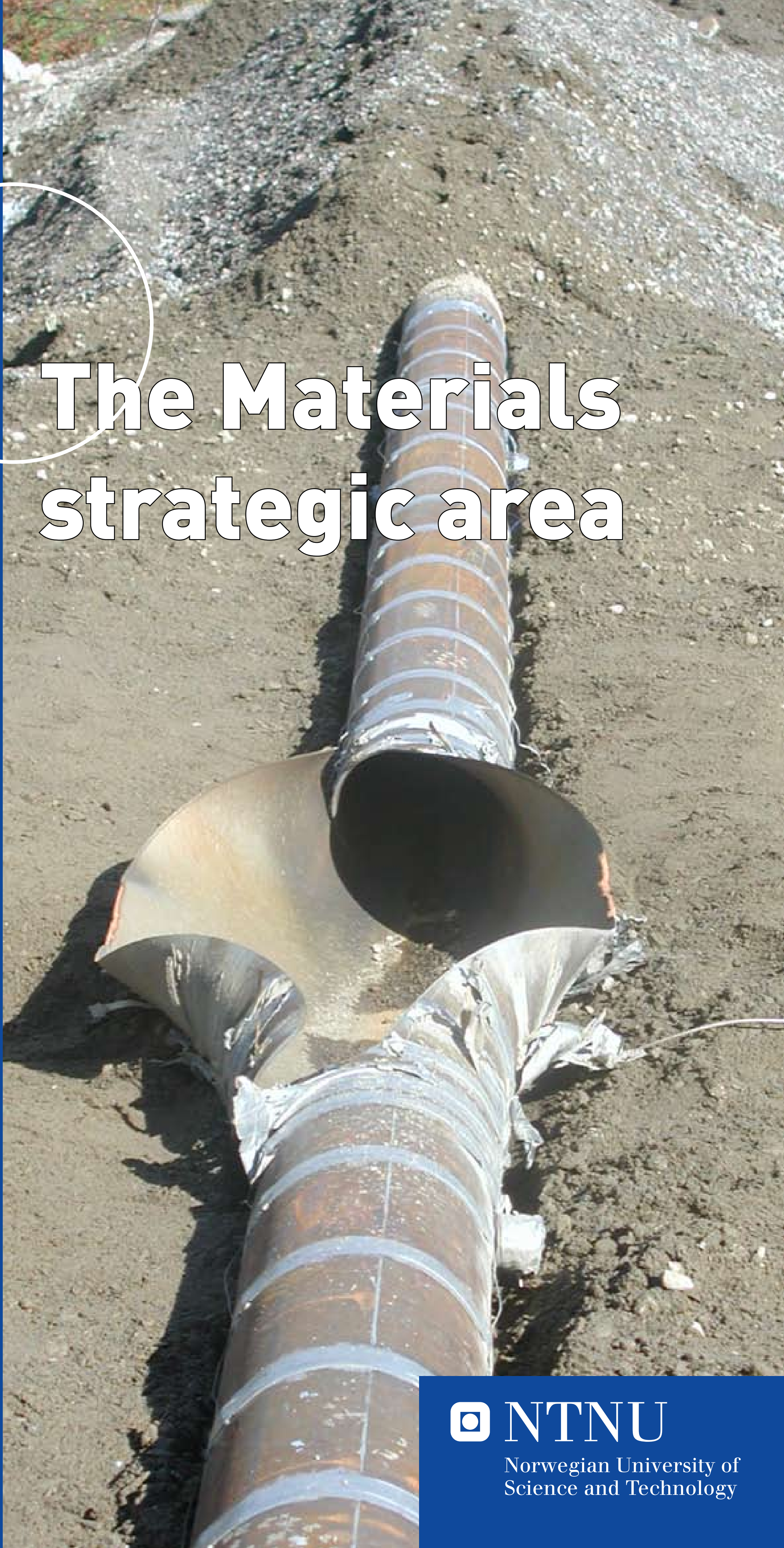
Annual Report 2007

The Materials strategic area



NTNU
Norwegian University of Science and Technology

What are the Strategic Areas at NTNU?

NTNU is a university with a broad academic scope, with its main focus on technology and the natural sciences. The university has about 20 000 students and 4800 staff.

NTNU's research has an international focus and our vision is to be internationally recognized as an outstanding university.

NTNU has selected six thematic interdisciplinary strategic areas that address the key societal challenges where NTNU is especially qualified to make a contribution:

- Energy and petroleum, resources and environment
- Globalization
- Information and communication technology
- Medical technology
- Marine and maritime research
- Materials

NTNU works in close collaboration with SINTEF, Scandinavia's largest independent research institute.

Visit us at **www.ntnu.no/strategicareas**

About Materials at NTNU

The Materials strategic research area, is a critical component in aiding NTNU to reach its goal of being among the top 10 technological and scientific universities in Europe by 2020.

The Materials strategic research area also seeks to exploit the synergism of multi-disciplinary materials research. Materials science at NTNU has for many years focused on structural materials, because of their importance to sustainable infrastructures and to the metallurgical and oil and gas industries. Light metals primary production and downstream processing has a long tradition in Norway, owing to access and cost-competitive hydroelectric power. Today, Materials at NTNU includes a wide variety of disciplines, including functional materials, polymers and composites, in addition to light metals and other advanced construction with materials such as modern steel, titanium and concrete.

Among the functional materials, silicon for solar cells is a very rapidly growing area with strong industry participation. New technologies for environmentally friendly energy utilization are of core importance. Close coordination with NTNU's newly established laboratory for nanomaterials and nanotechnology guarantees advances in electronic and sensor applications together with technologically advanced materials for bio-medicine, information technology and energy and petroleum. NTNU has developed strong research groups in all these areas, frequently in close collaboration with SINTEF and Norwegian industry.

In general, the Materials strategic area addresses the entire value chain for materials. The value chain extends from production and processing to design, construction and recycling. Materials research as a discipline develops fundamental knowledge about material processing and the control of material intrinsic structures and properties in order to develop new materials and processes for future applications and markets.

Building and maintaining critical expertise are at the core of NTNU's strategy. A primary task is to prepare students for master's and doctoral degrees in materials technology, as well as in the larger materials-realted arena.

Visit us at **www.ntnu.no/materialer/**

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Highlights 2007

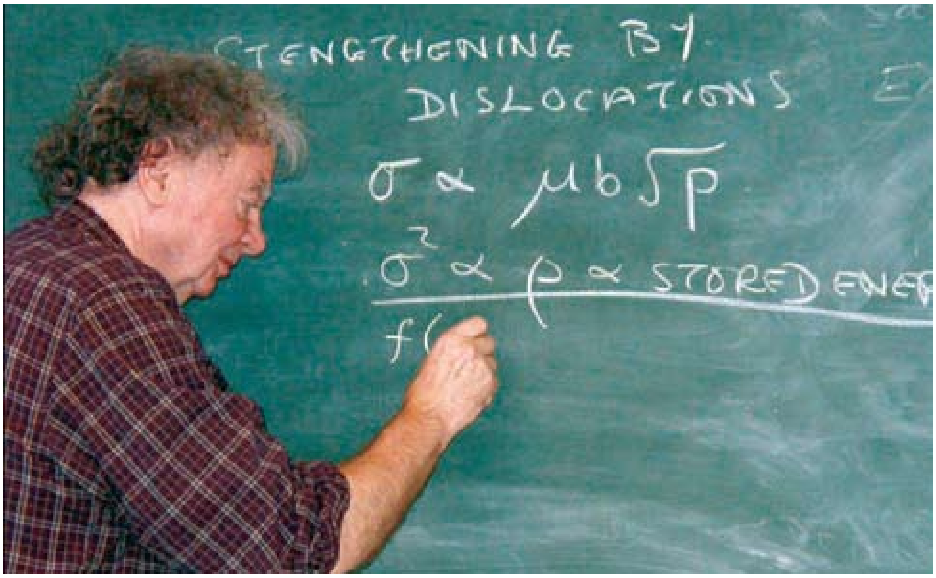
Materials matter

In light of the strategy *"NTNU 2020 - Internationally Outstanding"*, the strategy for the Materials strategic area was revamped, and was approved by the board in May 2007. The vision for the Materials area is for NTNU to make significant contributions to the sustainable production and use of materials and for NTNU to become an internationally leading centre of expertise in selected areas of production, characterization and use of materials, and that the university should be known for its in-depth expert knowledge and extensive interdisciplinary work across established research areas. Based on a complete evaluation of strengths, scope and the value chain perspective, four profile areas have been defined:

