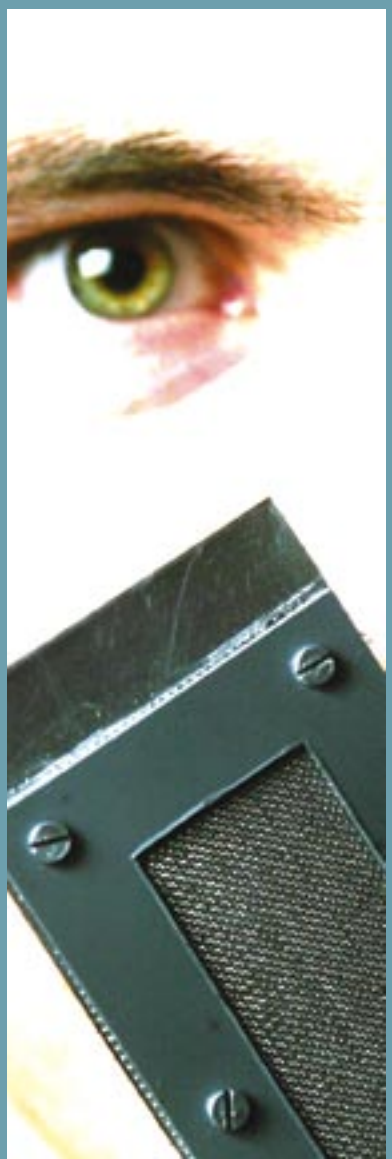
NTNU

# Annual Report 2003

## The Strategic Area Materials

## NTNU Norwegian University of Science and Technology



# What are the Strategic Areas at NTNU?

One of the main goals of NTNU is to be useful to society, by developing and maintaining the national technological skills needed to build a sustainable society.

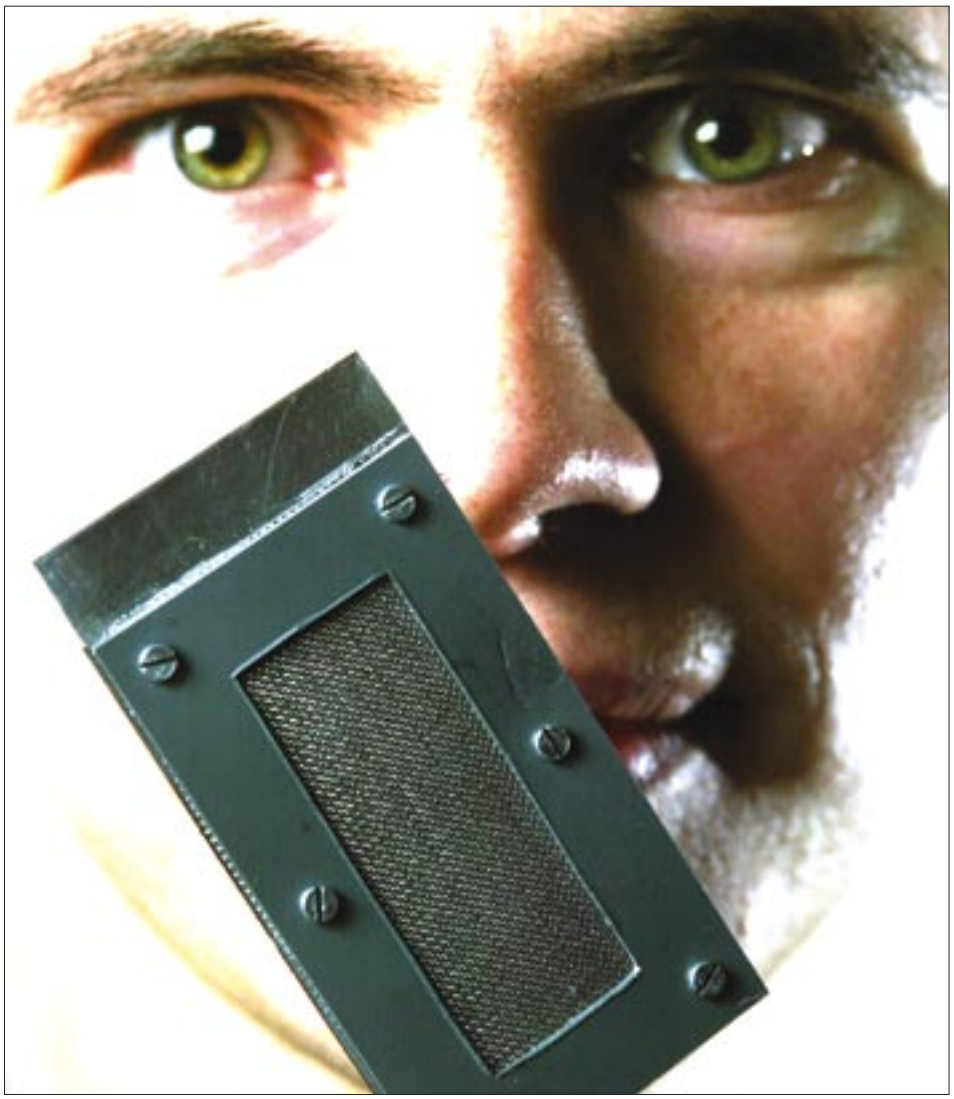
To realize this goal NTNU has given priority to five strategic areas where we desire to be among the internationally leading universities. These are Energy and Environment, Information and Communication Technology (ICT), Marine and Maritime Technology, Materials, and Medical Technology.

