

Annual Report 2006

The Strategic Area Materials

What are the Strategic Areas at NTNU?

One of the main objectives of The Norwegian University of Science and Technology (NTNU) is to provide Norway with international calibre technical know-how. To realize this goal, NTNU has given priority to six research areas where the aim is to be among the internationally leading universities. These are:

- Energy and Petroleum – Resources and Environment
- Globalization
- Information and Communications Technology (ICT)
- Marine and Maritime Technology
- Materials
- Medical Technology

Visit us at www.ntnu.no/strategicareas

About Materials at NTNU

The Materials strategic research area seeks to exploit the synergism of multi-disciplinary materials research. The recent explosive growth in computer, medical and environmental technology would not be possible without concurrent developments in new materials technology.

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 production has a long tradition in Norway owing to access to low-cost hydroelectric power. Today, Materials at NTNU includes a wide variety of disciplines, including functional materials, polymers and composites in addition to light metals and advanced construction with materials such as concrete, steel and aluminium. Functional materials is a collective term used to describe materials that serve functions other than structural purposes. Functional materials are key materials in the development of new technologies for environmentally friendly energy utilization, the petro-chemical industry, information technology and telecommunications. NTNU has developed strong research groups in these areas, frequently in close collaboration with SINTEF. Nanoscience and technology is a promising new research area that offers opportunities for the development of advanced technologies in the strategic areas Materials as well as Medical Technology, ICT, and Energy and Petroleum.

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 properties in order to develop new materials for future applications.

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Annual Report published by The Materials strategic area

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Photo front page: Solidification of dendrites in Al 20% Cu pictured by synchrotron radiation. Photo: R. Mathiesen and L. Arnberg.

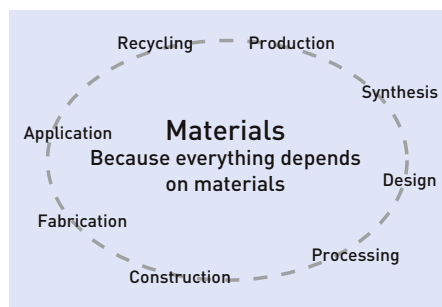
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Summary

Norway is one of the world's largest exporters of many vital materials, and is a major producer of aluminium, silicon, ferroalloys and plastics. For example, fully 25 % of the silicon for computers worldwide comes from Norway. Over the years, Materials Science at NTNU has developed strong research groups in a wide variety of disciplines, from geomaterials to semiconductors. As an interdisciplinary programme, **MATERIALS RESEARCH** at NTNU is conducted in seven departments in the Faculties of Natural Science and Technology, Engineering Science and Technology, and Information Technology, Mathematics and Electrical Engineering. Our research focuses on:

- Light metals
- Functional materials
- Polymers and composites
- Materials and integrity of structures



NANOMAT is the Research Council of Norway's main nanotechnology and new materials research programme. NTNU has been the lead university responsible for twelve of the research programme's projects and is a major contributor to projects headquartered at other Norwegian universities and research institutions. Large overarching projects are overseen by the national functional materials consortium, known as FUNMAT. These are:

- Functional Oxides for Energy Technology
- Materials for Hydrogen Technology
- Oxides for Future Information and Communication Technology

The NANOMAT 2005 conference was held in Trondheim. The conference highlighted nanotechnology and new materials' contributions in bringing Norway to the

international innovation front. Twenty-eight international and Norwegian experts made presentations at the conference, with one session allocated to energy and materials.

The **GEMINI CENTRES** are a model for strategic cooperation in which scientific groups at SINTEF and NTNU with parallel interests coordinate their scientific efforts and share resources. The centres are also a means of promoting education, research and business development. A number of different kinds of Gemini Centres have been established; two centres were launched in the Materials strategic area in 2006. These are the TEM Gemini Centre and the PV – Solar Cell Gemini Centre.

The collaboration between NTNU and SINTEF on advanced electron microscopy has been formalised by the establishment of the **TEM GEMINI CENTRE**. The new centre employs three TEM (Transmission Electron Microscope) – advanced magnifiers, which use electron beams to image the surfaces and interiors of materials. The centre's flagship is a field emission TEM, which offers a range of analysis methods with nanometer resolution. Material can also be studied at an atomic level. TEMs are used to determine relationships between material structures and properties, and are an important tool in developing new materials. The Gemini Centre uses their TEMs to study aluminium surfaces, precipitation in aluminium alloys, membranes, materials for hydrogen storage, thin films for electronic industries, nanoparticles, solar cells, and ceramics intended for use in fuel cells.



President – CEO U. Steinsmo, SINTEF congratulates NTNU-professor R. Holmestad and SINTEF's J. Walmsley on the new Gemini Centre. Photo: G. O. Johansen.

The **PV SOLAR CELL MATERIALS** Gemini Centre, was officially opened by Odd Eriksen, then Norwegian Minister of Trade and Industry in April 2006. The opening featured a panel discussion on Norway's solar energy research initiatives. The Gemini Centre brings together research at SINTEF and NTNU along the entire solar cell production chain. The major focus is on silicon and silicon-based solar cells, but researchers are also studying semiconductors in the form of thin films and nanostructured materials. Production of solar grade silicon using metallurgical techniques, as well as casting, wafer production, characterisation and modelling are the main focus of research at the centre. The Gemini Centre includes the "Heliosi" laboratory for casting solar-grade silicon, and features dedicated equipment for the characterisation of silicon wafers. The power efficiency of the finished solar cells can thus be related to material properties.

The **SIMLAB** (Structural Impact Laboratory) was selected as a Centre for Research-based Innovation by the Research Council of Norway in June 2006, with funding from 2007 to 2014. The centre's partners are Hydro Aluminium, BMW, AUDI, Renault, the Norwegian Public Roads Administration and the Norwegian Defence Estates Agency. SINTEF is a research partner. The goal is to establish technology platforms for the development of safe and cost-effective materials construction. The centre is led by Professor Magnus Langseth, and has an overall budget of 200 million NOK, which helps support the activity of about 20 researchers.

Projects that were coordinated under the cooperative research effort called **NORLIGHT** were central in light metals research at NTNU and SINTEF. NorLight has been financed jointly by the Research Council of Norway and the Norwegian light metals industry, with additional contributions from international companies. NorLight funding ended in 2006. The effort was comprised of long-term projects designed to build expertise in the

conversion and downstream applications of light metals. A national conference in Oslo in October 2006 marked the end of the six-year effort.

