida Hederström

The event gathered 66 participants from 8 Departments at NTNU and, SINTEF. This broad participation was reflected by the variety of the 18 presentations:

- Florian Mumm; *Nanofabrication using a biopolymer template.*
- Dionne Klein; *High-resolution microscopy studies of immunostimulatory DNA.*
- Catharina Davies; *Delivery of nanomedicine.*
- Magnus Olderøy; *Nanoscale control of mineral deposition within polysaccharide gel networks.*
- Kjell M. Vårum; *What about chitin and chitosans?*
- Daniel Huertas-Hernando; *Charge and spin transport in nanostructures.*
- Fervin Moses Anthonysamy; *Photoluminescence study of GaAs-based nanowires grown by molecular beam epitaxy.*
- Ørnulf Nordseth; *Growth and optical characterization of waveguiding epitaxial thin films of PLZT.*
- Magne Saxegaard; *Field and current induced magnetization reversal studied through spatially resolved point contacts.*
- Sverre Magnus Selbach; *Size-dependent properties of multiferroic nanoparticles.*
- Jianying He; *Size effect on mechanical properties of PS-DVB microspheres.*
- Per Martin Rørvik; *Template-free hydrothermal synthesis of $PbTiO_3$ nanorod arrays.*
- Francesco Madaro; *Synthesis of alkali niobate templates for textured KNN piezoelectrics.*
- Ton van Helvoort; *Aberration corrected transmission electron microscopy – what can it be used for?*
- Wakshum Mekonnen Tucho; *Microstructure and permeation studies of H_2 permeable Pd-Ag Membranes.*
- Christian Weigand; *Pulsed laser deposition growth of ZnO nanostructures for electron transport in hybrid inorganic/organic solar cells.*
- Tommy Mokkelbust; *Enhanced solar cell efficency by up conversion.*
- Duan Chen; *Application of carbon nanotube composites.*

Veeco-NTNU NanoLab AFM User Meeting

A User Meeting focusing on the multitude of options offered by Atomic Force Microscopy was arranged at NTNU, October 30. – 31, 2008, by Veeco Instruments and NTNU NanoLab. The meeting comprised lectures as well as practical demonstrations and gathered 45 participants.

- Bjørn T. Stokke, NTNU; *Introduction and overview of Nano activities at NTNU.*
- Fride Vullum, NTNU; *From atoms to microspheres - An introduction to AFM.*
- Børge Holme, SINTEF; *Combining White Light Interferometry and Atomic Force Microscopy in the study of silicoaluminop hosphate catalysts.*
- Patrick Markus, Veeco Instruments, Netherlands; *HarmoniX™ – Nanoscale mechanical properties mapping.*
- Makoto Takemasa, NTNU; *Single-molecule approach for characterization of polysaccharide interactions.*
- Henrik Bohr, Technical University of Denmark; *AFM studies of proteins arranged in arrays or in aggregations.*
- Kristofer Paso, NTNU; *Paraffin Wax Investigations with AFM.*
- Dr. Aji Mathew, Luleå University of Technology; *Evaluation of the structure of cellulose nanowhiskers, nanofibrils and their nanocomposites using atomic force microscopy.*
- Justin Wells, NTNU; *Performing conductivity measurements on the nanoscale using multi-contact probes.*

Discussing the options of the AFM in the cleanroom. Photo: Thomas Tybell

Seminars and Colloquia

During 2008 several seminars, colloquia and courses focusing on opportunities and practical issues of various instruments available in the clean room area for chemical methods have been arranged:

Applications of Rapid Thermal Processing (RTP) ovens

Frode Tyholdt from SINTEF Materials and Chemistry gave a lecture on the topic: Chemical solution deposition of textured and epitaxial films by rapid thermal processing. After the lecture, Tyholdt gave a practical demonstration of the RTP oven in the clean room.

Short introduction to Scanning Electrochemical Microscopy (SECM)

Prof. Øyvind Mikkelsen gave a lecture with the title: Scanning Electron Microscope – applications and possibilities. The lecture was followed by a practical demonstation of the instrument by MSc Silje Marie Skogvold.

Introduction Courses on Atomic Force Microscopy (AFM)

Associate Prof. Fride Vullum has given 7 half-day practical introduction courses in application of AFM. The course is a requirement for receiving user access to the NTNU NanoLab's AFM. All in all 25 people attended these courses in 2008.

In addition, several colloquia and seminars have been given by invited guests and local staff:

- Dr. Tamio Ikeshoji, RICS, National Institute of Advanced Industrial Science and Technology, AIST, Japan; *Nano-Technology and NanoScience in electronic device development and Nano-Simulations for fuel cells.*
- Associate Prof. Val Zwiller, the Kavli Institute of Nanoscience, TU Delft; *Quantum optics with nanowires and quantum dots.*
- Prof. Andy Kent, New York University; *Spin-Transfer in Magnetic Nanopillars.*
- Prof. J.M.Zuo, University of Illinois, Urbana-Chamapign; *Atomic Structure of Nanoparticles and Their Surfaces.*
- Prof. Reuben T. Collins, Colorado School of Mines, Golden, USA; *Organic Photovoltaics.*
- Dr. Chris Marrows, the University of Leeds; *Domain wall magnetoresistance and current driven motion.*
- Prof. John Weckert, the School of Humanities and Social Sciences at Charles Sturt University, Australia; *I don't care what you do so much as long as you worry about it: some considerations on responsibility.*
- Prof. Gabor A. Somorjai, the University of California, Berkeley; *The Nanoscience Revolution in Catalysis Science.*
- Professor Stephan Hell, the Max Planck Institute for Biophysical Chemistry, Department of NanoBiophotonics and University of Göttingen; *Far-field Nanoscopy.-F*
- Maria Engström, Center for Medical Imaging Science and Visualization, and University of Lindköping; *Nanoparticles as contrast agents in MR and cell studies.e*
- Thijs J.H. Vlug, the Technical University of Delft; *Molecular simulations of nanoscale pore or particle structures.*
- Associate Prof. Morten Kildemo, Dept of Physics, NTNU; *Optical response from nanostructured surfaces.*

Dissertations

The following candidates have defended their thesis for a PhD degree at NTNU in fields related to nanotechnology in 2008.