- Materials for the oil and gas industry
- Materials for energy technology
- Light materials
- Materials for sensors and electronics

Doctor Technicae Honoris Causa NTNU

Professor David J. Embury was appointed Doctor Technicae Honoris Causa NTNU at the university's annual meeting in 2007. Professor Embury's relationship with Norway began in 1972 and has continued to the present day, in his periodic teaching at NTNU, supervision of Norwegian students both at NTNU and in Canada, interaction with industries in Norway, and in serving on advisory committees for the RCN. Dr. Embury's research interests have focused on the deformation and fracture of metals and composites from a broad range of perspectives. His work on hardening mechanisms and the development of ultra-high strength steels was ground breaking in its time. He has also contributed greatly to our fundamental understanding of metal forming, age hardening, phase transitions and laminated materials. His interests extend from the atomic level up to macroscopic issues related to structural design. His research activities also involve a variety of international collaborations.



Dr. Embury lecturing at NTNU. Photo: Pål Ulseth.

SIMLab

NTNU's Structural Impact Laboratory, SIMLab, completed its first full year as a Centre for Research-based Innovation (SFI) in 2007. The centre has been funded by the RCN and cooperating partners until 2014, and had a 2007 budget of NOK 23 million.

Tested crash boxes. Photo: Mentz Indergaard

The main goal of the centre is to establish a technology platform for the development of safe and cost-effective structures made from aluminium, high-strength steels and polymers. These materials can be used in everything from reducing automobile weights, which can help improve fuel efficiency, to the production of lightweight protective gear that can be used in peacekeeping efforts. This diversity of goals led one researcher to describe his work as developing lightweight materials for peace and a cooler planet. Another important feature of the centre is its engagement with all aspects of materials research, from fundamental material characteristics to the macro-level of large structure design and construction.

The centre is being hosted by NTNU. SINTEF, Hydro and leading car manufacturers are the most important collaborating partners. The centre graduated 10 Master's students in 2007, and has six PhD students and 2 postdocs currently working on research projects.

Materials and structural integrity

There were five active strategic university programmes (SUP) in the Materials strategic area in 2007. The newcomer was Materials and Structural Integrity (MATSINT). This programme is important to NTNU because support for basic materials research, particularly construction materials, is very difficult to obtain. The objective of the programme is to develop improved methods for the assessment of structural integrity, notably damage mechanics, degradation mechanisms and related subjects. Steel and other high-strength materials are important for petroleum development in the Arctic.

The worlds first full scale burst testing of pipelines with hydrogen gas. SINTEF, NTNU and Tokyo University. Photo: Christian Thaulow

Pipelines of the future

The hydrogen society and CO_2 handling are two current topics of great interest, given future trends for global climate change and dwindling petroleum resources. A key issue for both is transportation, with pipelines likely to play a major role in future transportation networks. While we have years of experience with the transportation of natural gas through pipelines, we know relatively little about the safety issues related to pipeline transport of hydrogen and CO_2, which differ substantially from natural gas. An issue of particular concern regards pipeline holes. If a hole forms, will it stay small with a stable leak, or is there a risk of a crack propagating over long distances, which could cause major problems? In 2007 researchers from NTNU, SINTEF, the University of Tokyo and the Norwegian Armed Forces carried out the world's first crack arrest tests on pipes filled with hydrogen gas. A crack was initiated in a pressurised closed pipe, and the gas leaked out and exploded, while the pipe ruptured. The crack length and the fracture mode have been used to develop simulation models. Similar tests with pipes pressurised with CO_2 are planned.

AluRena

A major project in light metals research (NorLight) funded by the RCN and participating industries ended in 2006. This project helped develop expertise in downstream aluminium research. Roughly 30 PhDs were trained in fundamental and applied areas of light metals. As a follow-on to this work, researchers at SINTEF and NTNU initiated a national communication platform for aluminium research (AluRena) involving academia, institutes, the major industry companies and the RCN. However, due to extensive re-organization of Hydro (formerly Hydro Aluminium) this process was not fully completed. This effort will continue in the coming year, encouraged in part by positive signals from the industry.

TiBia

In the last seven years, NTNU has developed a strong research team focusing on the bulk nanostructuring of metals. One of the new projects started in 2007 at NTNU and SINTEF which builds on this expertise concerns ultra-fine grained pure titanium for biomedical applications (TiBia) funded under the RCN's NANOMAT programme. The main goal is to develop nanostructured, biocompatible and pure titanium for medical implants. It is believed that such materials have a promising future and can improve the quality of life for humans and animals. Advanced processing techniques and analytical characterization methods such as high resolution electron microscopy and X-ray synchrotron facilities will be employed in this effort. The underlying idea is to produce components with excellent mechanical and biomedical properties that can replace partly toxic titanium alloys or austenitic steels. This is a multi-disciplinary project involving teams from physics, materials technology, biotechnology and research institutes in Germany and Russia. Among the participants is Professor Ruslan Z. Valiev, who has been ranked among the top ten most cited researchers in the world in materials science.

Advances in microscopy

A major trend in materials research has been a shift to the ever smaller, whether in research on nano-materials or in the development of advanced equipment such as scanning electron microscopes that enables scientists to visualize the world at the nanoscale. But in 2007, Materials strategic area researchers showed that smaller isn't always better, at least when it comes to determining the degree of carbonization in cokes by image analysis. Coke characterization is critical in helping to reduce CO_2 emissions and energy consumption in carbon-based metal production, but the characteristics that are most of interest, chiefly porosity and degree of crystallisation, are most easily visualized using traditional optical microscopy. Researchers developed an automated technique for the analysis, where several hundred images at random positions are automatically acquired and analysed. These data can then be compared to reactivity data for different cokes.

Planning new infrastructure

The building infrastructure for Materials research and education at NTNU consists of several buildings spread across two campuses. This is a natural consequence of the fact that Materials strategic area encompasses eight different departments with dissimilar histories and roles. Considering the rapidly expanding activity related to silicon and solar cells along with the growth in light metals, NTNU has initiated a task force for planning new building infrastructure that would reflect these accelerating developments. Existing infrastructure and immediate needs has been identified, and plans for a new building on the main campus are put forth. Through the process SINTEF realized that they would benefit greatly from the plan and a shared vision exists. A new building is considered crucial in helping NTNU achieve its goal of offering a leading national research environment and for reaching the university's overall strategy – in particular for materials for energy technology and light metals.

Profile area: Materials for the oil & gas industry

In 2007, 1497 million barrels of oil were pumped from the depths of the Norwegian Continental Shelf, making Norway the third largest oil exporter in the world. But extracting these petroleum resources from the North Sea deeps has been a massive undertaking, requiring scientists and researchers to develop whole new technologies to cope with the inhospitable environment at an oil well in more than 1000 metres of frigid North Atlantic water. Among the players who have helped in this technological revolution are researchers in the Materials strategic area.

One key material that has helped make North Sea oil a reality is 13% Cr super martinsetic stainless steel (SMSS), which, while strong, is still subject to weaknesses and cracking often in connection to welds. This problem was a particular research focus in 2007. Another active area of research in 2007 examined the phase deformations found in SMSS that has been coiled for transport, where changes in microstructural properties increase the risk of hydrogen embrittlement in the steel. A separate project looked at problems caused by hydrogen induced stress cracking in SMSS and 25% Cr super duplex stainless steel (SDSS) used in offshore pipelines. Specialized equipment at NTNU means that researchers have been able to deform the metal and observe and map changes in microstructures in situ both before and after hydrogen charging, using a scanning electron microscope.

