NTNU – Trondheim
Norwegian University of Science and Technology

NTNU – Innovation and Creativity
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 to fine arts. Cross-disciplinary cooperation results in ideas no one else has thought of, and creative solutions that change our daily lives.

Department of Materials Science and Engineering
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The editor thanks

Brit Wenche Meland, Hilde Martinsen Nordø, Elin Kaasen and Hege Knutsdatter

for collecting the administrative data and taking care of the process of printing the report.

Skipsnes AS for printing.

Annual report for

Department of Materials Science and Engineering
Norwegian University of Science and Technology
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Internet address: http://www.ntnu.edu/mse

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EXTRACURRICULAR ACTIVITIES

Cooperation with SINTEF Petroleum Research. Project meetings and reporting on running projects. A series of meetings during the year at Statolit, Rotvoll and Sjødal, Norway.

Harald A. Bye

Harald A. Bye is Chairman of the Technical Committee, ISO / TC 226 (Materials for the Aluminium Industry).


The Norwegian Academy of Technological Sciences, Oslo, Norway, March 6, 2010. Industrial Council Meeting.


29th International Course on Process Metallurgy of Aluminium, Trondheim, Norway, May 31 - June 4, 2010. Chairman and lecturer on: “The principles of aluminium electrolysis” and “Cathode failure and cell service life for modern cells”.


Non-Ferrous Metals - 2010, Krasnoyarsk, Russia, September 2-4, 2010. Lecture on: “Power failure, temporary pot shutdown, restart and repair”.

Alstadhaug Tingrett, Mosjøen, Norway, October 5-6, 2010. Judge.


Norsk Standard, Oslo, Norway, November 17, 2010. Project meeting, ISO.

Vegar Øygarden

NorFERM symposium, Storaas Gjestegård, Kongsvinger, Norway, April 12-14, 2010. Presentation on: “Symposium on high temperature proton and mixed proton electron conductors for future energy technologies”.


Summer School: Ceramic membranes for green chemical production and clean power generation, Valencia, Spain, September 8-10, 2010.

Picture on front page:

Grey, ferrite-pearlite cast iron – light microscope, polarized light.

Photo: Pål Ulseth.

Brit Wenche Meland, Hilde Martinsen Nordø, Elin Kaasen and Hege Knutsdatter

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The Department of Materials Science and Engineering is at time being a very busy Department with high productivity, both with respect to teaching and research. Many on-going projects and new projects contribute to the new exciting knowledge being created; some of the activities are highlighted in this report. The high productivity gives the Department a good financial basis for investments in new and upgraded equipment and to maintain a high standard of our laboratories. This is only possible by the extraordinary efforts of the employees and students at the Department. The combination of high research and teaching activities is challenging. To improve this situation the Department is working to increase the scientific and the technical staff. Although the Department has taken several measures to reduce the workload, we are still looking at ways to reduce number of courses offered to reduce the teaching workload without sacrifice to the quality of the study program.

The Department has for several years focused on measures to increase the awareness on health, safety and environment (HSE). In the spring of 2010, the Norwegian Labour Inspection Authority (Arbeidstilsynet) conducted an inspection at three departments at NTNU, focusing on safe use of chemicals (“Bedre Kjemi”). Department of Materials Science and Engineering was given credit for having good standards and above the two other departments. Still, we have room for improvements and the Department is continuously working to improve routines and measures that will improve the safety in our laboratories. An important factor in the success of these efforts is the continuous focus from all employees and especially the dedicated efforts by our HSE coordinator.

The Department is strongly involved in study programs and research activities in important strategic areas at NTNU: Materials, Nanotechnology and Energy Technology. In 2010, two of our scientific members were assigned leadership roles. Professor Hans Jørgen Roven was reappointed as leader of the strategic area Materials after returning from sabbatical. Associate Professor Gabriella Tranell was appointed as leader of the Centre for Renewable Energy (SFFE). This is a virtual centre under the strategic area Energy and Petroleum – Resources and Environment, and has a coordination and consulting function for the education and research groups within renewable energy at NTNU, SINTEF and IFE. The SFFE-network at NTNU, SINTEF and IFE involves around 200 scientific staff members and 50 PhD students.