- Kjetil Børkje: *Theoretical studies of unconventional order in quantum many-particle systems.*
- Håkon Børli: *Modeling of Drain Current and Intrinsic Capacitances in Nanoscale Double-Gate and Gate-All-Around MOSFETs.*
- Anja Bye: *Gene expression profiling of inherited and acquired maximal oxygen uptake.*
- Eskil Kulseth Dahl: *Theoretical studies of condensed matter systems with multiple broken symmetries.*
- Bjørn Christian Enger: *Hydrogen production by catalytic partial oxidation of methane.*
- Tom Richard Evensen: *Nanoparticles in dilute solution: a numerical study of rotational diffusion.*
- Davi de Miranda Fonseca: *Phase separation and orientational ordering of synthetic Na-fluorohectorite clay particles in saline aqueous suspensions.*
- Jørn Foros: *Noise and dissipation in magneto-electronic nanostructures.*
- Martin Sigurd Grønsleth: *Theoretical Studies of Unconventional Superconductors.*
- Lars Hagen: *Regulation of DNA Base excision repair by protein interactions and post translational modifications.*
- Nina Hammer: *Au-TiO2 catalysts supported on carbon nanostructures for CO removal reactions.*
- Lina Jonasson: *Electrochemical formation of carbon nanostructures in Cryolitic melts.*
- Jan Petter Morten: *Coherent and Correlated Spin Transport in Nanoscale Superconductors.*
- Ronny Myhre: *Genetic studies of candidate genes in Parkinson's disease.*
- Yrr Asbjørg Mørch: *Novel Alginate Microcapsules for Cell Therapy – A study of the structure-function relationships in native and structurally engineered alginates.*
- Camilla Nordhei: *Aspects of electronic and structural properties of nanophase cubic ferrites studied by X-ray absorption spectroscopy, including the decomposition of carbon dioxide over hydrogen-reduced ferrites.*
- Per Martin Rørvik: *Synthesis of ferroelectric nanostructures.*
- Shimul Chandra Saha: *RF MEMS Switch Circuits.*
- Lei Shao: *Cross linking and Stabilization of High Free Volume Polymers for Gas Separations.*
- Ottar Sundheim: *Structure-function analysis of human enzymes initiating nucleobase repair in DNA and RNA.*
- Marte Thuen: *Manganese-enhanced and diffusion tensor MR imaging of the normal, injured and regenerating rat visual pathway.*
- Cathrine Broberg Vågbø: *Direct repair of alkylation damage in DNA and RNA by 2-oxoglutarate- and iron-dependent dioxygenases.*
- Carsten Wulff: *Efficient ADCs for Nano-Scale CMOS Technology.*

Publications

Nanomaterials

Antoni, P.; Malkoch, M.; Vamvounis, G.; Nyström, D.; Nyström, A; Lindgren, M. and Hult, A. *Europium confined cyclen dendrimers with photophysically active triazoles.* Journal of Materials Chemistry, 2008, 18, 2545.

Bedeaux, D. and Kjelstrup, S. *The measurable heat flux that accompanies active transport by Ca{2+} - ATPase.* Physical Chemistry, Chemical Physics – PCCP, 2008, 10, 7304.

Blomquist, J., Walle, L. E.; Uvdal, P.; Borg, A. and Sandell, A. *Water Dissociation on Single Crystalline Anatase TiO2(001) Studied by Photoelectron Spectroscopy.* The Journal of Physical Chemistry C, 2008, 112 (42) 16616.
Bresme, F.; Lervik, A.; Bedeaux, D. and Kjelstrup, S. *Water polarization under thermal gradients.* Physical Review Letters 2008, 101, (020602)

Chen, Y.; Roven, H. J.; Wang, Q.D.; Liu, M. and Lin, J. *Effect of the second phase on the microstructure of magnesium alloys during cyclic extrusion compression.* Materials Science Forum, 2008, 584-586, 523.

Chen, Y.; Wang, Q. D., Roven, H. J.; Liu, M.; Karlsen, M.; Yu, Y. and Hjelen, J.
Network-shaped fine-grained microstructure and high ductility of magnesium alloy fabricated by cyclic extrusion compression. Scripta Materialia, 2008, 58, 311.

Chen, Y.; Wang, Q.D.; Roven, H. J.; Karlsen, M.; Yu, Y.; Liu, M. and Hjelen, J.
Microstructure evolution in magnesium alloy AZ31 during cyclic extrusion compression. Journal of Alloys and Compounds, 2008, 462, 192.

Eberg, E.; Monsen, Å. F.; Tybell, T.; van Helvoort, A. and Holmestad, R. *Comparison of TEM specimen preparation of perovskite thin films by tripod polishing and conventional ion milling.* Journal of Electron Microscopy, 2008, 57(6), 175.

Evensen, T. R.; Elgsaeter, A. and Elgsaeter, A.
Free rotational diffusion of rigid particles with arbitrary surface topography: A Brownian dynamics study using Eulerian angles. Macromolecular Theory and Simulations 2008, Volum 17, 121.

Evensen, T. R.; Næss, S. N. and Elgsaeter, A.
Brownian Dynamics Simulations of Rotational Diffusion Using the Cartesian Components of the Rotation Vector as the Generalized Coordinates. Macromolecular Theory and Simulations, 2008, 17, 403.

Garberg, T.; Naess, S. N.; Helgesen, G.; Knudsen, K. D.; Kopstad, G. and Elgsaeter, A. *A transmission electron microscope end electron diffraction study of carbon nanodisks.* Carbon, 2008, 46, 1535.

Grainger, D. R. and Hagg, M.-B. *The recovery by carbon molecular sieve membranes of hydrogen transmitted in natural gas networks.* International journal of hydrogen energy, 2008, 33, 2379.

Haas, O.-E.; Simon, J. M.; Kjelstrup, S.; Ramstad, A. L. and Fouquet, P. *Quasi-elastic neutron scattering investigation of the hydrogen surface self-diffusion on polymer electrolyte membrane fuel cell catalyst support.* The Journal of Physical Chemistry C, 2008, 112, 3121.

He, J.; Zhang, Z.; Midttun, M.; Fonnum, G.; Modahl, G.I.; Kristiansen, H. and Redford, K. *Size effect on mechanical properties of micron-sized PS-DVB polymer particles.* Polymer, 2008, 49(18), 3993.

Jan Petter Morten (right) receives The Faculty of Natural Sciences and Technologys award for Best PhD Thesis 2008 from Vice Dean Åse Krokje (left) and Faculty Director Geir Walsø.
Photo: Marianne Sjøholtstrand.

Huber, F.; Venvik, H. J.; Rønning, M.; Walmsley, J. C. and Holmen, A. *Preparation and characterization of nanocrystalline, high-surface area Cu-Ce-Zr mixed oxide catalysts from homogeneous coprecipitation.* Chemical Engineering Journal, 2008, 137, 686.

Inzoli, I.; Simon, J.-M.; Bedeaux, D. and Kjelstrup, S. *Thermal Diffusion and Partial Molar Variations of n-Butane in Silicalite-1.* Journal of Physical Chemistry B, 2008, 112, 14937.