Norwegian companies are world leaders in supplying equipment for drilling operations. The NODE ART project, partly financed through the PETROMAKS programme, which is managed by the RCN, looks at the optimization of surface properties of huge hydraulic cylinders used in drill riser tensioning systems. During drilling, the drill riser must have a constant stroke, which is achieved with hydraulic cylinder systems connected to the riser. The load on the piston rods due to corrosion, wear, fatigue and mechanical loads during operation can be extreme. The goal is to develop reliable test methods for combined degradation mechanisms and to establish degradation models for actual combinations of substrate material and surface coating. The overall goal for the project is to have a piston rod that operates for a minimum of 5 years without maintenance, which is equivalent to 20,000 km of stroke length.

Oil and gas production isn't just about pumping oil from the seabed, though – oil platforms typically generate their own electricity with natural gas turbines. One 2007 research project examined to degradation found in natural gas turbine blades during use. These blades can be repaired, but their proper repair requires a good understanding of the degradation process.

One future trend in energy resources will be the increased production of methanol. NTNU researchers have been studying the challenges this process presents, particularly high temperature corrosion in nickel-based super alloys used in the conversion of natural gas to methanol. In cooperation with StatoilHydro, researchers are examining how changes in alloy composition affect corrosion characteristics, in particular pitting and metal dusting. This research was partly conducted in Grenoble, where synchrotron x-ray diffraction was used to characterize high temperature corrosion in specimens that had been exposed in actual plant use. The project has also developed computer models that allow steady-state corrosion rates to be predicted under varying exposure conditions.

Metal dusting in a Ni-based alloy. Photo: Jorun Zahl Albertsen

25% Cr SDSS – Microindents in austenite and ferrite phase after hydrogen charging. Microscope image: Marit Øverland.

Increasingly, oil and gas exploration is moving into the Arctic, which requires studies of the uniquely difficult conditions that result from low temperature operation. The acquisition of a Hysatron Triboindenter (nanoindenter) in 2007 now allows nanomechanical testing to explore issues related to the effects of hydrogen and low temperatures on steel. Treating steel with cathodic protection increases its corrosion resistance but also increases its susceptibility to hydrogen damage. Researchers are also interested in the kinds of stresses involved when temperatures dip below -60 °C, which can reasonably be expected in the Arctic. The goal is to modify the nanoindenter so that cold-induced stresses can also be examined. Information from the nanoindenter will be very important for multiscale materials modelling, an approach that is at the cutting edge of current day materials research.

Profile area: Materials for energy technology

The world's demands for energy are skyrocketing, with worldwide electricity generation in 2030 projected to total 30,364 terawatt hours per year, or nearly double the 2004 total of 16,424 terawatt hours, according to the US Energy Information Agency. But use of fossil fuels to feed this growth is problematic for many reasons, not the least of which is a projected decline in the availability of petroleum resources and the potential catastrophic problems linked to global warming. Researchers in NTNU's Materials strategic area are working in a number of alternative energy areas, from solar cell research, to saline powered energy, to hydrogen production and the capture of carbon dioxide from fossil fuel combustion.

NTNU's solar cell research involved several lines of inquiry, all centred in the PV-Solar Cell Materials Gemini Centre. Researchers are working on issues that range from quartz feedstock, to the production of metallurgical grade and solar cell grade silicon, to casting, wafer sawing and the characterization of materials, along with the development of third generation solar cells.

Stacking Silicon in a crucible for directional solidification. Photo: Melinda Gaal

Among the specific research efforts in 2007 was a project that examined how much bio-carbon can be used in the production of silicon from quartz, and another project that used glow discharge mass spectroscopy to study trace amounts of phosphorus and boron in the quartz feedstock. Different aspects of the casting and refining process, including an examination of how different coatings in casting moulds affect wafer microstructure and characteristics have been studied. Research also continued on the EU-funded project called FOXY, which has as its goal to lower the cost of metallurgical solar-grade silicon feedstock, and recycled electronic-grade silicon.

A research group worked on developing a model prototype for a quantum dot based intermediate band solar cell. Creating this type of solar cell involves the use of molecular beam epitaxy to make the quantum dots in a kind of nano-sized spray painting process. A quantum dot based intermediate band solar cell is what is known as a "third generation" solar cell, in that it enables more efficient use of solar energy in the production of electricity, which in turn boosts the efficiency of the cell. A solar cell using this technology could have a theoretical maximum efficiency of 87 percent, as compared to today's solar cells, which have a theoretical maximum efficiency of 41 percent, although actual efficiencies are much lower. Related efforts focused on the development of transparent electrodes and conversion layers integrated into the cell material, to further improve the solar cell's ability to use the solar spectrum.

Other energy-related research conducted in 2007 included work done by the Memfo group, which is developing membranes for gas separation and osmotic processes, and the KinCat Group, which works on heterogeneous catalysis. A sampling of projects completed in 2007 from these two groups looked at carbon nanofibres for applications in fuel cells, the sorption enhanced reaction process for hydrogen production, and the selective catalytic oxidation of hydrogen. One PhD project received the 2007 Hydrogen Prize from the Norwegian Hydrogen Forum for its contribution to the development of carbon membranes that can be used to separate hydrogen from natural gas. Researchers also continued their efforts in a range of EU funded projects, including NaturalHy, which is examining the possibility of co-transporting hydrogen with natural gas through Europe's gas network, and NanoGloWa, which focuses on nano-structured membranes against global warming.

Materials research also is playing an important part in the development of saline power, or the power that is derived from the osmotic differences between salt water and fresh water when the two are separated by a semi-permeable membrane. The key to making this energy source feasible is the membrane, which must have enough permeability to allow high water flux, but which must also hold back the salt ions. Work in 2007 on developing hydroxyethyl methacrylate, or HEMA, as the support structure for a thin film composite membrane has proven to be promising. Cooperators include SINTEF, GKSS of Germany and EMI Twente from the Netherlands.

Profile area: Light metals

Ever since the establishment of a strong aluminium industry in Norway more than 100 years ago, aluminium has been an important area of research and development at NTNU. Along with oil and gas, aluminium continues to be one of Norway's largest export industries, which makes NTNU's role in innovating advances in light metal technologies all the more important to the country's economy. The overall budget for light metals research in the university and institute sector was close to NOK 100 million in 2007.

The global demand for aluminium and aluminium products is increasing at the same time as the portion of recycled material is rising to match the amount of primary metal. This fact, together with rapidly growing environmental concerns, is being addressed by the RIRA project on the recycling and remelting of aluminium. The project is funded by industry partners and the RCN under the User-driven Research based Innovation (BIA) programme. Researchers are looking at the removal of coatings, polymers and pigments from post-consumer aluminium products, lowering metal losses and „upgrading" the quality of the melt. Another goal is to cut the energy needed for aluminium production.

Researchers are also examining current practices with aluminium cleanliness with an eye to potential future problems that might result during recycling.

In 2007, light metals researchers continued their work looking at the characteristics of aluminium as it solidifies in a cooling melt. Using synchrotron X-ray imaging, researchers imaged individual crystals and mapped their interface coordinates to validate computer models for microstructure formation. Being able to predict the location and type of microstructures in aluminium enables the prediction of local mechanical properties and possible casting defects.

NTNU researchers also worked in an EU-sponsored project called NADIA, which stands for New Automotive components Designed for and manufactured by Intelligent processing of light Alloys. Twenty-four industrial and research institutes from Sweden, Germany, Italy, Finland and Spain, along with NTNU and SINTEF are involved. The goal of the project is to develop predictive software tools for developing automotive castings. In another project NTNU and Hydro are working with French partners to develop new casting alloys that can work well in engines that must operate at the high temperatures now characteristic of new car models. Smaller, higher power engines can be more efficient, deliver better performance and offer superior pollution control options – but cooling them is extremely challenging.

Light metals researchers continued to pursue a range of important research topics designed to push the envelope of what we know about the performance of aluminium alloys. One project examined the impact properties of components produced by high pressure die casting, which is currently the most important die casting process.

Another project has examined aluminium alloys containing bismuth for use in slide bearings, which are extremely difficult to cast. For the first time ever, researchers have been able to image the movement of bismuth droplets in the alloys as related to temperature. The surface tension of these micro-droplets changes with the temperature of the alloy melt, which, along with gravity, determines how the droplets migrate. Imaging the process offers the possibility of controlling the segregation of bismuth in the melt.