Excellent student recruitment to our programs continued in 2010. For the PhD grants we continue to recruit at a high level with a good balance between Norwegian and foreign students. Together with our scientific staff, the PhD students and post docs are key players in creating new and advanced knowledge for the benefit of the society. In 2010, all our course descriptions were revised to make them more specific on learning outcome. This was done in combination with describing the overall learning outcome of the different study programs the Department is involved in. The result is that the students more clearly see what they are expected to master after each course. It is also hoped that this will be helpful knowledge for those recruiting our students.

The Department operates a large variety of laboratories. Many of the laboratories are operated in cooperation with SINTEF, our strongest research partner. We also operate several state of the art instruments were we serve other departments at NTNU as well as external research partners. Besides the established electron microscopy laboratory, the powder X-Ray Diffraction (XRD) laboratory has been developed to a high standard with approximately 100 active users. This has been possible by an excellent training program for new users and the high level of support offered to users.

The process to establish a new laboratory research infrastructure (Solbygg), mainly for the expanding research on solar cells, came more or less to stagnation in 2010, when it was decided that a sub-surface survey was needed to establish better knowledge of the stability of the building site. Since the financing of a complete “Solbygg” in line with the
initial plans seems to be difficult to achieve in the short term, it was decided to build a crystal puller laboratory inside the existing smelter laboratory. The new laboratory is to be finished in spring 2011.

In 2010 the Department got one new Associate Professor when Marisa Di Sabatino Lundberg started at the Department in June. Her field is solar cell materials. The Department has also got accept for advertising one new and one replacement scientific position. The hiring process will take place in 2011. This is good news for a department with capacity constraints in many teaching and research areas. We are also in the process of finding a replacement for Senior Engineer Jan Arve Baatnes who suddenly passed away in February. The Department took over some of the personnel duties regarding the PhD positions from the Faculty in 2010. As a consequence, Hilde Martinsen Nordøy is now in charge of the human resources management at the Department, working in close collaboration with the HR section at the Faculty.

Also in 2010 members of the Department were recognized for extraordinary contributions. Professor Otto Lohne received the “Elkem forskningsfonds Innovasjonspris for 2010” (Elkem Research Fund Innovation Price for 2010). He was recognized for his contribution in developing research and education on silicon solar cell materials. Professor Georg Hagen received, post mortem, Elkem’s honorary price for his pioneering contributions to the Norwegian solar cell research. Elin Harboe Albertsen received NTNU’s Working Environment Price for 2010 for her commitment to improve routines and awareness of HSE. Through dedication and creativity she has worked to improve working conditions for students, employees and guests at the Department. Sverre Magnus Selbach got the prize for best PhD thesis at the Faculty of Natural Science and Technology at NTNU in the academic year 2009/2010. Professor Jan Ketil Solberg got the prize for “Best teamplayer 2010” at the Faculty of Natural Science and Technology. This year we also want to recognize the Friday seminars organized by Professor emeritus Reidar Tunold. He has been central in organizing these seminars and has contributed strongly to make all our employees at the Department more aware of all the interesting and exciting research taking place at the Department.

Over the years the Department is involved in the organisation of many international courses, seminar and conferences. In June 2010 the Electroceramics XII was arranged in Trondheim with Professor Tor Grande as chairman. Several members of the Department participated in the organization committee and the Inorganic Materials and Ceramic Research Group did an excellent contribution in make the conference arrangement a success.

The annual report has the same outline as previous years. The first part comprises short reports on some of the current research in the four research groups at the Department, the annual list of publications in scientific journals and conference proceedings and the laboratory infrastructure. This is intended to give external readers an impression of the research being performed. The second part, which comprises an overview of the staff, current and completed Master-and PhD-students and extracurricular activities at the Department, is presenting a comprehensive overview of our annual activity and is more intended for the archives.