NORLIGHT

A 200 million NOK project portfolio from 2001-2006 at NTNU and SINTEF on the Conversion and Downstream Application of Light Metals:

- Metal forming
- Surface science
- Structural response
- Shaped castings
- Design and production
- Heat treatment fundamentals

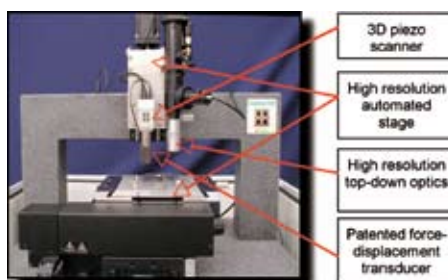
KIFEE (Kyoto International Forum for Environment and Energy) was established in 2004 to promote collaboration between Norway and Japan on energy and environmental efforts. In October 2005, approximately 20 NTNU researchers attended the "KIFEE Workshop on Environment, Energy and Materials" in Kyoto. A KIFEE symposium was also arranged in Trondheim in September 2006. This was the first KIFEE arrangement outside of Japan. A delegation of 40 Japanese university professors and researchers attended the symposium, along with about 100 Norwegian participants. A Memorandum of Understanding was signed between Japan's Doshisha University and NTNU during the symposium opening ceremony.

The **1ST CHINESE-NORWEGIAN SEMINAR** on light metals research was arranged in Trondheim in August 2005. Professors Wang and Lu from the National Light Metals Center at Shanghai Jiatong University participated, along with 10 NTNU researchers, both Norwegians as well as Chinese who currently reside in Norway. Contact with these Chinese universities was initiated by a delegation from NTNU to China in 2004.

Through the **STORFORSK** programme, the Research Council of Norway has set aside NOK 250 million for large interdisciplinary projects for 2005-2008. The scheme will strengthen researcher-initiated independent basic research. In choosing the projects to fund through this programme, the research council emphasised the excellence, innovative potential and scientific boldness of the proposals; successful projects also included international researchers and multinational research co-operation. Three out of 17 projects have been awarded to NTNU:

- Fundamentals of Condensed Matter, Arne Brataas
- Residual Stress Simulation for Integrity Assessment, Asbjørn Mo
- Transport on a nanoscale at surfaces and contact lines, Signe Kjelstrup

NTNU's **NANOMECHANICAL LABORATORY** opened in August 2006. The Hysitron TribolIndenter relies on an ultra-sensitive depth-sensing technique to provide unique opportunities for studying the mechanical properties of nanomaterials, biomaterials, nano-devices, and surfaces as well as conventional materials at the nanometer scale. Static and dynamic nanomechanical properties can be accurately measured both at high and low temperatures. A day-long seminar on nanoindentation technology and nanomechanics was organised in connection with the opening of the lab. Experts from China, Finland, France, Germany and USA as well as Norway were invited to present their recent results and in-house experiences in this new field. More than 70 people attended the opening seminar.



The Hysitron TribolIndenter



Rune Thorsen Barland and Tommy Mokkelbost in front of the spray pyrolysis unit. Photo: Julian Tolchard

Nano-sized oxide-based **CERAMIC POWDERS** can be produced using spray pyrolysis. A complete pilot plant for powder production with the capacity to produce between 5 and 10 kilos of powder per day has been established. A variety of different compositions has been produced and the method has demonstrated its versatility in producing high purity, homogeneous powders with a particle size that is less than 100 nm. The powders have shown excellent sintering properties, resulting in well-defined micro structures in the sub-micron range. The pilot plant is one of only a few production facilities found in Europe.

Professor L. Arnberg and Research Manager R. Mathiesen won the 2006 **SINTEF** prize for outstanding research for their work on metal solidification. Their research has enabled car manufacturers to replace steel components with light metal components to a far greater extent than was previously possible. In order to study solidification processes on a microscale, the research team has used the European Synchrotron Radiation Facility (ESRF) in Grenoble, France. Radiographs taken at time intervals during solidification have provided fundamental insights into this complex process, which allows better control of the microstructure of cast aluminium products. Aluminium's microstructure is of vital importance in the strength, ductility and corrosion resistance of the finished product.

ALUMINIUM RESEARCHER AWARDS

Professor N. Ryum was awarded the Polytechnical Anniversary Prize in 2005. Professor Ryum is the father of modern physical metallurgy in Norway and has contributed to the establishment of aluminium technology as an independent research area in Europe. At NTNU he launched the aluminium alloy research group, which emphasises aluminium and aluminium alloy research.

Professor H. Øye received a prize of honour from the Norwegian Metallurgical Association. He has played a key role in industrial aluminium production during the many decades of his career, in part by supervising 39 successful PhDs who now work in the industry and academia. His textbook "Cathodes in Aluminium Electrolysis" is used in curricula worldwide and has been translated into Russian and Chinese.

These two professors have served as the backbone of light metal research at NTNU.

Professor L. Arnberg and Research Manager R. Mathiesen are awarded the SINTEF prize for outstanding research. Photo: G. O. Johansen.



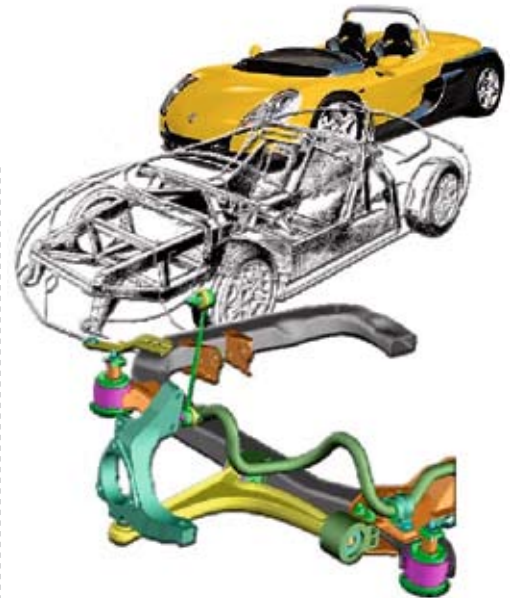
Focus Area: Light Metals

Abundant hydropower and strategic alliances at the turn of the 20th century brought the light metal industry to Norway. Now, nearly 100 years later, light metals and materials continue to play an important role in the country's economy, and in applied research at NTNU and SINTEF. The light metals industry is one of Norway's largest.

NTNU's light materials research agenda is dominated by aluminium research, but casting and casting technology for magnesium and silicon played a part in the research portfolio in 2005. Aluminium research has been much more wide-ranging, and includes forming, joining, alloy development, casting and solidification, nano-approaches, surface science and corrosion, construction engineering, and automobile crashworthiness. The largest light metals research programme in Norway in recent years has been NorLight, which has been funded by the industry and the Research Council of Norway (RCN). This programme (2001-2006) sunsetted in 2006, and had a budget of approximately 200 million NOK.