Wettability measurements by Jafar Safarian. Photo: Melinda Gaal

The use of TEM as a tool to study atomic level processes, allows light metals researchers to apply quantum mechanics to understand the properties of materials of interest to industry and society. One such 2007 project, partly funded by the RCN as a User-driven Innovation Project (BIP) involved not only Hydro but Steertech, which makes steering components for the automotive industry. Researchers are examining the structure of small precipitates in aluminium alloys using TEM, in pursuit of alloys that are stable at high temperatures, and that maintain their hardness over time.

A related project financed by the RCN's FRINAT programme is being undertaken with universities in Rouen in France, and Delft in Holland, and involves the use of Atom Probe Tomography. Researchers can use this tool to understand how clusters of magnesium atoms first begin to form in an aluminium alloy. Another cooperative effort involving Hydro is called ProExtrude, which looks at the effects of varying chemical impurities that may be associated with recycled aluminium.

Titanium as a strategic light metal is ubiquitous in modern society, found in everything from aeroplanes to dental implants. In 2007 NTNU researchers became involved with Norsk Titanium to develop a cost efficient and environmentally friendly process to produce titanium. The current process used to extract titanium from ore is highly energy intensive and consequently quite expensive.

Norsk Titanium's long-term objective is to become one of the world's leading producers of titanium and other highly valued metals. Norway offers a number of advantages to the company, in that the country has a good source of ore and available facilities for titanium production because a number of Søderberg aluminium production lines are being retired due to environmental reasons.

Light metals strategy

Hydro (formerly Hydro Aluminium, the largest aluminium company in Norway) has been a key collaborating partner with NTNU since the early 1970s. However, Hydro has recently gone through a major reorganization. At the same time, NTNU's light metals researchers have been challenged by a new and rapidly evolving marketplace. The demand for more research on silicon and PV materials has affected both funding and recruitment for light metals research. Thus, revitalization of joint research and new strategy initiatives were emphasized.

The number of students choosing studying light metal production and processing and alloy development has declined significantly, and the Norwegian light metals industry fears that recruitment will be increasingly difficult. At the same time the education curriculum at NTNU has been diluted with respect to its light metals focus and specific reinforcement and adjustments may be needed, including the addition of new academic positions. Six senior professors have retired among the three core light metals departments in recent years. Better coordination among the core light metals departments is needed.

Another strategic element is closer collaboration between researchers in light metals and in silicon and PV materials. The interplay amongst the TEM Gemini Centre, the electron microscopy lab and NTNU Nanolab is also an important instrument for meeting the challenges foreseen in the light metals, silicon and PV areas.

Anne Kvithyld studying heating of al aluminium on a hot stage. Photo: Melinda Gaal

Profile area: Materials for sensors and electronics

Researchers working with materials for sensors and electronics are exploring the emerging field of spintronics, in which an electron's direction of rotation, or spin, can potentially be harnessed to do work in nano-sized switches and other components. This field is just two decades old, with pioneers Frenchman Albert Fert and the German Peter Grünberg awarded the Nobel Prize in Physics in 2007. Technology based on these principles is now used to read data on hard drives in computers. It is also an area of research that poses intriguing theoretical questions whose answers offer the potential to unlock a whole new area of applications.

The advantage of using an electron's spin instead of actually moving the electron itself is that changing an electron's spin generates relatively little heat. And all it takes is the use of a ferromagnet to control the spin. The development of this technology promises to accelerate the miniaturization of consumer electronics, because one of the major limiting factors in building ever-smaller computers and other devices is the amount of heat produced. But spintronics is still very much in its infancy, with a number of theoretical and practical questions that NTNU researchers are attempting to answer.

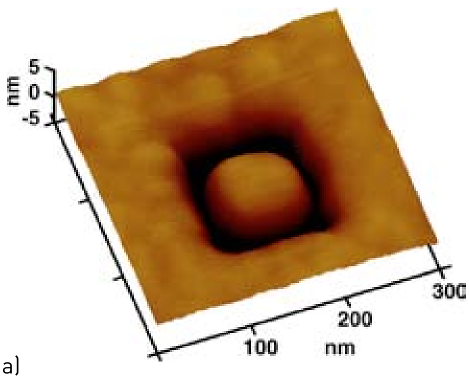
One of the most challenging aspects of spintronics is measuring many of the phenomena associated with spin. Efforts in 2007 included the construction of a dedicated scanning tunnelling microscope for making point contacts and making charge transport measurements. This type of equipment is important in studying both nanomagnetics and spintronics.

Two NTNU researchers also spent the 2006-2007 academic year in Oslo at the Centre for Advanced Study, as coordinators of a project on spin and charge flow in nanostructures. The Centre for Advanced Study is based at the Norwegian Academy of Science and Letters, and is a basic research institution where outstanding researchers from Norway and abroad are invited to spend a year, during which they are excused from all duties other than pure research.

A key project for investigating materials in sensors and electronics has been the Nationally Coordinated Project in Oxides for Future Information and Communication Technology, a NOK 52 million, 5-year project coordinated by NTNU and funded under the RCN's NANOMAT programme. NTNU researchers have worked on the development of novel materials for sensor technology, chiefly the synthesis and investigation of epitaxial complex oxide thin films with diverse electronic properties ranging from ferroelectric insulators to metals and superconductors. Two publications of interest from 2007 addressed the size-dependent properties of nanocrystalline $BiFeO_3$ particles and the formation and electronic properties of oxygen annealed Au/Ni and Pt/Ni contacts to p-type GaN. The study and manipulation of these materials on a sub-micrometer length scale using modern scanning probe techniques (AFM/STM/TEM/scanning auger spectroscopy) opens an experimental gateway to new insights in fundamental physics and opportunities for novel devices.

Researchers have also derived a Ginzburg-Landau effect for a system that shows the coexistence of ferromagnetism and spin-triplet superconductivity. This type of material has enormous technological potential from a long-term perspective, because it combines two important functions of magnetism and superconductivity. Other work has also looked at one-particle transport in unconventional superconductors and graphene, which is of interest from a fundamental physics viewpoint.

Other research in 2007 focused on unconventional superconductors and quantum transport in unconventional heterostructures, the description of new types of phase transitions in Bose-Einstein condensates, and the development of theories for unconventional order in high-temperature superconductors.



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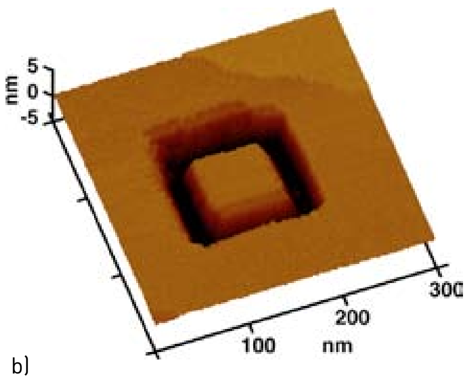


b)

Piezoelectric "nanodot" of $PbTiO_3$,
a) sputter-deposited on a thin film template of conducting $SrRuO_3$,
b) defined by means of a scanning probe etching technique.
Microscopy image: Chang Chuan You

The future for Materials research

In November 2006, NTNU adopted a new strategy plan called *"NTNU 2020 – Internationally outstanding"*. The new plan states that strategic areas are just as important as before in developing NTNU as an outstanding university. This strategy will form the basis for most of the activities at the university in the years to come. In light of this, the Materials strategic area strategy has been redeveloped.

A key goal for the Materials strategic area is for NTNU to become an internationally leading centre of expertise in selected areas of production, characterization and use of materials, and should be known for its in-depth expert knowledge and extensive interdisciplinary work across established research areas.

NTNU continues to make a specific effort to promote basic research related to nationally important strategic areas, and areas with future potential for industry and commerce. In view of this, four profile areas have been selected as priority areas:

Materials for the oil and gas industry

The offshore petroleum industry is the single most important industry in Norway. Future production methods for deep sea and arctic conditions and for marginal production fields will require durable materials and new systems for monitoring conditions. NTNU's goal is to be ranked among the world's top 10 scientific institutions in developing materials for use in the oil and gas industry. The focus is on equipment and components used in the entire oil and gas production value chain, from the production of oil and gas from reservoirs, to transport, and including export systems.