## About Materials at NTNU

The recent explosive growth in computer, medical and environmental technology would not be possible without the concurrent development of new materials.

Materials science in Norway has for many years focused on structural materials, because of their importance to the metallurgical and oil and gas industries. Light metals production has a long tradition in Norway because of access to low-cost hydroelectric power. Today, Materials Technology at NTNU includes a wide variety of disciplines, including functional materials, soft materials, light metals and advanced construction using materials such as concrete, steel, aluminium and wood. Over the years, NTNU has developed strong research groups covering all these areas.

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



*Trygve Burchhardt, SINTEF Materials Technology. Fuel cell battery.*

# Research highlights

The main activities have been divided among four areas: Light metals, Functional materials, Polymers and composites and Structural integrity. Within these subjects, two focus areas have been defined: Light metals and functional oxides. Polymers and composites are also being given special attention.

**The research agenda for Light metals is both broad and deep. Some examples are:**

- An enhanced understanding of phase transformations in advanced, new alloys (Al with Sc, Hf, etc.).
- New nano-scaled microstructures (100–300 nm grain size) are formed in commercial Al alloys. The mechanical strength of the modified alloy is doubled while the original ductility is maintained.
- Further enhancements of mathematical models for recrystallization, grain growth and plastic deformation as tools for prediction of material properties after processing of Al alloys.
- Development of a first-generation Al alloy with high temperature fatigue resistance (up to 180°C).
- Increased knowledge and insight into innovative techniques for metal forming and joining.
- High pressure die-casting of aluminium and magnesium alloys, with a focus on microstructure development and how it is affected by alterations of thermal and constitutional solidification conditions.

**Some results from our silicon-for-solar-cell activity include:**

- Establishment of a clean room laboratory for the casting of multicrystalline pure silicon for solar cell wafers.
- Competence in the characterisation of microstructure of silicon wafers (e.g. dislocation density over small and large areas, grain orientation and texture).
- Modelling the effect of dislocations and various types of grain boundaries on the lifetime of minority carriers. The results are comparable to the measured efficiency of solar cells made from wafers from neighbouring areas.

**The main functional materials** for the current research activities at NTNU are those based on transition metal oxides, most of them with a perovskite-related structure. Of particular importance in the last year was the discovery of new ferroelastic materials within the perovskite family, and progress in experimental studies of the finite size effect on the ferroelastic properties of epitaxial thin films and heterostructures. The physics group working on the theory of strongly correlated systems and nanotechnology is well recognised worldwide. Other important research topics in 2003 have been synchrotron X-ray diffraction studies of semiconducting polymers and production of carbon nanofibers.