Finally we would like to acknowledge the scientific staff for their contribution to this report. In particular we would like to acknowledge Secretary Hege Knutsdatter Johnsen and other members of the administrative staff for their efforts.
Senior Engineer Jan Arve Baatnes died unexpectedly on February 7, 2010.

Jan Arve Baatnes, born August 21, 1951, was hired as a mechanic in 1974. Prior to this he served an apprenticeship at SINTEF Metallurgy beginning in the autumn of 1967. Whilst there Jan Arve made a good impression on his colleagues, and during the school year 1968/69 he was granted leave to complete “Yrkesskolens linje for mekanikere”.

In addition to this, his apprenticeship included 35 months of formal training which concluded with a 3-day practical and theoretical test supervised by a specially appointed examination board. Topics in the training included: sampling, aim and sedimentation analysis, chemical and metallurgical laboratory work, refractory materials, construction equipment, instrumentation and additional theoretical training. He completed his military service in 1972/73, after which he continued in his position.

Through many years in his position at the Department, Jan Arve Baatnes contributed greatly to the metallurgical community both at Sintef and NTNU. He was well liked by both students and staff and will be remembered as a friendly colleague who was always willing to help others. For novice students he was an invaluable resource, and he helped greatly to improve the quality of countless doctoral dissertations and student reports.

Jan Arve Baatnes is strongly missed by colleagues and students.
1. The Department of Materials Science and Engineering organized, together with TU Bergakademie Freiberg, the 3rd Norwegian-German group seminar on Solar Cell materials. This is the third time this seminar is organized, and this year it was held at NTNU on October 4-6, 2010. The program of the seminar included two full days with 20 oral presentations and a visit to the Elkem Thamshavn plant in Orkanger. This event was attended by 33 participants from Freiberg, NTNU and SINTEF.

2. In May 2010, NTNU signed a collaborative agreement with Shanghai Jiao Tong University (SJTU) in Shanghai, China. As a continuation of this agreement, NTNU, SINTEF, SJTU and the Norwegian company Predictor and Chinese company Solar Fun signed a “5-party” collaboration agreement in the solar materials research area at a joint workshop held in Shanghai, October 21-22, 2010. In addition to the partner participants, Dr. Kari Kveseth, Science Counselor at the Norwegian Embassy in Beijing attended the meeting. As a part of the collaboration between NTNU and SJTU, a M.Sc. student from SJTU will take up PhD studies with the Department of Materials Science and Engineering at NTNU in spring 2011.

Marisa Di Sabatino and Gabriella Tranell

International EM related workshops

1. The Electron Microscope Laboratory (EM-lab) at DMSE arranged together with EDAX/TSL the 6th NTNU EBSD international workshop in Trondheim May 31 - June 2, 2010. This EBSD workshop brought together 23 participants from 10 countries.

2. EM-lab at DMSE arranged an international EDS workshop together with Bruker AXS Nordic in Trondheim, March 11-13, 2010. The workshop was attended by 28 participants from 6 countries.

Jarle Hjelen

Participants at the EBSD international workshop May 31 - June 2, 2010.
International courses on aluminium production

Institute of Inorganic Chemistry, later Department of Materials Science and Engineering has a long tradition to give international courses on aluminium electrolysis.

The participation was very low in 2009 as the aluminium price fell with more than 50%. International smelters would not allow their staff to travel to courses, but in 2010 the participation was back to normal as seen from the pictures.

Harald A. Øye

In 1994 the course “Fundamentals of Aluminium Production” was started and it was arranged in May 18-28, 2010 for the 16th time with 54 participants. This course was attended by totally 478 participants from 36 countries.

The “29th International Course on Process Metallurgy of Aluminium” was arranged in Trondheim May 31 – June 4, 2010 with 75 participants. Totally 2523 participants from 56 countries have attended the course throughout the years.