Under the auspices of the NorLight programme, researchers at NTNU and SINTEF worked collaboratively on projects that examined light metal forming, including the bending of thin-walled sections and hot and cold forging; the surface science of light metals, including pitting corrosion studies as well as chrome free and environmentally friendly pre-treatment of aluminium before coating or adhesive bonding; the shaped casting of light metals; the heat treatment of aluminium alloys; the design and production of light metal automotive products and processes; and the structural response of light metals.

Recent years have seen the focus in research move upstream in the aluminium value chain, meaning that casting technology has become increasingly important. Downstream research has seen a downturn in funding support, however. An example of this was the proposal to the Research Council of Norway (NFR) for funding for a



Norwegian Centre of Excellence at NTNU for the Modelling of Aluminium Alloy – Downstream Processing. While the proposal for this centre received the maximum score from the international review panel enlisted by the NFR as a part of the review process, the Research Council in the end decided not to fund it.

The Structural Impact Laboratory – SIMlab – was one of 14 centres awarded continuing funding of roughly 10 million NOK per year over the next 5-10 years under the Research Council of Norway's new Centres for Research-based Innovation programme, created in 2006. SIMlab's industrial partners are Hydro Aluminium, BMW, Renault and Audi. SIMlab researchers are developing the tools needed to design light-metal products that can survive high impact situations – car parts that are made of aluminium are the project's biggest focus.

2006 also saw the creation of a Norwegian Centre of Expertise in Materials and automation technologies which is comprised of an industrial cluster at Raufoss for aluminium R&D and downstream processing. A formal agreement between the Centre at Raufoss and NTNU was signed by the respective leaders of the two organisations.

A portion of the light materials research relies on being able to look at changes in materials at the atomic level. Accordingly, the light materials programme in 2006 purchased several new electron microscopes, including an advanced field emission microprobe and a high-resolution field emission scanning microscope.

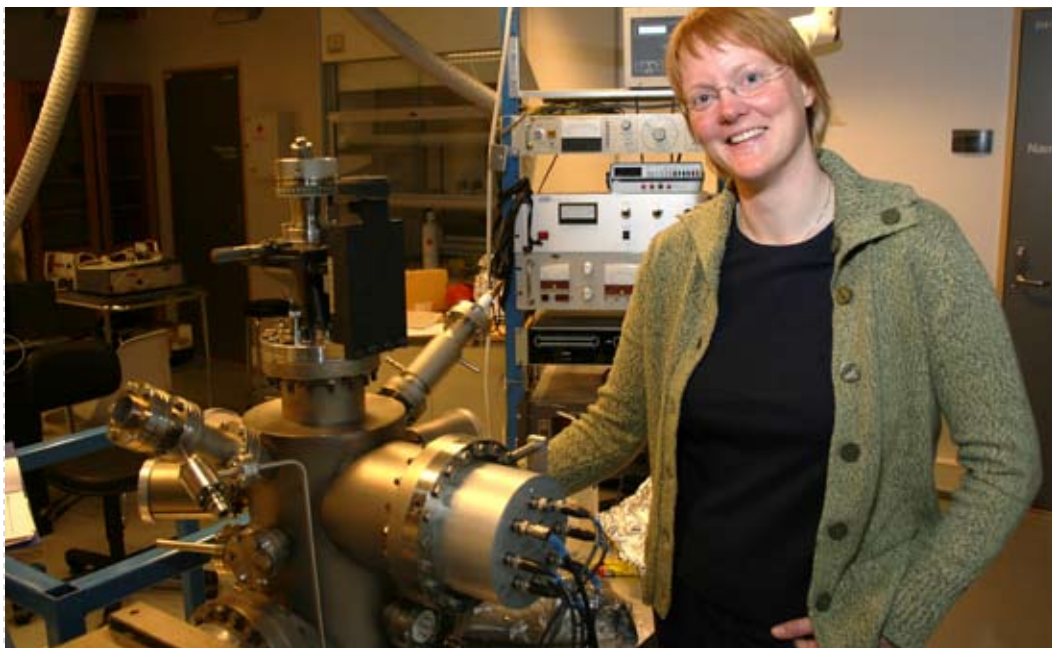
Focus Area: Functional Materials

NTNU's work on functional materials covers the entire product life cycle, from production, to use, to recycling. NTNU researchers have built on Norway's leadership role in providing silicon as a raw material to the world's markets and have strong partnerships with Elkem, which has the world's largest furnace for producing silicon metal at the company's Thamshavn plant.

An important development in recent years has been shifting to the study of value-added products; instead of supplying metallurgical quality silicon, which is 99 percent pure, Elkem and other businesses are looking to increase their production of highly pure silicon, which is 99.999 percent pure. This material is most valuable in making solar cell panels, a market that is growing on average about 40 percent per year.

Research in 2005 and 2006 focused on the production of pure silicon, casting of multicrystalline ingots, as well as examining the microstructures and the effects of impurities on efficiency in the silicon used to make solar cells.

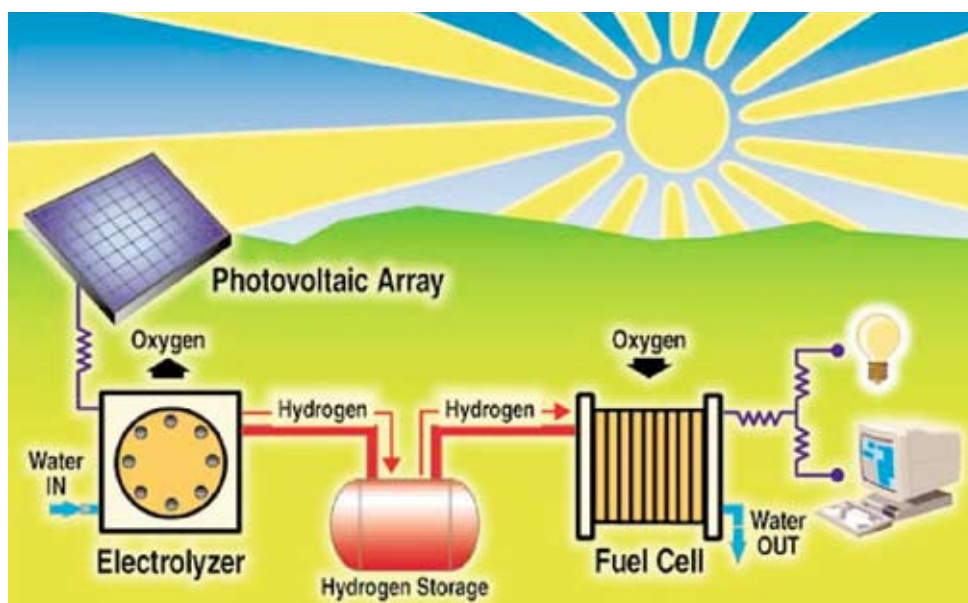
Collaborative research between NTNU and SINTEF saw a boost in 2006 when the two institutions created a new Gemini Centre



Turid Worren improves the efficiency of solar cells. Photo: Arne Asphell/ NTNU Info

called PV – Solar Cell Materials. The centre was founded by SINTEF Materials and Chemistry, and NTNU's Faculty for Natural Science and Technology, the Department of Materials Science and Engineering and the Department of Physics. The goal is to work on improving the production, characterisation, modelling, fabrication and/or use of materials that either will be a part of a solar cell system or that represent a necessary component in the manufacturing process.