Jia, Z.; Graver, B. K. F.; Walmsley, J. C.; Yu, Y.; Solberg, J. K. and Nisancioglu, K.
Effect of magnesium on segregation of trace element lead and anodic activation in aluminum alloys. Journal of the Electrochemical Society, 2008, 155(1), C1-C7.

Kjelstrup, S.; De Meis, L.; Bedeaux, D. and Simon, J.-M. *Is the Ca2+-ATPase from sarcoplasmic reticulum also a heat pump?* European Biophysics Journal, 2008, 38(1), 59.

Kvande, I.; Chen, D.; Yu, Z.; Rønning, M. and Holmen, A. *Optimization and scale-up of CNF production based on intrinsic kinetic data obtained from TEOM.* Journal of Catalysis, 2008, 256, 204.

Kvande, I.; Øye, G.; Hammer, N.; Rønning, M.; Raaen, S.; Holmen, A.; Sjøblom, J. and Chen, D. *Deposition of Au colloids on plasmachemically modified carbon nanofibers.* Carbon, 2008, 46, 759.

Larsen, M. H.; Walmsley, J. C.; Lunder, O.; Mathiesen, R. and Nisancioglu, K.
Intergranular corrosion of copper-containing AA6xxx AlMgSi aluminum alloys. Journal of the Electrochemical Society, 2008, 155.(11) C550-C556.

Lin, J.; Wang, Q.; Peng, L. and Roven, H. J. *Study on deformation behaviour and strain homogeneity during cyclic extrusion and compression.* Journal of Materials Science, 2008, 43(21) 6920.

Liu, M.; Roven, H. J. Murashkin, M. and Valiev, R. Z. *Deformation twins and stacking faults in an AA5182 Al-Mg alloy processed by high pressure torsion.* Materials Science Forum, 2008, 579, 147.

Liu, M.; Roven, H. J.; Ungar, T.; Balogh, L.; Murashkin, M. and Valiev, R. Z. *Grain boundary structure and deformation defects in nanostructured Al–Mg alloys processed by high pressure torsion.* Materials Science Forum, 2008 ,584-586, 528.

Liu, M., Roven, H. J.; Yu, Y. and Werenskiold, J. C.
Deformation structures in 6082 aluminium alloy after severe plastic deformation by equal-channel angular pressing. Materials Science & Engineering: A, 2008, 483–484, 59.

Marioara, C. D.; Andersen, S. J.; Birkeland, A and; Holmestad, R. *Orientation of silicon particles in a binary Al–Si alloy.* Journal of Materials Science, 2008, 43(14) 4962.

Matam, S. K.; Chen, D.; Walmsley, J. C. and Holmen, A. *Dehydrogenation of propane over Pt-SBA-15: Effect of Pt particle size.* Catalysis Communications, 2008, 9, 747.

Mayer, A.; Lambin, P. and Åstrand, P.-O. *An electrostatic interaction model for frequency-dependent polarizability: methodology and applications to hydrocarbons and fullerenes.* Nanotechnology, 2008, 19, 025203.

Photo: Anne Støre

Mayer, A. and Åstrand, P.-O. A Charge-Dipole *Model for the Static Polarizability of Nanostructures Including Aliphatic, Olephinic, and Aromatic Systems.* Journal of Physical Chemistry A, 2008, 112, 1277.

Mokkelbost, T.; Kaus, I.; Haugsrud, R.; Norby, T.; Grande, T. and Einarsrud, M.-A. *High-temperature proton-conducting lanthanum ortho-niobate-based materials. Part II: Sintering properties and solubility of alkaline earth oxides.* Journal of the American Ceramic Society, 2008, 91, 879.

Nagayoshi, H.; Nordmark, H.; Holmestad, R.; Matsumoto, N.; Nishimura, S.; Tersahima, K.; Walmsley, J. C. and Ulyashin, A. Silicon Whisker *Growth Using Hot Filament Reactor with Hydrogen as Source Gas.* Japanese Journal of Applied Physics, 2008, 47(6), 4807.

Nordhei, C.; Ramstad, A. L. and Nicholson, D. G. *Nanophase cobalt, nickel and zinc ferrites: Synchrotron XAS study on the crystallite size dependence of metal distribution.* Physical Chemistry, Chemical Physics – PCCP, 2008,10(7), 1053.

Nordmark, H.; Ulyashin, A.; Walmsley, J. C. and Holmestad, R. *A comparative analysis of structural defect formation in Si+ implanted and then plasma hydrogenated and in H+ implanted crystalline silicon.* Solid State Phenomena, 2008, 131-133, 309.

Nordmark, H.; Ulyashin, A.; Walmsley, J. C.; Holt, A. and Holmestad, R. *The temperature evolution of the hydrogen plasma induced structural defects in crystalline silicon.* Solid State Phenomena, 2008, 131-133, 315.

Pitt, M.; Vullum, P. E.; Sørby, M. H.; Sulic, M. P.; Jensen, C. M.; Walmsley, J. C.; Holmestad, R. and Hauback, B.C. *Structural properties of the nanoscopic Al85Ti15 solid solution observed in the hydrogen-cycled NaAlH4 + 0.1TiCl3 system.* Acta Materialia, 2008, 56(17), 4691.

Ochoa-Fernandez, E.; Rønning, M.; Yu, X.; Grande, T. and Chen, D. *Compositional effects of nanocrystalline lithium zirconate on its CO2 capture properties.* Industrial & Engineering Chemistry Research, 2008, 47, 434.

Ofstad, A. B.; Davey, J. R.; Sunde, S. and Borup, R. L. *Carbon corrosion of a PEMFC during shut-down/ start-up when using an air purge procedure.* ECS Transactions, 2008, 16, 1301.

Okuyucu, H.; Dahl, P. I. and Einarsrud, M.-A. *Coating of LaCoO3 thin film with sol-gel dip coating method.* Journal of Nanoscience and Nanotechnology, 2008, 8, 685.

Roven, H. J.; Liu, M. and Werenskiold, J. C. *Dynamic precipitation during severe plastic deformation of an Al–Mg–Si aluminium alloy.* Materials Science & Engineering: A, 2008, 483–484, 54.

Rydén, M.; Lyngfelt, A.; Mattisson, T.; Chen, D.; Holmen, A.; Bjørgum, E. *Novel oxygen-carrier materials for chemical-looping combustion and chemical-looping reforming: LaxSr1-xFey-yO3-δ perovskites and mixed-metal oxides of NiO, Fe2O3 and Mn3O4.* International Journal of Greenhouse Gas Control, 2008, 2, 21.