A new initiative was a course on “Innovation and Management for Aluminium Technology”, arranged through NTNU’s Department of Continuing Education and Professional Development on November 8 - 12, 2010. The participants were 13 executive directors from RUSAL, Russia’s aluminium producer. Oral presentations and written materials were both in English and Russian.
Over the last two decades “electroceramics” have become established as one of the most important research areas in materials science both through improvements in basic knowledge and their significant technological impact. The series of Electroceramics meetings have become an important forum to discuss recent advances and emerging trends in this developing field. The Inorganic Materials and Ceramic Research group at the Department was selected at the Electroceramics XI in Manchester 2008 to be the organizers of the next conference in this conference series, and Electroceramics XII was arranged in Trondheim in the period June 13-16, 2010.

The scope of Electroceramics XII was to allow the participants to present the most recent results and to exchange ideas on the advancement in the research development and applications of electroceramics in the following areas:
• Ceramic processing and basic science
• Thin films and interfaces
• Modelling
• Dielectric, ferroelectric, piezoelectric and pyroelectric materials
• Multiferroic, magnetic, semiconducting and superconducting materials
• Ionic, electronic and mixed conductors, fuel cells, photocatalysis
• Sensors, actuators and energy harvesting materials
• Varistors and thermostors

At the deadline for submission of abstracts, December 15, 2009, 477 papers were submitted. The final program included 3 Key-Note lectures, 16 invited speakers, 160 oral presentations and 240 poster presentations. The program was organised in 23 separate sessions. In total 319 delegates attended the conference. The delegates came from in total 33 different nations across 5 different continents. There was also an exhibition in parallel with the conferences presenting 6 sponsors. The social program consisted of a reception in RealFagbygget, a guided tour and reception at Ringve Museum, a conference banquet at Rica Nidelven Hotel and finally a concert in Nidaros cathedral.

The Key-Note lectures at Electroceramics XII: Professor Tadashi Takenaka, Tokyo University of Science, Japan, Professor Jean-Marie Tarascon, Université de Picardie Jules Verne CNRS, France, Professor Nicola Spaldin, University of Santa Barbara, USA (present at ETH Zürich, Switzerland).
The Key-Note lectures were given by Professor Tadashi Takenaka, Tokyo University of Science, Japan, on Lead-free ferroelectrics, Professor Jean-Marie Tarascon, Université de Picardie Jules Verne CNRS, France, on Lithium batteries and Nicola Spaldin, University of Santa Barbara, USA, on Multiferroics.

The local organization committee included Professor Tor Grande, which was the chairman of the conference, Professor Mari-Ann Einarsrud, Professor Kjell Wiik, Postdoc Sverre M. Selbach and Postdoc Per-Martin Rørvik from the Department, Professor Thomas Tybell from the Department of Electronics and Telecommunications, NTNU, Professor Truls Norby from the University of Oslo and Research Scientist Henrik Ræder and Research Director Rune Bredesen from SINTEF Materials and Chemistry.

All the group members of the Inorganic Materials and Ceramic Research Group spent a tremendous effort during the conference. The program and all the sessions were arranged smoothly without serious obstacles. We acknowledge financial support from TSO Materials at NTNU and the professional assistance from NTNU Videre to arrange the conference and take care of all the practicalities with the registration and the accommodation.

Tor Grande
Norway is one of the world’s leading producers of metallurgic silicon (Mg-Si), most of it being refined for sale to the electronic or chemical market or as alloying elements to Al. NTNU and SINTEF have been research and education partners of the Norwegian metallurgical industry for decades. The research and education covers the value chain for production of solar grade silicon (SoG-Si) from quartz and carbon to silicon wafers, with focus on raw materials, furnace technology, refining and casting.

The summer school on SoG-Si was arranged by NTNU for the first time in June 2010, and focused on the fundamental knowledge and theory of metallurgical silicon production and refining of metallurgical silicon to reach solar grade purity. An introduction to the quality requirements on silicon for wafer and solar cell production was given.