Materials for energy technology

A sustainable society can only grow based on renewable energy sources. For non-renewable sources, waste must be handled and disposed of in the most responsible manner possible. NTNU's goal in materials research is to be among the top 5 leading institutions in the production and characterization of silicon for solar energy, and among the top 10 institutions in research on CO_2 handling, as well as in research on new energy carriers such as hydrogen.

Photo: Melinda Gaal

Light materials

The car manufacturing industry is one of several markets for aluminium produced in Norway. This industry focuses on reduced CO_2 emissions. Lighter vehicles and new technologies for environmentally friendly fuels and engine systems will play a critical role in achieving this goal. NTNU will contribute through research on light materials designed to reduce fuel consumption in the transport sector. The university's goal is to be among the world's top 5 institutions in research on the production, casting, and forming of light metals.

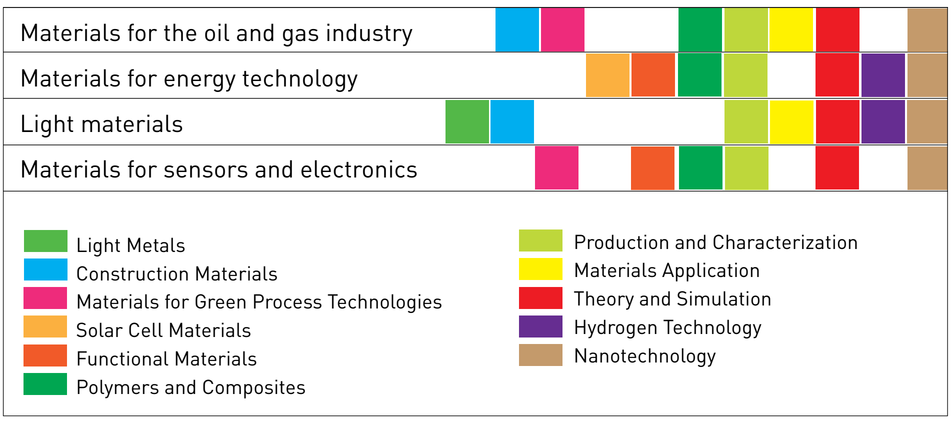
Materials for sensors and electronics

Materials suitable for sensors and electronic components are important in virtually all areas of society, as they are used in medical equipment, consumer electronics, industrial processes and cars. Such components require materials that have specific functional properties. NTNU's aim is to develop basic expertise and selected niche products using materials of this type.

Areas of strength

The academic activities that constitute materials research and education at NTNU are defined as areas of strength. These are areas where NTNU possesses high-level expertise, or has the potential to build such high-level expertise. Each area of strength supports several profile areas. Strategies for the areas of strength are described at the departmental level and at the Gemini centre level.

Interplay between strong areas and profile areas



Evaluation of the strategic area

NTNU's six thematic strategic areas were evaluated in 2007. The purpose of the evaluation was to follow up on NTNU's strategy, *"NTNU 2020- Internationally Outstanding"*. In particular, the evaluation was intended to contribute to enhanced strategic consciousness and to draw more attention to the university's strong academic fields and priority areas.

The Materials strategic area was evaluated by two international experts, David Embury, University Professor Emeritus of McMaster University, Canada, and Robert H. Wagoner, George R. Smith Chair and Professor of the Ohio State University, USA.

As part of the evaluation and basis for the international experts' work, the Materials strategic area did a fairly extensive survey of the activities, resources and scientific achievements since the formalization of the strategic areas in 2000. The survey illustrated impressive activity during the six years covered by the evaluation, including the award of 177 PhD degrees, 1115 published scientific papers, 20 published books and 62 book contributions, participation in 26 EU 5th and 6th framework projects, and a number of other achievements, such as prizes and awards.

Based on Materials' own survey and on-site interviews, the experts' main conclusions were:

- The Materials area has made excellent progress and has added significant value relative to the limited funds expended.
- The developments in nano science, solar energy and impact engineering are clearly of high international calibre and represent good examples of both internal and external collaboration, and could serve as role models for other areas of materials.
- The number of Materials area faculty has declined, and even replacement is not assured. In particular, solar cell and steel technology suffer from this shortcoming.
- Support for basic materials research is very difficult to obtain, but is critical for outward looking goals that are essential to achieve NTNU's broader goals.
- The Materials area is diverse, but has a valuable shared vision and coherent strategic plan.
- The Materials area can catalyse educational initiatives.
- Industrial interaction is very strong but can benefit by being more global.
- A basic thrust in multi-scale modelling should be initiated to support a wide range of more applied projects. Build on strong characterization capabilities.

One of these observations merits further discussion. As the evaluation committee correctly observed, the number of permanent faculty members in the departments that form the Materials strategic area has stagnated in recent years. Although the number of PhD students and postdocs has increased, the capacity to supervise students is not growing as the number of students grows. The evaluation committee raised this as one of the area's great inconsistencies: Why has the most important strategic tool - faculty positions - stagnated during a time when the concept of the strategic area was developed? An added concern is that the number of technical positions has also stagnated, due to lack of funding. As Materials is an area with significant industrial relevance, it is also increasingly more difficult to recruit faculty members and PhD students.

However, the area's productivity, measured as in graduated PhD candidates and publications per faculty member has grown. This has been possible mainly due to the fact that external funding for research, including for PhD studies, has grown.

Looking ahead, one of the most important challenges is to maintain a competence profile that is relevant to the industry and national priorities. We see many changes in the industry as industry players shift from production to maintenance of offshore installations; the growth of the silicon industry, the development of new, sophisticated sensors and control systems, and the development of new materials. This requires a transition in our expertise. Some of our faculty members are close to retirement, which allows for new opportunities for change. However, this will not be enough compared with the need, and help from the industry is necessary in order to keep up with the pace of change in both research and job markets.

The experts concluded that Materials is vital to the future excellence of NTNU and to the Norwegian economy as a whole. They stated that the area's range of topics is broad but well chosen both for current and future national needs, and that many activities are of very high international stature. Additionally, they said, in many areas the quality of equipment and the standard of experimental work is outstanding.

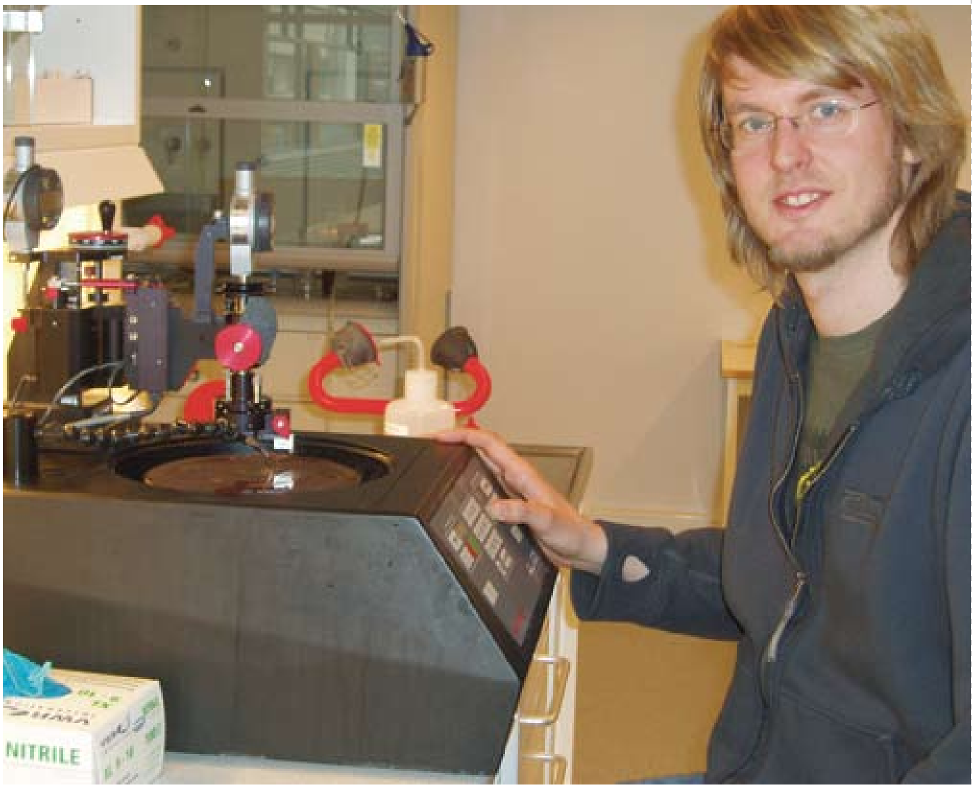
They also made recommendations that could improve Materials further. The recommendations included elements such as allocating more time to leadership of the area, improved internal collaboration, a more distinct profile, more aggressive faculty recruitment, new educational initiatives, and improved funding. These recommendations are currently being considered, and some have already been implemented.