Rørvik, P. M.; Almli, Å.; Van Helvoort, A.; Holmestad, R.; Tybell, T.; Grande, T. and Einarsrud, M.-A. *PbTiO3 nanorod arrays grown by self-assembly of nanocrystals.* Nanotechnology, 2008, 19, (225605).

Rørvik, P. M.; Lyngdal, T.; Sæterli, R.; Van Helvoort, A.; Holmestad, R.; Grande, T. and Einarsrud, M.-A. *Influence of volatile chlorides on the molten salt synthesis of ternary oxide nanorods and nanoparticles.* Inorganic Chemistry, 2008, 47, 3173.

Sandell, A.; Biplab, S.; Walle, L. E.; Richter, Hinnerk, J.; Plogmaker, S.; Karlsson, P.; Borg, A. and Uvdal, P. *Probing and modifying the empty-state threshold of anatase TiO_2: Experiments and ab initio theory.* Physical Review B. Condensed Matter and Materials Physics, 2008, 78 (075113)

Sanz-Navarro, C. F.; Åstrand, P.-O.; Chen, D.; Rønning, M.; van Duin, A. C. T.; Mueller, J. E. and Goddard III, W. A. *Molecular Dynamics Simulations of Carbon-Supported Ni Clusters Using the Reax Reactive Force Field.* Journal of Physical Chemistry C, 2008, 112, 12663.

Sanz-Navarro, C.; Åstrand, P.-O.; Chen, D.; Rønning, M.; van Duin, A. C. T.; Jacob, T. and Goddard III, W. A. *Molecular Dynamics Simulations of the Interactions between Platinum Clusters and Carbon Platelets.* Journal of Physical Chemistry A, 2008, 112, 1392.

Shao, L.; Samseth, J.; Hagg, M.-B. *Crosslinking and stabilization of high fractional free volume polymers for gas separation.* International Journal of Greenhouse Gas Control, 2008, 2, 492.

Shao, L.; Zhao, T.; Chen, D. and Hagg, M.-B. *Poly(4-methyl-2-pentyne) and Carbon Nanotube Mixed Matrix Membranes for Gas Separation.* American Chemical Society Symposium Series (ACS), 2008, 99, 180.

Starink, M. J.; Wang, S. C.; Qiao, X. G.; Gao, N.; Roven, H. J and Langdon, T. G. *Shear deformation and texture evolution in Al alloys processed for one pass by ECAP.* Materials Science Forum, 2008, 584-586, 679.

Szczygiel, P.; Roven, H. J. and Reiso, O. *Annealing of Al-Si alloys after equal-channel angular pressing.* Materials Science & Engineering: A, 2008, 493, 202.

Tucho, W. M.; Arstad, B.; Klette, H.; Walmsley, J.C.; Bredesen, R.; Venvik, H. J. and Holmestad, R. *Microstructural characterization of self-supported 1.6μm Pd/Ag membranes.* Journal of Membrane Science, 2008, 310, 337.

Vullum, P. E.; Lein, H. L.; Einarsrud, M.-A.; Grande, T. and Holmestad, R.
TEM observations of rhombohedral and monoclinic domains in LaCoO3-based ceramics. Philosophical Magazine, 2008, 88, 1187.

Westlund, R.; Glimsdal, E.; Lindgren, M.; Vestberg, R.; Hawker, C.; Lopes, C. and Malmström, E. *Click chemistry for photonic applications: triazole-functionalized platinum(II) acetylides for optical power limiting.* Journal of Materials Chemistry, 2008, 18, 166.

Photo: Anne Støre

Westlund, R.; Malmström, E.; Lopes, C.; Öhgren, J.; Rodgers, T.; Saito, Y.; Kawata, S.; Glimsdal, E. and Lindgren, M.
Efficient Nonlinear Absorbing Platinum(II) Acetylide Chromophores in Solid PMMA Matrices. Advanced Functional Materials, 2008, 18, 1.

Wu, Y.; Han, W.; Zhou, S. X.; Lototsky, Volodymyrovich, M.; Solberg, J. K. and Yartys, V. *Microstructure and hydrogenation behaviour of ball-milled and melt-spun Mg-10Ni-2Mm alloys.* Journal of Alloys and Compounds, 2008, 466, 176.

Yu, Z.; Chen, D.; Rønning, M.; Tøtdal, B.; Vrålstad, T.; Ochoa-Fernandez, E. and Holmen, A. *Large-scale synthesis of carbon nanofibers on Ni-Fe-Al hydrotalcite derived catalysts. II: Effect of Ni/Fe composition on CNF synthesis from ethylene and carbon monoxide.* Applied Catalysis A : General, 2008, 338, 147.

Yu, Z.; Chen, D.; Rønning, M.; Vrålstad, T.; Ochoa-Fernandez, E. and Holmen, A.
Large-scale synthesis of carbon nanofibers on Ni-Fe-Al hydrotalcite derived catalysts. I. Preparation and characterization of the Ni-Fe-Al hydrotalcites and their derived catalysts. Applied Catalysis A : General, 2008, 338, 136.

Yu, Z.; Fareid, L. E.; Moljord, K.; Blekkan, E. A.; Walmsley, J. C. and Chen, D.
Hydrodesulfurization of thiophene on carbon nanofiber supported Co/Ni/Mo catalysts. Applied Catalysis B: Environmental, 2008, 84, 482.

Zheng, J.-S.; Zhang, X.-S.; Li, P.; Zhou, X.-G.; Chen, D.; Liu, Y. and Yuan, W.-K.
Oxygen reduction reaction properties of carbon nanofibers: Effect of metal purification. Electrochimica Acta, 2008, 53, 3587.

Zhu, J.; Zhao, T.; Kvande, I.; Chen, D.; Zhou, X.; Yuan, W. *Carbon Nanofiber-Supported Pd Catalysts for Heck Reaction: Effect of Support Interaction.* Chinese Journal of Catalysis, 2008, 29, 1145.

Zhu, J.; Zhou, J.; Zhao, T.; Zhou, X.; Chen, D. and Yuan, W.
Carbon nanofiber-supported palladium nanoparticles as potential recyclable catalysts for the Heck reaction. Applied Catalysis A : General, 2008, 352, 243.

Zieba, R.; Desroches, C.; Chaput, F.; Carlsson, M.; Eliasson, B.; Lopes, C.; Lindgren, M. and Parola, S. *Preparation of functional hybrid glass materials from platinum(II) complexes for broadband nonlinear absorption of light.* Advanced Functional Materials, 2008, 19, 235.


Photo: Ida Hedeström

Nanoelectronics, -photonics and -magnetism

Brataas, Arne. *Nanoelectronics - Spin surprise in carbon.* Nature, 2008, 452, 419.