We believe that sustainable growth of the photovoltaic (PV) market requires that the future silicon for solar cells must come directly from a metallurgical process. This view is shared by many and new routes for Si production and refining are being developed. Among the new routes for the production of solar grade silicon, the upgraded metallurgical silicon is one of the good alternatives to replace the feedstock produced by the Siemens process. Many of the new routes consist of several steps.

The intention of this course was to give an overview and understanding of the process for Si production and the new refining processes that are emerging and to give some tools to optimize and develop new routes for production of solar grade silicon. The interest was high, and the limit of 50 participants was met within a short time. The participants came from 6 countries and 3 continents.

Lecturers
Associate Professor Rune B. Larsen, NTNU.
Associate Professor Marisa Di Sabatino, NTNU.
Dr. Julien Degoulange, Apollon Solar.
Dr. Harry Rong, Director Product Development and Innovations, Elkem Silicon Materials.
Associate Professor Gudrun Sævarsdottir, Reykjavik University.
Professor Merete Tangstad, NTNU.
Associate Professor Gabriella Tranell, NTNU.
Adjunct Professor Halvard Tveit, NTNU/Elkem.
Adjunct Associate Professor Eivind Øvrelid, NTNU/ SINTEF.
The current energy system in the world to a large extent relies on combustion of fossil fuels. This represents a major resource problem and is also forecasted to have a severe impact on world ecology through e.g. climate changes. Electrochemical technology and science is highly relevant for solving these problems, and electrochemical energy conversion and storage will remain an indispensable part of an alternative energy system, one that is inherently more sustainable and environmentally friendly than the current.

The Electrochemical Energy Group at the Materials Science and Engineering Department at NTNU works in research dedicated to energy conversion in fuel cells and hydrogen storage by water electrolysis, as well as battery research. One research interest is to limit CO poisoning of fuel cell catalyst and to solve the related problem of developing anode catalyst for Direct Methanol Fuel Cell (DMFC), among other things. This is pursued through the projects "Carbon-supported core-shell electrocatalysts for oxidation of small organic molecules", and "High temperature PEM fuel cells operating with organic fuels" funded by the Research Council of Norway [RCN] through the NANOMAT and RENERGI programs, respectively.

Bimetallic surfaces have since long time been known for their catalytic activity and selectivity, which often exceeds that of the individual components and have thus a wide range applications. Some platinum alloys show a better CO tolerance and stability in compare with pure platinum. In order to optimize the catalytic activity both the composition and architecture of the catalysts nanoparticle must be controlled. The ability to produce multi-component nanoparticles with optimized structures for other, selective or multifunctional reactions is expected to play a critical role in new energy conversion technologies. Monometallic, heterodimer, alloy and core-shell nanoparticles are examples of such structures.

There are still significant unknowns in the mechanisms of oxidation of CO and small organic molecules, in particular as the balance between the so-called bifunctionality and pure electronic effects are concerned, as well as in metal-support interactions. The core-shell project aims inter alia at contributing to their discrimination, and is expected to lead to highly original results and fundamental insights relevant for the design of electrocatalyst for direct oxidation of methanol and other small organic molecules.

The production of a nanoscale core-shell system, and their characterization, are challenging tasks. Professor

Figure 1:
Contributions to the CO-stripping mechanism: The ligand effect is illustrated to the left, the bifunctional effect in the middle one, and the process at a pure Pt catalyst is illustrated to the right. The potential at which the processes occur are indicated below the figures, the "?"V obtained for the ligand effect is currently being determined in the core-shell project.
Eichhorn’s group at the University of Maryland, USA, with which the NTNU group collaborates, has prosperously established synthesis procedure of the Ru@Pt core-shell nanoparticles. The structure is comprised of essentially metallic, crystallographically disordered Ru cores with thin, 1-2 monolayer Pt shells.