Laboratory facilities

Materials research has been transformed by the ability to examine the properties and composition of substances at the atomic scale – an effort that is only possible through the use of new and highly sophisticated imaging and computer equipment. The Materials strategic area has made it a priority to keep its laboratory facilities well equipped, whether independently or in cooperation with SINTEF, to further support and encourage this type of research.

Scanning tunnelling microscope

Scanning probe microscopy revolutionized our understanding of surface properties at the nanoscale. These techniques have been used to solve scientific problems from fundamental structure determination, to catalysis, to local studies of surface properties. One area where little research has been performed is the use of scanning probe microscopes to measure transport properties locally. Today such experiments are specifically important for the characterization of model systems for spintronics, where resistance is dependent on magnetic domain orientation and domain walls. By performing such studies with a scanning tunnelling microscope, local transport properties can be linked to the material composition and shape, right down to the atomic scale. Funding from RCN/NTNU has enabled the building of a unique scanning tunnelling microscope for studies of local transport properties in combination with surface order, chemical boding and composition. The long-term goal for the instrument is to allow for point contact based transport measurements with a bandwidth up to 40 GHz in the range 10 K-400 K. The equipment is complemented with an electron energy analyser for photo-emission studies, including X-ray and ultraviolet light sources. The new electron energy analyzer for photoemission studies has been installed on the STM vacuum chamber for in situ photoemission studies of chemical binding energies/electron structure of STM samples. The full instrumentation forms the basis for cross-disciplinary studies of model systems of interests for fundamental physics, chemistry and applied electronics.



Espen Eberg using the new multipreparation machine for tripod polishing. Photo: Randi Holmestad.

In situ thermal and chemical analysis

New equipment is now available to undertake simultaneous mass-, heat- and chemical analyses. The concept is based on a combined thermo gravimetric and calorimetric (DSC/DTA) unit that is able to measure mass and heat with a high accuracy from room temperature to 1650°C. This unit is combined with a quadrupole mass spectrometer, which enables in situ chemical analysis (by mass) of any gas specie escaping from the sample.

TEM sample preparation

Transmission Electron Microscopy (TEM) is an essential tool in both fundamental and applied materials science and physics research. The core activity is to study materials at the nanoscale level. In 2007, the TEM Gemini Centre invested in new equipment for sample preparation.

The challenge in TEM studies is to obtain a representative thin, electron transparent samples (<100 nm), but the thinning process must not affect the structure of the sample (crystallinity at internal interfaces and phases) or destroy too much of the surface. These artefacts are especially problematic when advanced microscopy techniques requiring ultrathin and clean crystalline samples are used, such as high resolution electron microscopy and high resolution annular dark field scanning TEM.

The new Gatan precision ion polishing system (PIPS) is an ion thinner that makes use of low sputtering angles to minimize damage from the ions in order to produce larger and cleaner electron transparent areas. In addition, it is possible to cool the sample with liquid nitrogen, which avoids local heating that can result in structural changes, such as phase transformations and precipitation of other phases. An ion mill with cooling is the first of its kind in Europe.

Third generation solar cells

A laboratory dedicated to the deposition of thin films and nano materials for third generation solar cells was established at NTNU. The main deposition technique for this technology is called pulsed laser deposition, or PLD. A researcher visited Professor Hani E. Elsayed-Ali's research group at Old Dominion University in Virginia, USA to learn how to grow germanium quantum dots in a silicon matrix using PLD. Elsayed-Ali's group has a great deal of experience in using PLD to deposit these types of sample structures, and has been able to deposit as many as 50 high quality layers. The visit lasted two months and was funded by the Materials strategic area.

Field Emission Scanning Electron Microscope (FESEM)

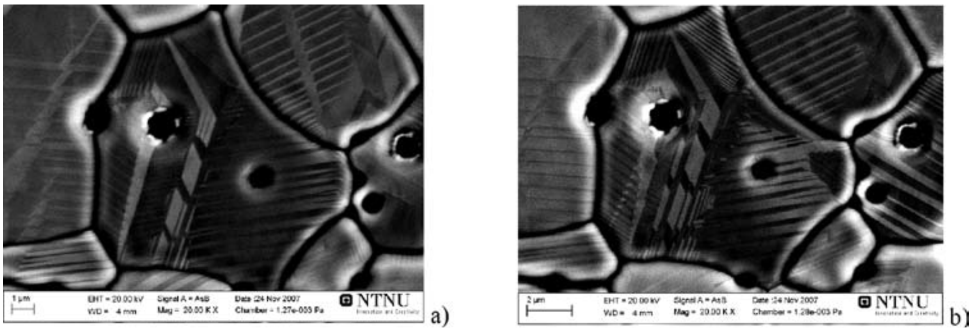
The electron microscopy (EM) laboratory has recently invested in a new high resolution FESEM that is designed to examine the microstructures of a wide range of materials. The microscope is equipped with a variety of imaging, analytical and diffraction detectors (in-lens SE, in-lens BSE, EDS and EBSD), and an in-situ stage that provides detailed surface information for samples at the nanometre scale level and up to the decimetre level.

Some of the latest technological innovations and developments related to materials characterization using EBSD in the FESEM include:

- Ultra fast EBSD pattern acquisition and increased flexibility and reliability during subsequent data analysis.
- The automatic characterization of large sections, such as 100x70 mm silicon wafers, using the combined EBSD beam and stage scanning mode.
- The simultaneous operation of a deformation unit and a heating unit in the microscope chamber. This equipment offers in-situ thermo-mechanical testing coupled with ESBD. The figure shows high resolution backscatter electron images of one particular $LaCoO_3$ ceramics at zero load and after 250 MPa compression respectively, showing domain reorientation due to an externally applied mechanical field.

New Optical Microscope (SCOM)

A liquid helium based Scanning Confocal Optical Microscope (SCOM) from Attocube Systems will be installed in the new nano-optics lab in June 2008. The SCOM is based on rejecting out-of-focus light, through a combination of illuminating single points of the sample with a laser, and using blocking pinholes. The horizontal resolution achieved can reach as small as 1/3 of the optical wavelength with a sample positioning accuracy as small as 10 nm. The SCOM will thus enable optical imaging and spectroscopy with a high lateral resolution, combined with high collection efficiency, in the visible to the near-infrared wavelength range. The system will have an inbuilt superconducting magnet (11 Tesla) along with electrical wire connections. The new laboratory is intended for studies of optical, electrical and magnetic properties on individual nanostructures and photonic semiconductor nanowires structures and devices that are now being developed at NTNU. It is also anticipated that groups that are doing research on nanostructured semiconductor materials for 3rd generation solar cells, nanostructured ferro-electric oxides, magnetic nanostructures and carbon nanotubes will use the facilities.



Domain structures in $LaCoO_3$, a) before and b) after compression. Photo: Morten Karlsen

Collaboration with SINTEF

NTNU has extensive collaboration with SINTEF both in specific research projects and in formal collaboration in a number of research centres. SINTEF is a partner in NTNU-managed projects and vice versa. The Gemini Centres are a model for strategic cooperation, where scientific groups at NTNU and SINTEF with parallel interests coordinate their scientific efforts and share resources. The centres are also a means of promoting education, research and business development. The vision for the Gemini Centres is to be an international joint force at the leading edge of research.