Functional Materials also saw a great deal of activity in 2005 and 2006 under the auspices of FUNMAT, a nationally funded project focusing on three important aspects of advanced oxide materials: Functional Oxides for Information and Communications Technology (ICT), Functional Oxides in Energy Technology, and Hydrogen. FUNMAT is a coalition of researchers from NTNU, SINTEF, the University of Oslo and the Institute for Energy Technology. The programme, which began in 2002 and is expected to last a decade, has an average annual budget of approximately NOK 150 million. NTNU researchers were specifically involved in heading up the Functional Oxides for ICT project, which has as its focus the development of new materials that can be used in circuit boards, optical components and mechanical systems built at the nanoscale. The goal is to feed future ICT demands, such as computers with great computational speeds, and increased capacities for data storage. Other researchers have made significant contributions to the Hydrogen project.



The hydrogen society based on renewable energy. Illustration: IFE

Focus Area: Materials and structural integrity

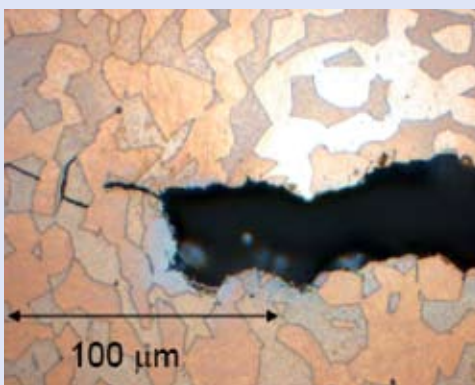
A number of projects under the Functional Oxides for Energy Technology, including work on fuel cells and membranes, and synthesis and fabrication work, have also been headed by NTNU researchers. The fuel cells and membranes work featured a special focus on Solid Oxide Fuel Cells (SOFC) and mixed conducting membranes, with the goal to produce gas separation membranes from ceramics. Oxygen permeable membranes may be used in the partial oxidation of natural gas to produce synthetic gas and to separate oxygen from the air, while proton conductors can be used for hydrogen separation. Both types of processes can be integrated into power production with CO₂ capture (precombustion decarbonisation and oxyfuel processes).

One of the fundamental tensions in making membranes of this nature is the inevitable need for compromise between crafting a material that will allow a high flux, as permitted by a high surface exchange rate and high ionic conductivity, and the mechanical and chemical compatibilities of the various materials. The focus of the work has mainly been on proton conducting materials. The total budget for the project has been NOK 20.44 million.

The synthesis and fabrication group focused on thin and/or nano-size oxide materials of high purity and controllable stoichiometry. These materials have mainly been produced using spray pyrolysis, in NTNU's new spray pyrolysis centre, as well as using sol-gel synthesis for the preparation of materials and thin films, and metalorganic chemical vapour deposition, or MOCVD, which is a process that is complementary to sol-gel synthesis. This project has had a budget of NOK 7.69 million.

Functional Materials has also been active in international cooperative research projects under various EU-funded projects. One such project is ULCOS, the Ultra-Low CO₂ Steelmaking project, which started in 2004 and ends in 2009. The project has been funded under the EU's 6th framework programme. As the name

Norway's petroleum industry is constantly pushing the envelope of what is possible, and research from NTNU is helping with that development. In 2005 and 2006, researchers in the Materials and Structural Integrity focus area have been working to solve the vexing problem of hydrogen-induced cracking in stainless steel pipelines used by the petroleum industry. Five doctoral students and one master's student were working on this problem. The research is partly being conducted at a nano-level, as researchers look at the effects of hydrogen on mechanical properties of the stainless steel.



The arctic is another area where research from the Materials and Structural Integrity Focus Area has been particularly important. Researchers are working to develop new materials for construction and pipelines that must tolerate the extreme temperatures of the arctic. SINTEF and the Materials and Structural Integrity Focus Area established a cooperative Gemini Centre in June 2004, where the two institutions share information and expertise. The Gemini Centre, called "Robust Material choice and Design – Offshore Applications", has generated a series of research projects, including the research programmes on arctic materials and hydrogen induced stress cracking, as well as projects to develop smart pipes, and a programme called SINMAT, or structural integrity of materials.

25% Cr super duplex stainless steel (UNS S32760) under cathodic protection in natural seawater. Hydrogen induced stress crack (HISC) in front of an artificial notch. The crack is propagating through the ferrite phase and seems to stop in the austenite phase.

suggests, the goal of the project has been to develop steelmaking processes that limit greenhouse gas emissions. NTNU researchers have focused on developing fixed site carrier membranes from different materials that can capture CO₂ from high volumes of flue gasses. Other membrane-related research at NTNU that has been funded under the EU's 6th framework programme and has been ongoing through 2005 and 2006 is NaturalHY, in which carbon and mixed matrix membranes are used to recover hydrogen from natural gas; ENGAS; and NanoGloWa, in which mixed matrix membrane materials with carbon sieves or nanostructured fillers are used to selectively capture greenhouse gases.

Focus Area: Polymers and composites

The world of polymers and composites is particularly important in Norway, where roughly 500 small and medium sized enterprises manufacture plastic products. NTNU researchers in the area have continued their work with carbon fibre composites, which have seen use in the petroleum industry, specifically in the fabrication of tethers to help anchor TLP platforms, and in the use of electrically conductive compounds and plastics. Researchers applied for two patents in 2005.

Other work continued on bionano-composites, in which the reinforcing material has nanometer dimensions. These substances take advantage of the properties of their biological components, which can be natural fibres such as hemp, flax, or cellulose, to provide properties that are useful in medicine, coatings, and packaging. The advantage of using biological components is that the products are made from renewable resources and are completely biodegradable or recyclable – a true eco-friendly cradle-to-grave approach. One of the most promising areas of basic research has been work with nanocomposites formed with



Biopolymer based nanocomposites for medical applications.

microcrystalline cellulose (MCC) as the reinforcement and polylactic acid (PLA) as a matrix. PLA is a polyester made from lactic acid and MCC is cellulose derived from high quality wood pulp by acid hydrolysis to remove the amorphous regions, and which forms particulate aggregates of cellulose whiskers.