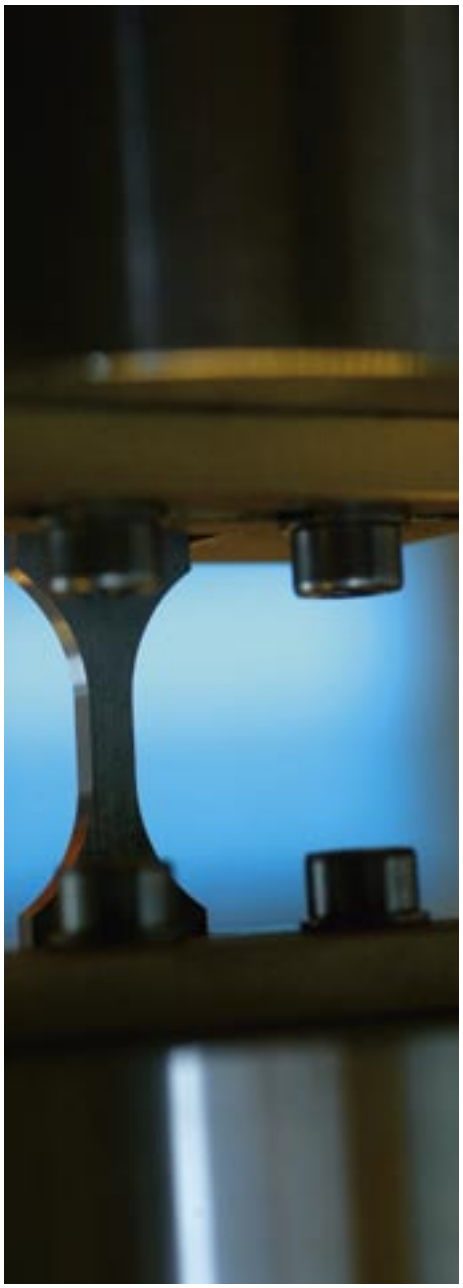


*The flying wing runs on solar power, NASA photo.*

# Focus areas

## Light metals

Aluminium and to a lesser extent magnesium alloy technology has dominated our research activities in the last 10–20 years. This technology includes electrolysis, alloy development, phase transformations, microstructure versus properties, electrochemical characterisation, process technology and modelling. All of these activities have close links to industrial R&D – essentially on the processing side, but with a gradual shift towards product manufacturing and design. In recent years, research related to silicon alloys has increased, with in-depth interest in solar cell and energy technology.



*Material testing.*

Within this area there has been a considerable amount of externally financed work. The main contributors have been the Research Council of Norway and the Norwegian light metal industry, by means of several strategic university and institute programmes (SUP and SIP) and quite a few competence projects that involve user participation (KMB). Research groups participated in four projects funded under the EU's Fifth Framework Programme for Research and Technological Development. In the VIR projects, the European aluminium industry, along with leading universities and research institutes, have joined efforts to create a "Through Process Model" for the development of the aluminium microstructure during its production. We aim to maintain our visibility in this area of expertise in the Sixth Framework Programme, with our involvement in the SPROLA and Super-Light-Car projects.

Eight KMB projects make up the key area of Processing and Use of Light Metals, in a programme known as NorLight. If the necessary strategic efforts are conducted, the Norwegian light metals industry ought to be able to increase its turnover from roughly 3.5 billion NOK in 1999 to some 10 billion NOK in 2010, with a concomitant increase in the number of people employed in this industry. Such a rate of growth requires a significant development of competence and a major research effort. The projects fall within these high-priority light metal R&D areas: shaping, surface science, behaviour of structures, and design for fabrication and casting. The Norwegian light metals industry already stands at the cutting edge in these areas, giving it the opportunity to be a world leader in the field. The programme will extend from 2001 to 2007. A mid-term evaluation of the projects this year has shown good progress, with results mostly in line with the scientific goals.

The vision for the light metals technology program is to meet the future demands for developing and characterising a new generation of materials based on recycled metal.

## Functional materials

During the last decade, activity in ceramic science and engineering has increased with an emphasis on non-oxide ceramics, materials for solid oxide fuel cells and oxygen-permeable membranes. Nanotechnology and materials technology are strategically important fields of scientific research, and both present considerable industrial potential. Nanotechnology includes nanoscience and may be defined as new synthesis and processing techniques, using nature's own building blocks (atoms, molecules or macromolecules) for the intelligent design of functional materials, components and systems with attractive qualities and functions, where dimensions and tolerances from 0.1 to 100 nm play a decisive role.

The NANOMAT programme is an initiative to support basic knowledge, with two priorities:

- To develop new materials, with a focus on functional materials.
- To focus on selected parts of nanotechnology.



*Aluminium alloys have a high energy-absorption capacity being utilized in crash-boxes.*



*An optimum ski base structure can increase the speed of a skier with about 10 % under some snow conditions.*

Research groups within Materials have obtained significant financing through the Research Council of Norway's NANOMAT programme. Support has been given to groups to work with FUNMAT. The FUNMAT consortium for research within functional materials was established in 2002 in order to implement the national research plan. Partners in the projects represent the two largest universities in Norway (UiO and NTNU) and the two largest research institutes (SINTEF and IFE). NTNU is the coordinator for the Oxides for Future ICT programme and contributes strongly to the other FUNMAT projects and the SUP in Nanostructural and soft materials (COMPLEX). Furthermore, research projects in bio-nanocomposites, surface effects (Scientific Design and Preparation of New Catalysts and Supports) and modelling of nanostructures have received support. The total contribution from NANOMAT for research groups at NTNU is 61.5 million NOK for the period 2003–2006.