Brataas, A.; Tserkovnyak, Y. and Bauer, G.E.W. *Scattering theory of Gilbert damping.* Physical Review Letters, 2008, 101, (037207).

Børkje, K. and Sudbø, A. *Effective theory of fluctuating orbital currents in high-Tc cuprate superconductors.* Physical Review B. Condensed Matter and Materials Physics, 2008, 77 (092404)

Dahl, E. K.; Babaev, E. and Sudbø, A. *Hidden vortex lattices in a thermally paired superfluid.* Physical Review B. Condensed Matter and Materials Physics, 2008, 78(144510)

Dahl, E. K.; Babaev, E. and Sudbø, A. *Unusual States of Vortex Matter in Mixtures of Bose-Einstein Condensates on Rotating Optical Lattices.* Physical Review Letters, 2008, 101.(255301)

Dahl, E. K.; Babaev, E.; Kragset, S. and Sudbø, A. *Preemptive vortex-loop proliferation in multicomponent interacting Bose-Einstein condensates.* Physical Review B. Condensed Matter and Materials Physics, 2008, 77(144519)

Dahl, Ø.; Grepstad, J. and Tybell, T. *Crystalline and dielectric properties of sputter deposited $PbTiO_3$ thin films.* Journal of Applied Physics, 2008, 103, 114112-1-114112-8

Dasa, L. N.; Partiarche, G.; Zhou, H.; Harmand, J. C.; Weman, H. and Fimland, B.-O. *Growth and structural characterization of GaAs/GaAsSb axial heterostructured nanowires.* Journal of Crystal Growth, 2008, 8, 4495.

Dasa, L. N.; Patriarche, G; Largeau, L; Zhou, H.; van Helvoort, A.; Glas, F; Harmand, J. C.; Fimland, B.-O. and Weman, H. *Zinc blende GaAsSb nanowires grown by molecular beam epitaxy.* Nanotechnology, 2008, 19, 275605.

Dasa, L. N.; Patriarche, G.; Zhou, H.; Hoang, T. B.; Anthonysamy, F. M.; Grønsberg, S.; van Helvoort, A.; Fimland, B.-O. and Weman, H. *Growth and characterization of GaAs nanowires with defect-free zinc blende GaAsSb inserts.* Nano letters, 2008, 8, 4459.

Foros, J.; Brataas, A. Tserkovnyak, Y; Bauer, G.E.W. *Current-induced noise and damping in nonuniform ferromagnets.* Physical Review B. Condensed Matter and Materials Physics, 2008, 78, 140402.

Haugen, H.; Huertas-Hernando, D. and Brataas, A. *Spin transport in proximity-induced ferromagnet graphene.* Physical Review B. Condensed Matter and Materials Physics, 2008, 77, 115406.

Kragset, S.; Babaev, E. and Sudbø, A. *Effects of boundaries and density inhomogeneity on states of vortex matter in Bose-Einstein condensates at finite temperature.* Physical Review A. Atomic, Molecular, and Optical Physics, 2008, 77, 043605

Linder, J.; Andriy, N. and Sudbø, A. *Nontrivial interplay of superconductivity and spin-orbit coupling in noncentrosymmetric ferromagnets.* Physical Review B. Condensed Matter and Materials Physics, 2008, 78, 172502.

Linder, J.; Sperstad, I. B.; Nevidomskyy, A. H.; Cuoco, M. and Sudbø, A. *Coexistence of itinerant ferromagnetism and a nonunitary superconducting state with line nodes: Possible application to UGe2.* Physical Review B. Condensed Matter and Materials Physics, 2008, 77, 184511.
Linder, J. and Sudbø, A. *Tunneling conductance in*

Photo: Ida Hedeström

s- and d-wave superconductor-graphene junctions: Extended Blonder-Tinkham-Klapwijk formalism. Physical Review B. Condensed Matter and Materials Physics, 2008, 77, 064507.

Linder, J.; Yokoyama, T.; Huertas-Hernando, D. and Sudbø, A. *Supercurrent Switch in Graphene Junctions.* Physical Review Letters, 2008, 100, 187004.

Linder, J.; Yokoyama, T. and Sudbø, A. *Density of states near a vortex core in ferromagnetic superconductors: Application to STM measurements.* Physical Review B. Condensed Matter and Materials Physics, 2008, 78, 064520.

Mo, F.; Chernyshov, D.; Thoresen, L. S.; Breiby, D. W. and Tybell, T. *X-ray study of the impact of a weak electric field on the domain structure in PbTiO3 thin films.* Acta Crystallographica Section A: Foundations of Crystallography, 2008, A64, C520-C521.

Morten, J. P.; Brataas, A.; Bauer, G.E.W.; Belzig, W. and Tserkovnyak, Y. *Proximity-effect-assisted decay of spin-currents in superconductors.* Europhysics letters, 2008, 84, 57008.

Morten, J. P.; Huertas-Hernando, D.; Belzig, W. and Brataas, A. *Elementary charge transfer processes in a superconductor-ferromagnet entangler.* Europhysics letters, 2008, 81, 40002.

Morten, J. P.; Huertas-Hernando, D.; Belzig, W. and Brataas, A. *Full counting statistics of crossed Andreev reflection.* Physical Review B. Condensed Matter and Materials Physics, 2008, 78, 224515.

Nguyen, A. K. and Brataas, A. *External control of a metal-insulator transition in GaMnAs wires*. Physical Review Letters, 2008, Volum 101, (016801).

Poli, N; Morten, J. P.; Urech, M; Brataas, A.; Haviland, D. B. and Korenivski, V.
Spin injection and relaxation in a mesoscopic superconductor. Physical Review Letters, 2008, 100, 136601.

Takahashi, R.; Dahl, Ø.; Eberg, E.; Grepstad, J. and Tybell, T. *Ferroelectric stripe-domains in PbTiO3 thin films: depolarization field and domain randomness.* Journal of Applied Physics, 2008, 104, 064109-1-064109-7

Takahashi, R.; Grepstad, J.; Tybell, T. and Matsumoto, Y. *Photochemical switching of ultrathin PbTiO3 films.* Applied Physics Letters, 2008, 92, 112901.

Tserkovnyak, Y; Brataas, A. and Bauer, G.E.W. *Theory of current-driven magnetization dynamics in inhomogenous ferromagnets.* Journal of Magnetism and Magnetic Materials, 2008, 320, 1282.

Xiao, J. Bauer, G.E.W. and Brataas, A. *Charge pumping in magnetic tunnel junctions: Scattering theory.* Physical Review B. Condensed Matter and Materials Physics, 2008, 77, 180407R.

Xiao, J.; Bauer, G.E.W. and Brataas, A. *Spin-transfer torque in magnetic tunnel junctions: Scattering theory.* Physical Review B. Condensed Matter and Materials Physics, 2008, 77, 224419.