A physicochemical as well as an electrochemical characterization of the produced material has been performed, and the structure’s identity has been confirmed. This successful synthesis implementation allowed performing further and advanced electrochemical characterization of the novel electrocatalyst. We have thus recently verified that the homogeneity of the samples are such as to allow interpretation in terms of isolating the ligand effect from the bifunctional, and shown the former is a dominating one in terms of the oxidation potential for CO at these core-shell catalysts.

This type of synthesis and control of bimetallic nanocatalyst architecture is crucial for knowledge in mechanistic evaluation / rational advance of heterogeneous catalytic transformations. From a practical point of view, the work may lead to new and more efficient catalysts for fuel cells anodes and other areas of applications.

As a result of collaboration with the University of Maryland the whole synthesis procedure was entirely and successfully adopted in the Chemical Area in NTNU’s NanoLab, and subsequent characterisation performed in the laboratories at the Materials Science and Engineering Department at NTNU. The Ru@Pt 1:1 core-shell nanoparticles were synthesized by using a sequential polyol process. Ru(acac)$_3$ (acac = acetylacetone) was initially reduced in refluxing ethylene glycol (EG) in the presence of polyvinylpyrrolidone (PVP) stabilizers (MW = 55000). The resulting Ru cores were subsequently coated with Pt by adding PtCl$_2$ to the Ru/EG colloid and heating to 200 °C. This work is also done in collaboration with the Chemical Engineering Department at NTNU.

![Figure 2: Model of the Ru@Pt core-shell structure.](Photo: Piotr Ochal)

![Figure 3: STEM-EDS line spectra of 4.5 nm obtained Ru@Pt (1:1) NP. Relative atomic % composition values (vertical axis) of Pt (red) and Ru (blue) are plotted against the line scan probe position (horizontal axis) and are given next to the STEM images.](Photo: Piotr Ochal and Svein Sunde)

Piotr Ochal, José Luis Gomez de la Fuente, Mikhail Tsypkin, Dmitry Bokach, Frode Seland, Reidar Tunold, Navaneethan Mutthuswamy (Chemical Engineering, NTNU), Magnus Renning (Chemical Engineering, NTNU), De Chen (Chemical Engineering, NTNU) and Svein Sunde
**Figure 4:**
PhD student Piotr Ochal and Dr. José Luis Gómez de la Fuente performing electrochemical characterization of a core-shell catalyst.
High temperature PEM water electrolysis for the hydrogen economy

Water electrolysis (WE) is the process of splitting water into hydrogen and oxygen by applying a potential between two electrodes. WE has been an important industrial process in Norway in connection with the manufacture of fertilizers. At the present there is a renewed interest in WE in conjunction with a future energy society that does not depend on fossil fuels. A method of storing and transporting vast amounts of energy is needed. Converting excess electricity to hydrogen is one option. This can, at the moment, only be done by WE. A different possible use of large quantities of hydrogen is a methanol based economy. Hydrogen and carbon dioxide can be converted to methanol and used as a fuel. The Electrochemical energy technology group has been working on both fundamental and practical aspects of WE for several years.

The traditional method of WE is the alkaline electrolyser that uses a strong alkaline electrolyte and steel or nickel electrodes. A more recent method is the polymer electrolyte membrane (PEM) WE. It has several advantages compared to the traditional method. These include: More compact size, higher current densities, no need to pump a corrosive electrolyte through the system and purer products. Because of the acidic environment in PEM WE platinum is used as the cathode catalyst, whilst noble metal oxides, typically iridium oxide based, are used on the anode. Increasing the temperature of a PEM WE from 80 °C, as is normal for both alkaline and PEM WE, to a temperature above 100 °C gives additional benefits such as an improved heat balance that reduces the need for a cooling system, improved kinetics and a decrease in the overall energy requirement for hydrogen production. Solid oxide fuel cells (SOFC) operate at an even higher temperature, often in the range of 500–1000 °C. The materials challenges have, for the time being, prevented the commercialisation of SOFC.