Additional areas of interest are production of carbon nonofibres and thermodynamics of materials.

## Polymers and composites

It is estimated that plastics and composite materials will make up approximately 50% of the total volume of produced materials in the future. Norway has access to raw material for bulk polymer production and has a viable plastics production industry. There is a need for new innovative products and processing techniques; a major focus should be the control of product microstructure and new products for packaging and biocompatible polymers for medical purposes. Composites are widely used today and are being more frequently used in the offshore industry, such as in ultra deep-water developments. Knowledge about composites will be critical for competitiveness in selling equipment to the offshore industry. Renewable raw materials for polymers and composites also represents an important international research field for sustainable development.

In addition to the NANOMAT project described earlier, there are several projects that are exploring natural fibre composites, polyloefins and polymer processing. The projects are mainly funded by the Research Council of Norway in combination with industrial contributions and strategic grants from NTNU.

## Interdisciplinary activities

Collaboration with NTNU's strategic area Energy and Environment has been strengthened in 2003. The two strategic areas have jointly financed a demonstration/educational laboratory for materials technology with respect to renewable energy (HySol lab). There is a Materials representative at The Gas Technology Centre. Moreover, research groups within Materials Technology and Energy and Environment are working together on the NANOMAT projects Materials for hydrogen technology and Functional oxides for energy technology.

Solar cell research has been conducted in close collaboration with research groups in the university's Energy and Environment strategic area. The market for silicon for solar cell applications is increasing at a rate of 20–30 % per year, suggesting optimism in the market and strong potential growth. Two KMB projects focus on solar cells, with particular attention given to silicon production routes.

## Incentives

**Materials has supported the following activities as a way to develop new ideas into future projects:**

- Plating of Al alloys in low-melting electrolytes.
- HySol – a laboratory for hydrogen and solar cell technology.
- A research network for SPD processing of nanostructured Al alloys.



*Microstructure of an as-cast aluminium alloy.*

- Nanoscience and nanotechnology: an interfacultary seminar series.
- A strategy seminar on steel applications.
- The 5th Nordic Baltic Scanning Probe Microscopy Workshop.
- An APFIM-investigation of nucleation of dispersoids in aluminium alloys.

## International activities

Materials Technology has provided financial support to Norwegian researchers travelling abroad, visiting foreign researchers at NTNU, seminars, and support for researchers participating in European research projects. Several research groups have been very active, but up until to now, two projects (SFINX and NAPOLY) have been funded under the EU's Sixth Framework Programme Research and Technological Development.

**Funding for international activities has been provided to:**

- "Fundamentals of nano-scale physics", an invited presentation at the NEDO conference in Nagoya, Japan.
- A student exchange with the Warsaw University of Technology.
- Development of cooperation between NIST and NTNU within Scanning Probe techniques.
- Atom probe experiments of early stage precipitation in AlMgSi alloys at the University of Rouen, France.
- Visits at Laboratoire de Mécanique et technologie/Ecole Normale Supérieure de Cachan, Paris, France to establish mathematical models for strain localisation during material failure.
- Studies of crashworthiness at the research centre of Relault in Paris, France.

## Key figures

Research groups at NTNU working on materials-related problems are found in four faculties (NT, IVT, IME and DMF). The staff includes 65 academic positions, 150 PhD students and 40 postdoctoral students. Most scholarships are financed by the Research Council of Norway, often in combination with industrial funding. Some scholarships are provided by NTNU to support strategic areas. In 2003 two PhD students were appointed with internal grants from NTNU.

## Arrangements

The NorLight conference was arranged in January. Representatives from industrial policy groups, industry and commerce, car manufacturers, researchers and entrepreneurs shone light on the technological and social challenges facing the light metals industry. The second day of the conference included 14 contributions from NorLight projects. The conference attracted 170 participants, of which 40 were Master's degree students.

The International Course on Process Metallurgy of Aluminium has been arranged annually for more than 20 years. The biannual International Summer School on Aluminium Technology in Trondheim was organised this year. Both courses attracted more than 100 international participants.

Nanotechnology is rapidly evolving into a major research field worldwide. It brings together disciplines such as electrical engineering, chemistry, physics, biology and materials science. To address technologically relevant questions, a seminar series in the field of nanoscience and nanotechnology has been established. There have been four seminars in 2003 with contributions by high-level international scientists.