Research into the use of wood as a filler and/or reinforcement in thermoplastics has also been productive. Wood offers the advantage of low density, high stiffness and strength, and low price, as well as minimizing the abrasion of equipment used to form the composite material. A

team of students from the Polymers and Composites focus area won a first place in the Mid-Norway Regional Venture Cup competition with a business idea that involved using wood to make thermoplastic planks.

Researchers in polymers and composites have also strong ties with researchers in Japan. In 2006, the 10th Japanese –European Symposium on Composite Materials was held at Shinshu University in Nagano, Japan. The symposium is an outgrowth of co-operative research between NTNU researchers and their Japanese counterparts. The first of the joint meetings was held in 1990.



Team Board Extrusion won the local Venture cup in 2005 with a contribution based on extruded thermoplastics for laminate flooring. Photo: Terje Bjørnson

Strategic objectives

Three substantial events in the last two years have provided guidance for NTNU's Materials research strategy.

A new government White Paper on research, "Commitment to research", was released in the spring of 2005. The document describes the country's goal of becoming a leading research nation by focusing on quality, innovation and thematic priorities in research.

A national evaluation of institutions that provide engineering sciences education was conducted in 2004. To follow up on the evaluation, the Research Council of Norway appointed a team to develop a subject plan. The plan outlines a research strategy for the next 15 years in eight thematic areas, describing the current status and future challenges for these areas. One of the areas highlighted is materials. The plan describes how materials research should concentrate on production and recycling of light metals, materials for solar cells, ferroalloys, synthetic and natural polymers and composites, and nanostructural and functional materials. Materials engineering and in particular advanced materials will be vital in oil and gas exploration in the years to come.

The committee chose to prioritise four areas, based on global challenges and

Norwegian know-how, and which represent important business sectors in Norway:

- Energy production in northern areas
- Renewable energy
- Sustainable infrastructure
- Food from the north

Different aspects of materials research are fundamental to the development of the first three areas.

The Foresight project Advanced Materials 2020 was undertaken by the Research Council of Norway in 2005. The project describes the challenges facing materials and nanotechnology research in Norway, provides possible scenarios for 2020, and presents strategic recommendations. Materials and nanotechnology provide a springboard for the development of new technology and products related to energy, environment, health, ICT and transport. Success in these fields requires the ability to translate basic science into industrial applications. The foundation for industrial development in Norway is the country's expertise in materials research along the entire value chain, from materials science, through advanced products to recycling, and combined with materials knowledge from the nano- to the macro-scale.

Priorities in the Materials strategic area reflect the ideas expressed in these projects and documents, with a strategy focusing on

light metals as well as materials for oil and gas, sustainable energy and ICT.

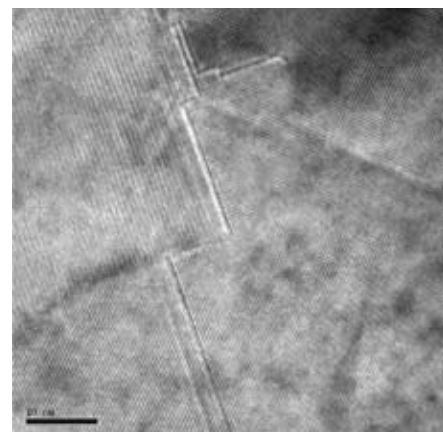
The board of NTNU and SINTEF agreed in February 2005 on a mutual strategic alliance, with a strategy called "Internationally outstanding together". The alliance reflects the strong correspondence between NTNU's strategic research areas and SINTEF's corporate research areas. The strategy calls for a focus on the main priorities for each group, as well as internationalisation, research and business politics, and infrastructure. The co-operative effort has resulted in the development of road maps for each area. NTNU and SINTEF will together promote light materials, as well as materials for the oil and gas industry, energy technology, and nanotechnology.

GEMINI CENTRES

Strategic cooperation in which scientific groups with parallel interests coordinate their scientific efforts and share resources.

There are five Gemini Centres in the Materials research area:

- Marine construction
- Materials and energy
- PV - solar cell materials
- Robust materials selection and design – offshore applications
- Transmission electron microscopy (TEM)



High resolution transmission electron microscopy pattern of SrRuO_3 .

Photo: A.T.J. van Helvoort/TEM Gemini Centre.

White Paper – National priorities



International activities

COLLABORATION WITH JAPAN

The Kyoto International Forum for Environment and Energy (KIFEE) was originally created by Japanese universities in the Kyoto region for the development of an international arena for strategic cooperation between universities working to develop a sustainable society. Their inspiration was the Kyoto Protocol.

BILATERAL PROJECTS WITH JAPAN

Project title	Collaborating university
Electrolysis systems	Doshisha University and Kyoto University
Surface and interfacial phenomena related to preparation of nanostructured materials	Kyoto University
Nanostructured and ceramic materials for energy applications	Osaka Prefecture Univ. and Kyoto Univ.
Advanced Biological Materials	Kansai/Tokyo and Kyoto Univ.

When the Bilateral Agreement on Technological Cooperation between Japan and Norway was signed in 2004, NTNU was invited to participate in KIFEE, in part because of its long-term and strong relationships with the universities in the region. Both the opening seminar and the first KIFEE Symposium on “Materials and Processes for Environment and Energy” were arranged in Kyoto in 2004. NTNU recruited a joint delegation from the Materials and Energy & Petroleum strategic areas. Four areas were selected for workshops:

- Process Engineering
- Advanced Inorganic Materials
- Advanced Biological Materials
- Electrolysis Systems

A workshop on Environment, Energy and Materials was organized in October 2005 as the second major event in the development of KIFEE. The workshop focused on advancing networks and co-operative research in the four selected areas. About 20 Norwegian researchers met with their Japanese colleagues.