Ytterdal T. Nanoscale Analog CMOS Circuits for Medical Ultrasound Imaging Applications. I: 2-D Modeling of Nanoscale Multigate MOSFETs. Beijing, Kina: IEEE 2008 ISBN 978-1-4244-2186-2. s. 1697-1700

Bionanotechnology

Akbari, M. and Krokan, H. E. *Cytotoxicity and mutagenicity of endogenous DNA base lesions as potential cause of human aging.* Mech Ageing Dev., 2008, 129, 353.

Akbari, M.; Visnes, T.; Krokan, H. E. and Otterlei, M. *Base excision repair by human mitochondrial extracts involves both single-nucleotide insertion and long-patch DNA synthesis.* DNA Repair, 2008, 7, 605.

Baekken, P. M; Skorpen, F.; Stordal, E.; Zwart, J. A. and Hagen, K. *Depression and anxiety in relation to catechol-O-methyltransferase Val158Met genotype in the general population: the Nord-Trøndelag Health Study (HUNT).* BMC Psychiatry. 2008, 8, 48.

Bernsand, M.; Zhao, C. M.; Håkanson, R.; Stenström, B.; Chen, D.and Norlén, P. *Ischemia mobilizes histamine but not pancreastatin from ECL cells of rat stomach: evidence for a cytosolic histamine compartment.* Cell Tissue Res, 2008, 333, 405.

Bye, A, Høydal M. A,; Catalucci, D.; Langaas, M.; Kemi, O. J.; Beisvag V.; Koch, L. G.; Britton, S. L.; Ellingsen, Ø. and Wisløff, U. *Gene expression profiling of skeletal muscle in exercise-trained and sedentary rats with inborn high and low VO2max.* Physiol Genomics, 2008, 35, 213.

Bye, A; Langaas, M.; Høydal, M. A.; Kemi, O. J.; Heinrich, G.; Koch. L.G.; Britton, S. L.; Najjar, S. M.; Ellingsen, Ø. and Wisløff, U. *Aerobic capacity-dependent differences in cardiac gene expression.* Physiol Genomics, 2008, 33,100.

Cederkvist, F. H.; Parmer, M. P.; Vårum, K. M.; Eijsink, V. G. H. and Sørlie, M.
Inhibition of a family 18 chitinase by chitooligosaccharides. Carbohydrate Polymers, 2008, 74, 41.

Christensen, B. E.; Vold, I. M.N. and Vårum, K. M. *Chain stiffness and extension of chitosans and periodate oxidised chitosans studied by size-exclusion chromatography combined with light scattering and viscosity detectors.* Carbohydrate Polymers, 2008, 74, 559.

Egecioglu, E., Stenström, B.; Pinnock, S. B.; Tung, L. Y.; Dornonville de la Cour, C.; Lindqvist, A.; Håkanson, R.; Syversen, U.; Chen, D. and Dickson, S. L. *Hypothalamic gene expression following ghrelin therapy to gastrectomized rodents.* Regul Pept., 2008, 146, 176.

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Eide, I.P.; Isaksen, C.V.; Salvesen, K.A.; Langaas, M.; Schønberg, S.A. and Austgulen, R. *Decidual expression and maternal serum levels of heme oxygenase 1 are increased in pre-eclampsia.* Acta Obstet Gynecol Scand., 2008, 87, 272.

Eijsink, V. G. H.; Vaaje-Kolstad, G.; Vårum, K. M. and Horn, S. J. *Towards new enzymes for biofuels: lessons from chitinase research.* Trends in Biotechnology, 2008, 26, 228.

Einbu, A. and Vårum, K. M. *Characterization of chitin and its hydrolysis to GlcNAc and GlcN.* Biomacromolecules, 2008, 9, 1870.

Erikson, A.; Davies, C. de L.; Næss, S. N.; Sikorski, P. and Andersen, H. N.
Physical and Chemical Modifications of Collagen Gels: Impact on Diffusion. Biopolymers, 2008, 89, 135.

Erikson, A.; Tufto, I.; Bjønnum, A. B.; Bruland, Ø. S. and Davies, C. de L.
The impact of enzymatic degradation on the uptake of differently sized therapeutic molecules. Anticancer Research, 2008, 28(6A, 3557.

Fagerli, U. M.; Holt, R.U.; Holien, T.; Vaatsveen, T. K.; Zhan, F.; Egeberg, K. W.; Barlogie, B.; Waage, A.; Aarset, H.; Dai, H. Y.; Shaughnessy, J. D. Jr, Sundan, A, and Børset, M. *Overexpression and involvement in migration by the metastasis-associated phosphatase PRL-3 in human myeloma cells.* Blood, 2008, 111, 806.

Hagen, L.; Kavli, B.; Sousa, M. M. L.; Diaz, J.P.; Liabakk, N. B.; Aslaksen, P.B.; Torseth, K.; Sundheim, O.; Otterlei, M.; Hørning, O.; Jensen, O .N.; Krokan, H. E. and Slupphaug, G. *Cell cycle-specific UNG2 phosphorylations regulate protein turnover, activity and association with RPA.* The EMBO J. 2008, 27, 51.

Gellein, K.; Lierhagen, S.; Brevik, P. S.; Teigen, M.; Kaur, P.; Singh, T.; Flaten, T. P. and Syversen, T. *Trace element profiles in single strands of human hair determined by HR-ICP-MS.* Biol Trace Elem Res. 2008, 123, 250.

Heath, S.C.; Gut, I. G.; Brennan, P.; McKay, J.D.; Bencko, V.; Fabianova, E.; Foretova, L.; Georges, M.; Janout, V.; Kabesch, M.; Krokan, H .E.; Elvestad, M.B.; Lissowska, J.; Mates, D.; Rudnai, P.; Skorpen, F.; Schreiber, S.; Soria, J .M.; Syvänen, A. C.; Meneton, P.; Herçberg, S.; Galan, P.; Szeszenia-Dabrowska, N.; Zaridze, D.; Génin, E.; Cardon, L. R. and Lathrop, M. *Investigation of the fine structure of European populations with applications to disease association studies.* Eur. J Hum. Genet. 2008, 16, 1413.