A workshop on the areas and interfaces among polymers, polymer composites, soft materials and medical technology was organised. The focus was on nanoscaled materials and related subjects. Among the objectives of the workshop were updates on international trends within these fields. The programme included invited keynote lectures by leading international experts.

# Summary

History shows us that breakthroughs in materials science have always formed the nucleus for the evolution of new technological eras. Materials science has grown out of disciplines such as metallurgy, polymer science, condensed matters chemistry and physics. Materials technology adds value to Norwegian industries, such as the production and processing of metals, primarily aluminium, magnesium, silicon and ferroalloys, as well as other materials. But if these industries are to grow, they need to be able to innovate. A clear example is the way semiconductors and optical fibres form the basis for all modern information and communication technology. "Functional materials" is a collective term that describes materials used for functional purposes (e.g. electrical, dielectrical, optical, magnetic) but not for structural applications. Work with such materials presently dominates international materials science research. Advances in materials science are of major importance for progress in areas like environment, health, communication, transport and consumer goods.

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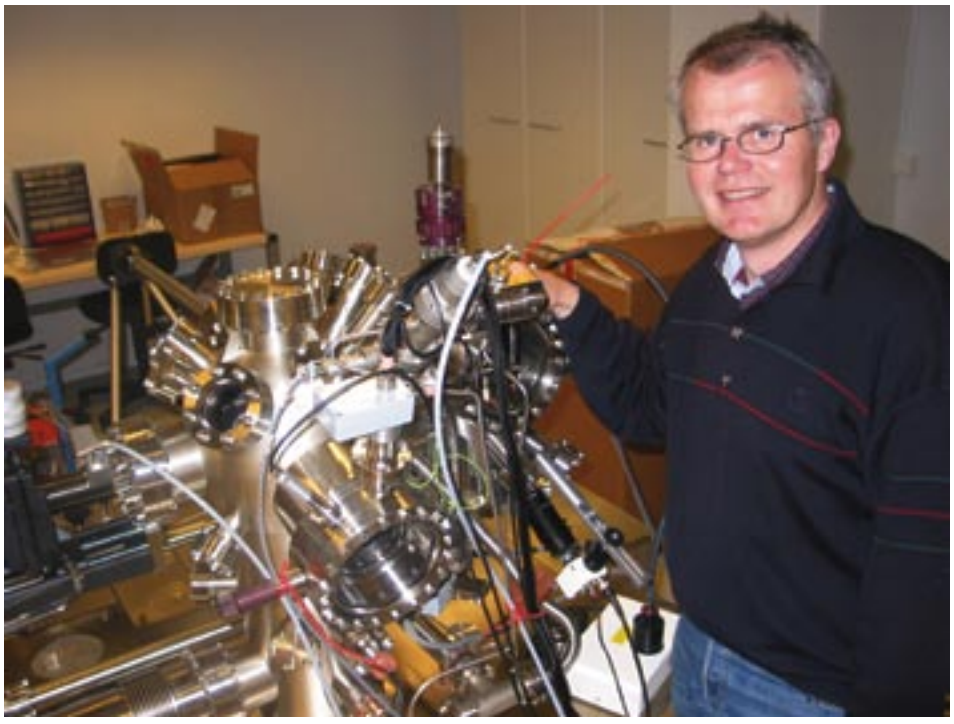
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**NTNU have defined five strategic areas of research. Besides Materials, these are:**

ENERGY & ENVIRONMENT: "Technology for a cleaner future"

NTNU is engaged in improving knowledge about sustainable production and the consumption of energy. Knowledge about new sources of renewable energy and energy carriers is particularly important.

ICT: "NTNU's research within ICT must hold both national and international significance"

Our strategy within ICT is organised according to methods for advanced and creative research. Researchers should have the freedom to do in-depth studies of their research fields. At the same time, NTNU can utilize a wide range of academic and scientific expertise – from physics to philosophy – to develop interdisciplinary products.

MARINE and MARITIME TECHNOLOGY:

This strategic area seeks to strengthen the knowledge required to maintain competitive and sustainable marine and maritime industries. During the last 30 years, aquaculture and the offshore development of petroleum resources have been added as significant activities at NTNU. Almost 250 person-years are devoted to such research at the university.

MEDICAL TECHNOLOGY:

We believe that strategic cooperation between different disciplines will generate innovative ideas and solutions. Hence, there is a close collaboration between researchers working in technology and medicine. The objective of this research is the provision of optimized individual treatment and medication for our patients.

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

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