The second KIFEE Symposium was arranged in Trondheim in 2006. This was the first KIFEE arrangement in Norway. The objective was to further develop research cooperation between the institutions involved with the “Materials and Processes for Environment and Energy” research area. The programme was comprised of strategic sessions as well as workshops

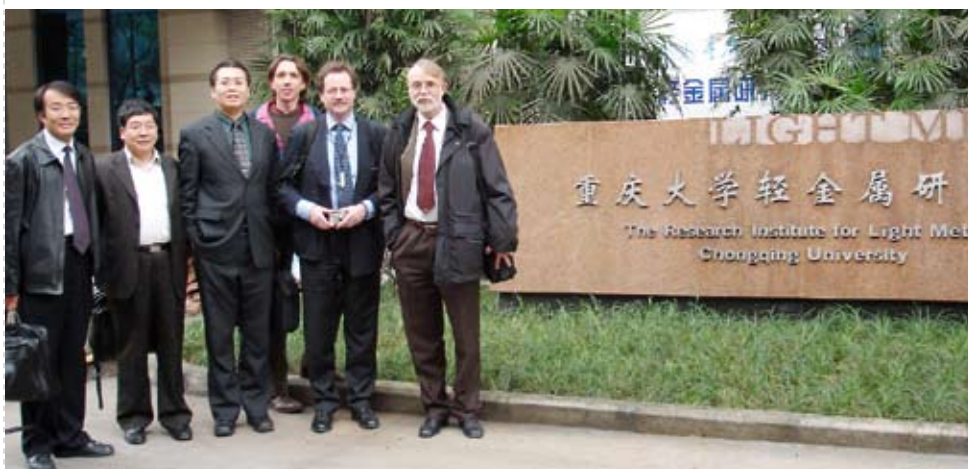
for developing co-operative networks on specific topics. A delegation of 40 Japanese university professors and researchers and 100 Norwegian participants attended the symposium.

Support from NTNU and the Research Council of Norway has enabled the KIFEE collaboration. In 2006 four bilateral projects have received support from the Research Council of Norway to further develop the KIFEE programme.

COLLABORATION WITH CHINA

The Chinese demand for light alloys such as aluminium, magnesium and silicon is rapidly increasing due to the country's rapid economic growth, with the likely result that China will become Norway's chief market for aluminium exports in the future. With support from NTNU and the Research Council of Norway, closer contact with China in light metals research has evolved over the last two years.

Contact with Chinese universities was initiated by a delegation from NTNU to China in 2004. NTNU's first bilateral seminar in light metals was organised in Trondheim in August 2005. Chinese delegates came from the National Engineering Research Centre for Light Alloy Forming, at Shanghai Jiatong University (SJTU). The purpose of the seminar was to stimulate collaboration and to explore the possibility of joint funding initiatives from the science foundation in China, NFR in Norway and the Chinese and Norwegian light metal industries. The delegation also met representatives from SINTEF, and from the Hydro Magnesium R&D Centre in Porsgrunn and the Hydro Aluminium R&D Centre at Sunndalsøra.



NTNU visited the Research Institute for Light Metals at Chongqing University in november 2006. From the left: Prof. Q. Liu (Chongqing Univ.), M. Liu and Prof. L. Zhang (NTNU), Prof. A. Godfrey (Tsinghua Univ.), Prof. H. J. Roven and Prof. E. Nes (NTNU). Photo: Lifeng Zhang

International courses

A formal collaborative agreement between NTNU and SJTU was signed in May 2005 in Shanghai, with a similar agreement signed between NTNU and Chongqing University in June 2006.

A delegation from NTNU visited Tsinghua University in Beijing, another potential collaborator, in autumn 2005. In June 2006, NTNU representatives joined the 14th International Conference on the Strength of Materials in Xi'an, and visited the Hydro Magnesium Plant in Xi'an, which expressed strong interest in joint research.

A second delegation from NTNU, including representatives from the Materials and Energy and Petroleum strategic research areas, visited Shanghai Jiao Tong University (SJTU) and Chongqing University (CU) in November 2006, both of which are interested in future joint research efforts.

The Materials strategic area also agreed at the end of 2006 to support the 2nd Chinese – Norwegian Seminar on Light Metals, scheduled for 2007 in Shanghai. In October 2006, Yojun Chen from SJTU began a five-month stay at NTNU, financed by the National Science Foundation of China. The new Chinese program for researcher exchange announced late 2006 is another great opportunity to enhance our research collaboration with China (financed by the China Scholarship Council, CSC); NTNU is already involved in several metallurgical projects financed by the CSC.



26 students from 15 countries attend the summer course "Solar cells – power of the future" in 2005.

The 24th and 25th "International Course on Process Metallurgy of Aluminium" was arranged in 2005 with 73 participants from 27 countries and in 2006 with 86 participants from 24 countries.

The summer school "Fundamentals and their application in aluminium production" was arranged for the 13th consecutive year in May 2006. There were 44 participants from 16 nations. In May 2005 the course attracted 38 participants from 12 countries.

The 8th "International Summer School on Aluminium Alloy Technology" this time with focus on Solidification and Casting of Aluminium and Magnesium Alloys was arranged in Trondheim in August 2006.

The 8th **INTERNATIONAL SUMMER SCHOOL** on Aluminium Alloy Technology took place in Trondheim on August 21-25, 2006. The theme was Casting and Solidification of Aluminium and Magnesium Alloys. Fourteen internationally known experts from Europe and the United States were featured as lecturers. The school attracted approximately 30 students from 11 countries, and addressed topics such as solidification, melt treatment, casting processes and defects, modelling, design and heat treatment of casting. The Summer School is more than a contribution to NTNU's overall commitment to continuing education and training – it is also an important networking activity.

Teachers at the 8th International Summer School for Aluminium Alloy Technology. From upper left: Dr. O. Reiso, Hydro Aluminium. Prof. M. Makhlof, WPI. Mr. J. Jorstad, JLJ Technologies. Lower, from left: Prof. L. Greer, Cambridge University. Dr. C. A. Gandin, Ecole des Mines de Paris. Prof. L. Arnberg, NTNU. Prof. D. Apelian, WPI and Mr. D. Weiss, Eck Industries. Photo: Melinda Gaa

EU's 6th Framework Programmes NTNU participates in these materials-related projects:

- SFINX - Superconductivity - Ferromagnetism Interplay in Nano-structured Hybrid Systems, NMP-STREP
- NAPOLY – Possibilities through Advancements in Nanotechnology for Development of High Value Ecofriendly New Biopolymers and their Applications, NMP-SSA
- ULCOS – Breakthrough Technologies for the Steel Industry to Address the Global Warming Challenge in Europe, NMP-IP
- NATURALHY – Preparing for the Hydrogen Economy by using the Existing Natural Gas System as a Catalyst, Energy-IP
- FOXY –Development of solar-grade silicon feedstock for X wafers and cells, by purification and crystallisation, Energy-STREP
- DYNAMAX – Dynamic Magnetoelctronics, IST-STREP
- NanOxiDe - Novel Nanoscale Devices based on functional Oxide Interfaces, NMP-STREP
- NADIA- New Automotive components Designed for and manufactured by Intelligent processing of light Alloys, NMP-IP
- NanoGlowa – Nanostructured materials against Global warming, NMP-IP
- ENCAP – Enhanced Capture of CO₂, Energy-IP
- FURIM – Further Improvement and System Integration of High Temperature Polymer Electrolyte Membrane Fuel Cells, Energy-IP
- ENGAS – Environmental Gas Management, RI-TA
- MARSTRUCT – Network of Excellence on Marine Structures, Transport - NoE

Seminars and short courses

The strategic area builds 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.