Hung, R. J.; McKay, J. D.; Gaborieau, V.; Boffetta, P.; Hashibe, M., Earidze, D.; Mukeria, A.; Szeszenia-Dabrowska, N.; Jolanta, L. M; Rudnai, P.;, Fabianova, E., Mates, D., Bencko, V., Foretova, L., Janout, V., Chen, C., Goodman, G., Field, J., Liloglou, T.; Zinarianos, G.; Cassidy, A.; McLaughlin, J.; Liu, G.; Narod, S.; Krokan, H. E.; Skorpen, F.; Elvestad, M. B.; Hveem, K.; Vatten, L.; Linseisen, J.; Clavel-Chapelon, F.; Vineis, P.; Bueno-de-Mes] uita, H. B.; Lund, E.; Martinez, C.; Bingham, S.; Rasmuson, T.; Hainaut, P.; Riboli, E.; Ahrens, W., Benhamou, S.; Lagiou, P.; Trichopoulos, D.; Holcatova, I.; Merletti, F.; Kjærheim, K.; Agudo, A.; Macfarlane, G.; Talamini, R.; Simonato, L.; Lowry, R.; Conway, D.;Enaor, A.; Healy, C.; Eelenika, D.;Boland, A.;Delepine, M.; Foglio, M.; Lechner, D.; Matsuda, F.; Blanche, H.; Gut, I.; Heath, S.; Lathrop, M. and Brennan, P. *A genome-wide association study identifies a susceptibility locus for lung cancer encompassing nicotinic acetylcholine receptor subunit genes on 15q25.* Nature, 2008, 452, 633.

Iversen, A. C.; Nguyen, O. T.; Tømmerdal, L. F.;, Eide, I. P.; Landsem, V. M.; Acar, N.; Myhre, R.; Klungland,H. and Austgulen R. *The HLA-G 14bp gene polymorphism and decidual HLA-G 14bp gene expression in pre-eclamptic and normal pregnancies.* J Reprod Immunol., 2008, 78, 158.

Jakobsen, C.H.; Størvold, G. L.; Bremseth, H.; Follestad, T.; Sand, K.; Mack, M. K. S.; Lundemo, A.G.; Iversen, J. G., Krokan, H.E. and Schønberg, S.A. *DHA induces ER stress and growth arrest in human colon cancer cells – associations with cholesterol and calcium homeostasis.* J. Lipid Res., 2008, 49, 2089.

Kaur, P.; Schulz, K.; Heggland, I.; Aschner, M. and Syversen, T. *The use of fluorescence for detecting MeHg-induced ROS in cell cultures.* Toxicol In Vitro., 2008, 22, 1392.

Larsen, E. L. P.; Randeberg, L. L.; Gederaas, O. A.; Arum, C-J.; Hjelde, A.; Zhao, C.-M.; Chen, D.; Krokan, H. E., and Svaasand, L. O. *Monitoring of hexyl 5-aminolevulinate induced photodynamic therapy in rat Bladder cancer by optical spectroscopy.* J. Biomed. Optics, 2008, 13, 044031.

Marken, E.; Maurstad, G. and Stokke, B. T.
Quantitative analysis of atomic force microscopy topographs of biopolymer multilayers: Surface structure and polymer assembly modes. Thin Solid Films, 2008, 516, 7770.

Maurstad, G.; Mørch, Y. A.; Bausch, A. R. and Stokke, B.T. *Polyelectrolyte layer interpenetration and swelling of alginate-chitosan multilayers studied by dual wavelength reflection interference contrast microscopy.* Carbohydrate Polymers, 2008, 71, 672.

Olsen, Ø.; Thuen, M.; Berry, M.; Kovalev, V.; Petrou, M.; Goa, P. E.;, Sandvig, A.; Haraldseth, O. and Brekken, C. *Axon tracing in the adult rat optic nerve and tract after intravitreal injection of MnDPDP using a semiautomatic segmentation technique.* J Magn Reson Imaging, 2008, 27, 34.

McKay, J.D.; Hung, R. J., Gaborieau, V.; Boffetta, P.; Chabrier, A.; ZaridzeD.; Mukeria, A.: Szeszenia-Dabrowska, N.: Lissowska, J.; Rudnai, P.; Fabianova, E.; Mates, D.; Bencko, V.: Foretova, L.; Janout, V.; McLaughlin, J.; Shepherd, F.; Montpetit, A.; Narod, S.; Krokan, H. E.; Skorpen, F.; Elvestad, M. B.; Vatten, L.; Njølstad, I.; Axelsson, T.; Lubiński, J.; Matyjasik, J.; Lener, M.; Oszutowska,


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D.; Chen, C.; Goodman, G.; Field, J.; Liloglou, T.; Xinarianos, G.; Cassidy, A.; Zelenika, D.; Boland, A.; Delepine, M.; Foglio, M.; Lechner, D.; Matsuda, F.; Blanche, H.; Gut, I.; Heath, S.; Lathrop, M. and Brennan, P. *Identification of gene region 5p15.33, comprising the telomerase reverse transcriptase gene, as a novel lung cancer susceptibility locus among 6,000 lung cancer cases and 9,500 controls.* Nature Genetics, 2008, 40,1404.

Moses, E. K.; Johnson, M. P.; Tømmerdal, L.; Forsmo, S.; Curran, J. E.; Abraham, L. J.; Charlesworth, J. C.; Brennecke, S. P.; Blangero, J. and Austgulen, R. *Genetic association of preeclampsia to the inflammatory response gene SEPS1.* Am J Obstet Gynecol., 2008, 198, 336.e1-5.

Myhre, R.; Steinkjer, S.; Stormyr, A.; Nilsen, G. L.; Abu Zayyad, H.; Horany, K.; Nusier, M. K. and Klungland, H. *Significance of the parkin and PINK1 gene in Jordanian families with incidences of young-onset and juvenile parkinsonism.* BMC Neurol., 2008, 8, 47.

Myhre, R.; Toft, M.; Kachergus, J.; Hulihan. M. M; Aasly, J. O.; Klungland, H. and Farrer, M. J. *Multiple alpha-synuclein gene polymorphisms are associated with Parkinson's disease in a Norwegian population.* Acta Neurol Scand., 2008, 118, 320.

Myhre, R.; Klungland, H.; Farrer, M. J. and Aasly, J. O. *Genetic association study of synphilin-1 in idiopathic Parkinson's disease.* BMC Med Genet., 2008, 9, 19.

Nilsen, N. J.; Deininger, S.; Nonstad, U.; Skjeldal, F.; Husebye, H.; Rodionov, D.; von Aulock, S.; Hartung, T.; Lien, E.; Bakke, O. and Espevik, T. *Cellular trafficking of lipoteichoic acid and Toll-like receptor 2 in relation to signaling: role of CD14 and CD36.* J Leukoc Biol., 2008, 84, 280.

Nørsett, K. G.; Laegreid, A.; Kusnierczyk, W.; Langaas, M.; Ylving, S.; Fossmark, R.; Myhre, S.; Falkmer, S.; Waldum, H. L. and Sandvik, A. K. *Changes in gene expression of gastric mucosa during therapeutic acid inhibition.* Eur J Gastroenterol Hepatol., 2008, 20, 613.