Materials-related Gemini Centres:
Robust materials selection and design – offshore applications
Materials and energy
Marine constructions
PV - solar cell materials
Transmission electron microscopy (TEM)

Other centres and laboratories:
NanoLab
Centre for Renewable Energy
Gas Technology Center
Electron microscopy lab

International activities

Collaboration with China

The Materials strategic area has participated in a joint project over the last five years with the Globalization strategic areas. Participants from various departments at NTNU have studied different issues in regard to the rapid changes in China. The Materials strategic area has established excellent collaborative relationships with Shanghai Jiao Tong University (SJTU) in light metals. Professor Hans J. Roven was officially appointed guest professor at SJTU for the period 2007-2010. Moreover, close collaboration activities in the primary metal production area is developed. Joint research projects have been funded by Norwegian sources and the National Science Foundation (NSF) in China. There have been several researcher exchanges, and NTNU was also given the opportunity to host one light metals Chinese PhD student financed by the China Scholarship Council (CSC). In November 2007, NTNU and SJTU arranged the 2nd Chinese-Norwegian Symposium on Light Metals in Shanghai. The symposium involved 36 invited participants from the two countries. The third bilateral symposium on light metals will be arranged in China in 2009.

Collaboration with Japan - KIFEE

Following the establishment of the Kyoto International Forum for Environment and Energy (KIFEE) and successful meetings in 2004, 2005 and 2006, the Third KIFEE Symposium was held in Otsu, Shiga Prefecture in Japan in December 2007. More than 40 participants from Norway took part in the meeting. The University of Oslo has officially joined the KIFEE family. The symposium program featured a general strategic session in addition to the special sessions on the four targeted areas of collaboration; Process Engineering, Advanced Inorganic Materials, Advanced Biological Materials, and Electrolysis Systems. A new topic, "Education in Energy and Environment" was introduced, which will be a permanent fixture in the KIFEE collaboration in the future. A plenary session on the Lake Biwa Sustainable Energy System was also featured, partly because the location of the symposium was on the shores of Lake Biwa. The Fourth KIFEE Symposium will be held in Norway in the spring of 2009.

Funding from the RCN and NTNU has made it possible to follow up on the 2007 bilateral projects. The electrolysis project activities were mainly related to the development of a method for supplying dissolved oxygen to polluted regions of Lake Biwa by electrolysis. The advanced biological materials session focused on biomaterials for drug delivery, physical characterization of biopolymer-based nanoparticles, gelling polysaccharides, antimicrobial biopolymers, materials for tissue engineering, biodegradable plastics, and cellulose crystal models. The advanced inorganic materials area has focused on synthesis methods for nanoparticles, films and porous materials, nanostructured materials, surface modification and functionalization of surfaces, electrode materials and electrodes for energy technology, materials for energy control and solar cells. Of special great importance is the mutual exchange of students.

Collaboration with Japan - Aluminium

In 2007 the NT faculty approved an Agreement on Cooperation in Research and Education between the Graduate School of Science and Engineering for Research, University of Toyama, Japan.

Collaboration in Europe

In November, 2007, a delegation from NTNU including a representative of the Materials strategic area visited ETH Zurich

Chinese and Norwegian delegates to the 2nd Chinese – Norwegian symposium on light metals. Photo: SJTU

International cources

to lay the groundwork for future possible cooperative research ventures between the two institutions.

ETH Zurich is in the IDEA League network, a group of just 5 European universities that are internationally recognized for their strong research efforts, particularly in science and technology. Imperial College London, TU Delft, RWTH Aachen and Paris Tech are the other members of the network. While the network is not open to new members, NTNU researchers already have a number of ties to researchers in the different institutions.

Three areas were identified as suitable starting points for cooperative research; these were nanostructured titanium for biomedical applications, nanostructured light metals, and surface technology, particularly with respect to thin films and silicon. Researchers agreed to maintain contact with the idea of undertaking cooperative efforts in the context of existing projects, while exploring the possibility of joint research proposals under the EU's 7th Framework Programme. Student exchanges were also identified as an effective method for building links between the two institutions.

The ninth international **"Summer school on aluminium alloys"** organised by NTNU and SINTEF in August 2007 attracted 59 participants from eleven countries. The school represents the state of the art in aluminium alloys technology. The lecturers included renowned European and American experts from universities and the aluminium industry. The lectures focused on the basic metallurgy and mechanics controlling the evolution of microstructure and properties during industrial processing.

This year's special topic was thermo-mechanical processing and forming of aluminium, ranging from casting and solidification to forming and formability of rolled sheets and extruded profiles, with a focus on multi-scale approaches.

The 26th **"International Course on Process Metallurgy of Aluminium"** was arranged in 2007 with 95 participants from 26 countries.

The **"Fundamentals and their application in aluminium production"** summer school was arranged for the14th consecutive year in May 2007, with 51 participants from 14 countries.

Multifunctional materials

Innovative ideas for materials and devices that integrate physical properties, such as charge, photons, phonons, and spin, have emerged at a rapid pace in the field of modern materials science, specifically with magnetic semiconductors and GMR materials. Such multifunctional systems comprise a broad area of research with an enormous potential impact on increased performance, reliability, and flexibility, while decreasing cost, size, and power.

These were issues addressed at the "European workshop of multifunctional materials", organized jointly by Univ. Minnesota and NTNU in Averøy, Norway in June 2007. This workshop was the 4th in a series of US AFOSR/ONR-sponsored workshops on functional materials science, with three previous events held in Latin America.

The 5 days workshop gathered scientists from academia and laboratories in the US Canada, Japan, Israel, and 6 different European countries. Topical sessions were devoted to ferroelectrics, magnetics, multifunctional & multiferroic materials, heterojunctions, interfaces and superlattices, oxide thin film growth and characterization, nanostructures, and devices.

9th International summer school on Aluminium alloy technology, Trondheim 2007. Photo: Melinda Gaal

Seminars and short courses

The strategic area helps to build networks for scientists and engineers to allow for the exchange of ideas and experiences to stimulate cross-disciplinary work. A number of seminars and workshops have been organised.

Characterization of solar cell silicon

A two-day course in the characterization of solar cell silicon was arranged at NTNU in November 2007. There were about 20 participants from Norwegian industry, SINTEF and NTNU working with characterization and analysis of solar cell silicon. The course included the theoretical background for solar cells along with laboratory exercises. The theoretical section of the course covered primary topics ranging from atom and band theory, semiconductors, up through the functionality of solar cells to crystal structures and effect of crystal defects.

nanoC network

The nanoC network is a platform promoting fundamental investigations related to carbon nanomaterials, with a focus on synthesis, characterization and applications. The backbone of the nanoC network has been a series of seminars with national and international participants. The 3rd NTNU seminar on Synthesis and Applications of Carbon Nanofibres/ Nanotubes was arranged at NTNU in February 2007. The focus was on large-scale synthesis and industrial applications, and potential commercial opportunities of carbon nanomaterials for upgrading Norwegian natural gas.

The network has established a cooperative relationship with the East China University of Science Technology (ECUST) on the use of carbon nanofibre for catalyst supports and catalysts. During 2007 three guest researchers came from ECUST to visit the NTNU catalysis group, and a project to use carbon nanofibre supported Pt catalysts for using organic hydrides in hydrogen storage has been initiated.

Defects and Defect Engineering in Solar Silicon

Defects in the silicon crystal are responsible for reduced solar cell efficiency. Defect Engineering is the concept of managing these defects so that they have the least possible impact on the device. In June 2007 NTNU arranged a workshop covering these two subjects. The idea behind the arrangement was to gather young researchers in the field from around the world and to give them time to discuss the issues in more relaxed surroundings and with more time than at busy conferences. The people participating at the workshop came from NTNU, SINTEF, IFE, the

Take a challenge – new products and processes. Photo: Kim Nygård

Norwegian industry, with several special invitees from foreign institutions. The two-and-a-half day meeting featured ten short presentations and plenty of time for discussion.