SEMINARS AND SHORT COURSES 2005

- The annual Light Metal Surface Science (LMSS) Conference, 15-16 June 2005
- Seminar - Atomistic Modelling in Aluminium Alloys 23-24 June 2005
- Microstructural effects in corrosion of aluminium alloys, Dr. Rajan Ambat Technical University of Denmark (DTU) 26 January 2005
- Lecture on Aluminium electrolysis, Prof. H. Øye, 25 February 2005
- Ultra fine grain size materials by ECAP processing, Prof. H.J. Roven, 30 March 2005
- Guest lecture "Studies of Formability in Al alloys", David Wilkinson, McMaster Univ., Canada, 14 April 2005
- NorLight – 7 lunch presentations in 2005
- First Chinese – Norwegian Seminar on Light Metals, 30 August 2005
- Guest lecture "Development of a hydrogen infrastructure" Dr. Arend de Groot, ECN, 24 February 2005
- Guest lecture "Solar cells" Dr. Rita Glenne, REC, 18 February 2005
- Short course "Soft Condensed Matter on Surfaces", Prof. Jan Genzer, North Carolina State University, 7-9 March 2005
- 3rd Norwegian User Meeting - Application of Synchrotron Radiation, 10-11 March 2005
- 5th NTNU – EBSD seminar, EBSD software and applications, 19 May 2005
- Guest lecture "Dimensionally stable anodes for oxygen evolution", Prof. Achille De Battisti, University of Ferrara, Italia, 27 June 2005
- Guest lecture "The synthesis of coiled carbon nanotubes and the preparation and properties of CNTs – polymers nanocomposites", Professor János B. Nagy Faculté Universitaires Notre-Dame de la Paix, Belgium, 25 January 2005

- Guest lecture "Combinatorial approach for flux mediated epitaxy", Dr. Takahashi, Tokyo Institute of Technology, 18 February 2005
- Lecture "Stresses in Finescale particles", Prof. T. Grande, 9 March 2005
- Lecture "Synthesis of Inorganic and Ceramic Nano-materials", Prof. M.-A. Einarsrud, 23 February 2005
- Guest lecture "ONERA France Ultra fine scale cellular Materials for Aerospace applications", Prof. Jason Nadler, 6 April 2005
- Guest lecture "Tomographic studies of Damage and Fracture" David Wilkinson, McMaster Univ., Canada, 13 April 2005
- Guest lecture "Transformation of Hierarchical biological materials to anorganic carbon + ceramic materials" Oscar Paris, Max Planck Institute Postdam Germany, 28 April 2005
- Lecture "An overview of Nanomaterials present and future at NTNU", Prof. T. Tybell, NTNU, 4 May 2005
- Guest lecture "Length scale effects in the mechanical behaviour of thin metal films", Prof. Joost J. Vlassak, Harvard University, 29 April 2005
- Guest lecture "Quantum computing", Prof. Vadim Geshkenbein, ETH, Zürich, 27 May 2005
- Micro and Nanomechanics seminar, Q-S Zheng, Prof. Yang-Tse, Tsinghua University, 8 - 9 August 2005
- 2nd NTNU seminar on the synthesis and applications of carbon nanotubes/nanofibers, 21 September 2005
- Guest lecture CNF as catalyst, multiscale structure and catalytic performance", Prof. Wei-Kang Yuan, East China University of Science and Technology, Shanghai, China, 21 November 2005
- Guest lecture "Phase separation in several alloys as investigated by 3D Atom Probe", Dr. Williams Lefebvre, Université de Rouen, 25 November 2005
- TOP25 articles in the journal Corrosion Science: "Formation and characterisation of a chromate conversion coating on AA6060 aluminium"

- Lunder, O.; Walmsley, J.C.; Mack, P.; Nisancioglu, K. Corrosion Science, Volume 47, Issue 7, 1 July 2005, Pages 1604-1624

SEMINARS AND SHORT COURSES 2006

- Guest lectures by Dave Embury, McMaster University, Canada, 1-16 February 2006
Microstructural design in aluminium alloys.
Ultra-high strength materials
Mechanical properties of modern structural steels.
Fracture and formability of 5000-series alloys
Rapid annealing to develop new microstructures.
Mechanical properties of hybrid metallic structures.
- SINTEF seminar "Future materials need nanotechnology", Oslo, 7 February 2006.
- Guest lecture "Surface and Interface Magnetism in Complex Oxide Thin Films and Nanostructures", Dr. Yayoi Takamura, 7 February 2006
- The 4th THIOX meeting, 19-21 March 2006
- Lecture "The ferro manganese process – from micro to macro", Prof. M. Tangstad, NTNU, 16 February 2006
- Lecture "Silicon for solar cells. R&D at NTNU and SINTEF", Prof. O. Lohne, NTNU, 24 February 2006.
- Guest lecture "Aluminium alloy development and product performance", Prof. Il O. Jensrud, Raufoss Technology & Industrial Management (RTIM), Norway, 2 March 2006
- Seminar "Materials production and environmental issues", 22 March 2006
- Seminar "Modelling of Microstructure and Texture and the Resulting Properties during the Thermo-mechanical Processing of Aluminium Sheets", Prof. Il O. Engler, Hydro Aluminium Deutschland GmbH, R&D Bonn, 16 March 2006
- Lecture "Transport Phenomena and CFD Application during Process Metallurgy", Prof. L. Zhang, 30 March 2006.