Olsen, Ø.; Thuen, M.; Berry, M.; Kovalev, V.; Petrou, M.; Goa, P. E.; Sandvig, A.; Haraldseth, O. and Brekken, C. *Axon tracing in the adult rat optic nerve and tract after intravitreal injection of MnDPDP using a semiautomatic segmentation technique.* J Magn Reson Imaging., 2008, 27, 34.

Qiu, W.; G,u H.; Zheng, L.; Zhou, J.; Chen, D. and Chen Y. *Pretreatment with edaravone reduces lung mitochondrial damage in an infant rabbit ischemia-reperfusion model.* J Pediatr Surg., 2008, 43, 2053.

Qiu, W.; Zheng, L.; Gu, H.; Chen, D. and Chen, Y. *Comparison between adult and infant lung injury in a rabbit ischemia-reperfusion model.* J Thorac Cardiovasc Surg., 2008, 136, 352.

Rakvåg, T. T.; Ross, J. R.; Sato, H.; Skorpen, F.; Kaasa, S. and Klepstad, P. *Genetic variation in the catechol-O-methyltransferase (COMT) gene and morphine requirements in cancer patients with pain.* Mol Pain., 2008, 18, 64.

Reitan, N. K.; Juthajan, A.; Lindmo, T. and Davies, C. de Lange. *Macromolecular diffusion in the extracellular matrix measured by fluorescence correlation spectroscopy.* Journal of Biomedical Optics, 2008, 13, 054040.

Sletmoen, M.; Maurstad, G. and Stokke, B. T. *Potentials of bionanotechnology in the study and manufacturing of self-assembled biopolymer complexes and gels.* Food Hydrocolloids, 2008, 22.

Slørdahl, T. S.; Hov, H.; Hol, R.U.; Baykov. V.; Syversen, T.; Sundan, A., Waage, A. and Børset, M. *Mn2+ regulates myeloma cell adhesion differently than the proadhesive cytokines HGF, IGF-1, and SDF-1alpha.* Eur J Haematol., 2008, 81, 437.

Strand, S. P.; Issa, M. M.; Christensen, B. E.; Vårum, K. M. nad Artursson, P. *Tailoring of chitosans for gene delivery: Novel self-branched glycosylated chitosan oligomers with improved functional properties.* Biomacromolecules, 2008, 9, 3268.

Sundheim, O.; Talstad, V. A.; Vågbø, C. B.; Slupphaug, G. and Krokan, H.E. *AlkB demethylases flip out in different ways*. DNA Repair, 2008, 7, 1916.

Sæther, H. V.; Holme, H. K.; Maurstad, G.; Smidsrød, O. and Stokke, B. T. *Polyelectrolyte complex formation using alginate and chitosan.* Carbohydrate Polymers, 2008, 74, 813.

Tessem, M. B.; Swanson, M. G.; Keshari, K. R.; Albers, M. J.; Joun, D.; Tabatabai, Z. L.; Simko, J. P.; Shinohara, K.; Nelson, S. J.; Vigneron, D. B.; Gribbestad, I. S. and Kurhanewicz, J. *Evaluation of lactate and alanine as metabolic biomarkers of prostate cancer using 1H HR-MAS spectroscopy of biopsy tissues.* Magn Reson Med., 2008, 60, 510.

Thuen, M.; Berry, M.; Pedersen, T. B.; Goa, P. E.; Summerfield, M.; Haraldseth, O.;, Sandvig, A. and Brekken, C. *Manganese-enhanced MRI of the rat visual pathway: acute neural toxicity, contrast enhancement, axon resolution, axonal transport, and clearance of Mn2+.* J Magn Reson Imaging, 2008, 28, 855.

Tierney, S.; Hjelme, D. R. and Stokke, B. T. *Determination of swelling of responsive gels with nanometer resolution. Fiber-optic based platform for hydrogels as signal transducers.* Analytical Chemistry, 2008, 80, 5086.

Toft, J. H; Lian, I. A.; Tarca, A. L.; Erez, O; Espinoza, J.; Eide, I. P.; Bjørge, L.; Draghici, S.; Romero, R. and Austgulen, R. *Whole-genome microarray and targeted analysis of angiogenesis-regulating gene expression (ENG, FLT1, VEGF, PlGF) in placentas from pre-eclamptic and small-for-gestational-age pregnancies.* J Matern Fetal Neonatal Med. 2008, 21, 267.

Visnes, T.; Pettersen, H. S.; Akbari, M.; Kavli, B.; Slupphaug, G. and Krokan, H.E. *The rate of base excision repair of uracil is controlled by the initiating glycosylase.* DNA Repair, 2008, 7, 1869,

Westbye, M.P.; Feyzi, E.; Aas, P.A.; Vågbø, C.B.; Kavli, B.; Hagen, L.; Sundheim, O.; Liabakk, N.-B.; Slupphaug, G.; Otterlei, M. and Krokan, H. E. *Human AlkB homologue 1 is a mitochondrial protein that repairs 3-methylcytosine in DNA.* J. Biol. Chem., 2008, 283, 25046.

Widerøe, M; Brekken, C.; Kavelaars, A.; Skranes, J.; van Bel, F.; Heijnen, C. and Brubakk, A.M. *Manganese-enhanced MRI (MEMRI) of ongoing inflammation and delayed neuronal death six weeks after hypoxia-ischemia (HI) in the neonatal rat brain.* Archives of Disease in Childhood, 2008, 93, Suppl. II, A207.

Yin, Z.; Jiang, H.; Syversen, T.; Rocha, J. B.; Farina, M. and Aschner, M. *The methylmercury-L-cysteine conjugate is a substrate for the L-type large neutral amino acid transporter.* J Neurochem., 2008, 107, 1083.

Zhao, C. M.; Furnes, M.; Stenström, B.; Kulseng, B. and Chen, D. *Characterization of obestatin- and ghrelin-producing cells in the gastrointestinal tract and pancreas of rats: an immunohistochemical and electron microscopic study.* Cell Tissue Res., 2008, 331, 575.

Zhao, C. M.; Martinez, V.; Piqueras, L.; Wang, L.-X.; Taché, Y. and Chen, D. *Mechanism of gastric acid secretion in somatostatin receptor 2 deficient mice: shift from endocrine/paracrine to neurocrine pathways.* Endocrinology, 2008, 149, 498.

Patents

Werenskiold, J. C.; Auran, L.; Roven, H. J.; Ryum, N. and Reiso, O. *Screw extruder for continuous extrusion of materials with high viscosity.* [Patent] Patentnr./Lisensnr.: WO 2008/063076 A1 Registrert 2008-05-29

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