Nanomechanical testing

Nanomechanical testing facilitates the study of local material properties in small components that cannot be tested using traditional equipment. One of the main activities at NTNU's Nanomechanical Lab has been the testing of fracture properties of polymer nanoparticles or "Ugelstad-spheres". In 2007 NTNU and SINTEF invested in a second nanomechanical indenter, which is reserved for testing structural materials. At the same time, collaboration with Saarland University (UdS) which has several years of experience using nanomechanical testing in their metallic materials research was initiated.

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

Clean energy

A Norwegian-Chinese seminar on clean energy was arranged at NTNU in August 2007. Roughly 40 participants attended the seminar along with four professors from China. The Chinese delegates came from the Dalian Institute of Chemical Physics (DICP) and Tsinghua University. DICP is the largest institute working on catalysis especially for natural gas conversion in China, and is one of the organizations of Chinese Academy. The main objective of the seminar was to establish contacts and exchange research progress from the different institutions in the field of clean energy. The seminar covered hydrogen production from fossil fuels and biomass derived liquids, and catalysis for green processes. A possible cooperative effort between NTNU and DICP was discussed.

Materials-related EU projects with NTNU Participation

EU 7th framework programme

There were ten applications from NTNU to the Nanosciences, Nanotechnologies, Materials & New Production Technologies (NMP) programme in 2007. Unfortunately, none of these projects was awarded funding.

EU's 6th Framework Programme

- DYNAMAX – Dynamic Magnetoelectronics, IST-STREP
- ENCAP – Enhanced Capture of CO_2, Energy-IP
- FOXY – Development of solar-grade silicon feedstock for X wafers and cells, by purification and crystallisation, Energy-STREP
- FURIM – Further Improvement and System Integration of High Temperature Polymer Electrolyte Membrane Fuel Cells, Energy-IP
- MARSTRUCT - Network of Excellence on Marine Structures, Transport - NoE
- NADIA - New Automotive components Designed for and manufactured by Intelligent processing of light Alloys, NMP-IP
- NanoGlowa – Nanostructured materials against Global warming, NMP-IP
- NanOxiDe - Novel Nanoscale Devices based on Functional Oxide Interfaces, NMP-STREP
- NATURALHY – Preparing for the Hydrogen Economy by using the Existing Natural Gas System as a Catalyst, Energy-IP
- SFINX - Superconductivity – Ferromagnetism Interplay in Nanostructured Hybrid Systems, NMP-STREP
- ULCOS – Breakthrough Technologies for the Steel Industry to Address the Global Warming Challenge in Europe, NMP-IP

ULCOS seminar

ULCOS is a five-year, EUR 55 million project that has as its goal finding innovative solutions to cut CO_2 emissions from the iron and steel industry. The research consortium held its 3rd annual seminar in Tromsø in March. Manufacturing processes such as electrolysis, use of hydrogen, use of carbon and natural gas with CO_2 capture and sequestration are all being evaluated, with the target to cut emissions by 30-70 percent as compared to current day blast furnaces. NTNU researchers are investigating iron production using natural gas, and the use of electrolysis to produce iron. The use of electrolysis with an inert oxygen-evolving anode offers the potential of completely cutting CO_2 emissions from the process, as long as the electricity itself comes from renewable sources. The NTNU research is focused on molten salts electrolytes.

Master's and PhD programmes in Materials

NTNU offers variety of materials-related topics master's and PhD programmes. The study programmes are listed below.

A new international master's programme in silicon and ferroalloy production has been developed, with the first students to begin in 2008.

Master's two- and five-year engineering programmes

- Chemistry and biotechnology
  Chemical engineering
  Materials chemistry and energy conversion
- Electronics
  Photonics, micro technology and nanoelectronics
- Materials science and engineering
  Electrochemical energy conversion
  Ceramics materials science and functional materials
  Corrosion and surface technology
  Materials development and processing
  Materials selection and product development
  Process metallurgy and electrolysis
- Product development and production
  Product development and materials

Master's five-year engineering programmes

- Nanotechnology
  Nanostructured materials
- Physics and mathematics
  Technical physics

Master's two-year engineering programmes

- Chemistry Structural chemistry
- Electronics
  Nanoelectronics and micro technology
- Physics
  Optics and condensed matter physics

International master's programmes

- Light Metals Production
- Condensed Matter Physics
- Chemical engineering

PhD programmes

- Chemical engineering
- Chemistry
- Electrical engineering
- Engineering design and materials
- Materials science and engineering
- Physics
- Structural engineering

Materials in facts and figures

The Materials strategic area had a management budget of NOK 2 million in 2007 for administration, coordination and seed capital. The seed capital has been used to support develop new ideas for future projects, to provide access to research infrastructure, and to establish national and international scientific networks.

NTNU is state funded and the research activities are funded by external sources. Materials scientists were involved in approximately 80 research projects with total annual external funding of NOK 150 million. Major financial support has come from the Research Council of Norway (RCN). NTNU has a close working relationship with SINTEF, the largest independent research foundation in Scandinavia.

The RCN provides funding to the majority of research projects in the Materials strategic area. NANOMAT is the RCN's main research programme in the field of nanotechnology and new materials. Eight new NANOMAT projects were awarded to NTNU in 2007. In total NTNU is in charge of 20 NANOMAT projects and is a major contributor to additional projects. PETROMAKS is the RCN programme for optimal management of petroleum resources. NTNU has the leadership for four materials-related PETROMAKS projects. The RCN also provides funding for independent projects to support basic research. Grants for seven independent projects in mathematics and the physical sciences (FRINAT) were given to the Materials strategic area in 2007. In addition there are about 30 active projects with other RCN funding schemes. Furthermore, the RCN provides funding for advanced scientific equipment.

The staff
- 56 Professors
- 17 Associate professors
- 13 Professor emeritus
- 20 Adjunct professors
- 7 Research scientists
- 36 Postdoctoral positions

Publications in 2007
- 124 scientific papers published in international journals, level I
- 87 scientific papers published in international journals, level II
- 208 scientific conference presentations
- 53 scientific conference posters

Scholarships
Most scholarships are financed by the Research Council of Norway, often in combination with industrial funding. About 10 % of scholarships are directly provided by NTNU to support the strategic areas. In 2007 two new scholarships were funded by the Materials strategic area; a PhD student working on materials for energy technology and a postdoc working in ferroelectric materials. The situation at the turn of 2007 was:
- 67 PhD students in progress
- 26 PhD degrees awarded to students in the Materials strategic area in 2007

Professor Bjørn Hafskjold, director of the Materials strategic area at NTNU. Photo: Gorm Kallstad

Board
The strategic area has an advisory board made up of members from inside and outside of NTNU. The administrative management of the Materials strategic areas is hosted by faculty of Natural Sciences and Technology.

- Ingve Theodorsen (Board chair), Executive Vice President, StatoilHydro
- Mari Wilhelmsen, Vice President, Hydro, Performance Management Extrusion Eurasia, Lausanne
- Dr Torstein Haarberg, Executive Vice President, SINTEF Materials and Chemistry
- Dr Alf Bjørseth, Chairman, Scatec
- Dr Randi Haakenaasen, Prinsipal Scientist, Norwegian Defence Research Establishment
- Professor Arne M. Bredesen, Manager of the Energy and Petroleum strategic area, NTNU
- Professor Jostein Grepstad, Vice dean of Faculty of Information Technology, Mathematics and Electrical Engineering, NTNU

Management
The Materials strategic area is organized across several faculties and departments and has its own management. The management team consists of representatives from each of the profile areas.
- Director of Materials: Bjørn Hafskjold, Dean of Faculty of Natural Sciences and Technology
- Coordinator: Dr Marianne Videm, until July 2007
- Light metals: Professor Hans Jørgen Roven
- Materials for sensors and electronics: Professor Thomas Tybell
- Materials for oil and gas: Professor Roy Johnsen
- Materials for Energy Technology: Professors May-Britt Hägg (on leave from July 2007) and Merete Tangstad
- Materials technology study programme: Professor Merete Tangstad

Members of the management group (left to right); Thomas Tybell, Roy Johnsen, Hans Jørgen Roven, Marianne Videm and Merete Tangstad. Photo: Melinda Gaal

Annual Report for The Materials Strategic Area 2007

NTNU

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

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