- Guest lecture "Order in disordered materials: linking structure, energetics and ion transport", Prof. S. Stølen, UiO, Norway, 31 March 2006
- Guest lecture "Relaxor ferroelectrics", Ben Burton, NIST, 10 August 2006.
- Opening seminar for NTNU Nanomechanical Laboratory, 29 August 2006
- Guest lecture "Spatially Resolved Magnetic Resonance of Materials", Prof. B. Balcom, University of New Brunswick, Canada, 15 September 2006.
- Seminar "Fundamentals, Practice and Modelling during Metal Recycling, Refining and Processing" 16 October 2006
- Guest lecture "Spark Plasma Sintering (SPS)", Dr. C. Estournès, CNRS, France, 26 October 2006
- Guest lecture "Surface Electrochemistry of Iodine Modified Pt (111)", Prof. D. Harrington, University of Victoria, Canada, 27 October 2006
- Guest lecture "UMCP fuel cell research - with focus on solid oxide fuel cells (SOFC) in particular", Prof. G. Jackson, University of Maryland College Park (UMCP), 27 October 2006
- Guest lecture "UMCP hydrogen research - efforts within nano-architected catalysis", Prof. B. Eichhorn, University of Maryland College Park (UMCP), 27 October 2006
- Guest lecture "Synthesis, Characterization, and Hierarchical Ordering of Mesoporous Silica", Dr. A. M. Lindh, Åbo Academy, Finland, 6 November 2006.
- Guest lecture "Intermediate Temperature Solid Oxide Fuel Cells (ITSOFC)", Dr. F. Mauvy, University of Bordeaux, France, 29 November 2006
- Lecture "Layer refining - a new process for producing Solar Silicon", E. Olsen, 1 December 2006

TRAVELLING GRANTS FROM MATERIALS AREA 2005

- Professor D. Embury from McMaster University, Hamilton, Canada was a guest researcher at NTNU for six months. Light metals and nanotechnology
- PhD student H. Hasting, 2 months in 2005 at University of Rouen, France. Light metals
- PhD student E. Sandnes, 7 months at University of Wroclaw, Poland. Light metals
- MSc student Ch. Mikalsen, ESIA, Annecy, France. Light metals
- Professor K. Oksman was a guest researcher at University of Toronto, Canada. Polymers and composites.
- Professor M. Sain University of Toronto, Canada visited NTNU. Polymers and composites.

2006

- Professor H. Weman and B. O. Fimland visited University of Copenhagen, Denmark and CNRS, Paris, France. Functional materials.
- Professor Lifeng Zhang attended "Fifth International Conference on Computational Fluid Dynamics in the Process Industries" in Australia. Light metals.
- Professor C.-G. Gustafson attended "10th Japanese European Symposium on Composite Materials" at Shinshu University, Nagano, Japan. Polymers and composites.
- Professor E. Nes and L. Zhang visited Tsinghua University, Beijing, China. Light Metals.
- Professor K. Marthinsen and L. Zhang, European Aluminium Technology Platform, Brussels, Belgium. Light metals.
- MSc student Ch. Mikalsen, ESIA, Annecy, France. Light metals.
- T. Krogstad, Dr. M. Di Sabatino and Professor O. Lohne visited the University of Milano, Italy. Functional materials.
- MSc student A. Smirnova from Bauman Moscow State University, Russia was an exchange student at NTNU for one month. Materials and structural integrity.



"The suns mirror" Sculpture by Gunnar S. Gundersen. The glass bulb focus the sun light which burns traces in the Aluminium plate.

Photo: Tor Åsmund Evjen

Master's and PhD programmes in Materials

NTNU offers five-year master's programme in a variety of materials-related topics, while a two-year master's programme is available for students with an undergraduate degree. The study programmes are listed below.

Master's two- and five-year engineering programmes

- Chemistry and biotechnology
Chemical engineering
Materials chemistry and energy conversion
- 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

- Electronics
Photonics, micro technology and nanoelectronics
- 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

PhD programmes

- Materials science and engineering
- Chemistry
- Chemical engineering
- Physics
- Product development and materials
- Electrical engineering

Materials in facts and figures

The Materials strategic area had a management budget of NOK 2.4 and 2.6 million allocated to strategic activities in 2005 and 2006, respectively. Financial support has been provided to develop new ideas for future projects, to provide access to research infrastructure, and to establish national and international scientific networks. NTNU is state funded. Materials scientists were involved in approximately 50 research projects with total annual external funding of NOK 150 million. Major financial support has come from the Research Council of Norway. Norsk Hydro is the strategic area's most important industrial partner. NTNU has a close working relationship with SINTEF, the largest independent research foundation in Scandinavia.

The staff

- 73 academic positions
- 16 adjunct professors
- 8 professors emeritus
- 7 researchers
- 34 postdoctoral positions
- 125 PhD students

Publications in 2005 and 2006

- 374 scientific papers have been published in international journals
- 445 conference contribution of which 320 were scientific presentations

Scholarships

Most scholarships are financed by the Research Council of Norway, often in combination with industrial funding. About 10 % of the scholarships are directly provided by NTNU to support the strategic areas.

- 26 and 19 PhD degrees were awarded to students in the Materials strategic area in 2005 and 2006 respectively

Erik Sandvold

The Materials strategic area lost one of its greatest supporters with the death of Erik Sandvold in October 2006. Dr. Sandvold was just 49 years old. He served as the dynamic leader of the Materials strategic area's Board. Sandvold was research director at Hydro, and was a strong spokesperson for the need for Norway's political leaders to support research.



He recognized the potential that could result from strong cooperation between universities, research institutes and industry, and in 2004 he initiated the establishment of a co-operative research plan among Hydro, NTNU and SINTEF, which has resulted in a number of new co-operative projects. He was also involved with the Research Council of Norway, most recently as the head of a broad programme to support research based innovation. He will be deeply missed.

Board

- Dr.ing. Erik Sandvold (Board chair): Vice Director, Head of Hydro Aluminium R&D, Norsk Hydro ASA, until October 2006
- Dr. ing. Unni M. Steinsmo: President CEO, SINTEF, until January 2005
- Dr. ing. Kai Johansen: Director of Research, Elkem ASA
- Professor Arne M. Bredesen: Vice dean, Faculty of Engineering Science and Technology, NTNU
- Professor David Nicholson: Dean, Faculty of Natural Sciences and Technology, NTNU
- Professor Jostein Grepstad: Vice dean, Faculty of Information Technology, Mathematics and Electrical Engineering, NTNU

Management

- Director of Materials: Bjørn Torger Stokke, Vice dean Faculty of Natural Sciences and Technology, NTNU, until November 2005
- Director of Materials: Bjørn Hafskjold, Dean, Faculty of Natural Sciences and Technology, NTNU, from November 2005
- Coordinator: Dr.ing. Marianne Videm
- Light metals: Professor Hans Jørgen Roven
- Functional materials: Professor Tor Grande, 2005
- Functional materials: Professor Thomas Tybell, 2006
- Polymers and composites: Professor Kristiina Oksman, 2005
- Polymers and composites, Professor May-Britt Hägg, 2006
- Materials and structural integrity: Professor Stig Berge, 2005
- Materials and structural integrity: Professor Roy Johnsen, 2006
- Study programme, Materials technology: Professor Otto Lohne

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Professor Bjørn Hafskjold is the director of the Materials strategic area at NTNU. Photo: Gorm Kallestad, Scanpix/NTNU Info



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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