Increasing the temperature of PEM WE gives several material challenges. The catalysts must withstand higher temperatures without corroding or agglomerating, the construction materials must be stable and the polymer electrolyte must retain sufficient conductivity and mechanical strength for the task. We focus on the catalyst and the membrane in our research.

At temperatures below 100 °C Nafion membranes are the typical choice. However, they loose their mechanical properties and to some extent their conductivity at temperatures above 100 °C. The usual replacement is a polybenzimidazole (PBI) membrane. Unfortunately the PBI membrane needs to be doped with phosphoric acid to achieve the required conductivity. This is problematic as phosphates are known to adsorb strongly on oxides. If the catalyst surface is blocked by adsorbed phosphate species the rate of the oxygen evolution reaction (OER) will be slower, and the overall efficiency of the WE will be lower.

We conducted a screening study to test the effect of different electrolytes on the OER on iridium oxide. As a model system we used anodically formed iridium oxide films and liquid electrolytes. 0.1, 0.5, 1 and 2 M solutions of phosphoric acid, sulphuric acid and perchloric acid were used as the electrolyte. The temperature range for the experiments was from 0 °C to 150 °C (the measurements above 100 °C were conducted in a glass autoclave). The polarisation curves in Figure 1 show that the oxygen evolution reaction is significantly slower in phosphoric acid at all temperatures. Chang-

Figure 1: The oxygen evolution reaction on AIROF in various 0.5 M electrolytes at 25 °C and 80 °C.
ing the temperature does not alter this picture. The practical implication of this is that it is important to check if increasing the temperature actually improves the overall efficiency of the system under study. In addition the experiments show that the anion affects the structure of the catalyst. The oxide film is more open to penetration by water and ions in phosphate solutions than in sulphate or perchlorate solutions.

The stability of both catalysts and the system as a whole is best studied in conditions as close to the actual operating conditions as possible. The test station, see Figure 2, can be used to test both PEM WE and fuel cells at temperatures up to 150 °C and pressures up to 15 bar. We have done extensive testing of oxide catalysts for WE in the test station.

Mixed oxide catalyst, such as iridium-manganese, iridium-tantalum or iridium-ruthenium oxide, can have a higher catalytic activity than pure iridium oxide. In addition the amount of noble metals in the catalyst can be reduced. Adding ruthenium oxide, in itself an excellent catalyst for the OER, does indeed increase the catalytic activity of the catalyst. On the other hand manganese and tantalum only work as diluents. The problem with the mixed catalysts is that the stability is not good enough. The activity quickly declines; after six hours the activity is halved and after 100 h the activity is less than 20 % of the initial activity. For practical applications the mixed catalysts are not stable enough.

Decreasing the catalyst particle size gives a higher surface area per mass of catalyst. However the stability of catalysts decreases with decreasing particle size. To test this we prepared a range of catalysts with grain sizes from 3 nm to 6 nm in diameter. There was indeed an inverse relation between the size and the stability of the catalyst. The catalysts with the smallest sizes lost over 80 % of their initial activity over a period of 100 h. The catalysts with the larger sizes did have a lower initial activity; however they remained stable over the 100 h test period. The optimum catalysts size, with respect to both the activity and the stability, is in the 5–6 nm range for the iridium oxide catalysts produced here.

To determine the size of the pure iridium oxide catalysts for the stability study we used both XRD and electrochemical methods. The diffraction data and the electrochemical measurements give approximately the same result for particles with diameter over 4 nm. For the smaller sizes the diffraction data is not reliable, however the electrochemical techniques can still be used.

This project was funded by the European Commission through the 7th Framework Programme and by NTNU.

Lars-Erik Owe, Mikhail Tsypkin and Svein Sunde
Impedance analysis of porous electrodes in electrochemical systems

Electrochemical impedance spectroscopy (EIS) is a technique for the characterisation of electrochemical systems in which a sinusoidal stimulus (usually the potential) is applied to an electrode. The associated sinusoidal response (the current) is measured both with respect to its amplitude and phase. The impedance is calculated as the ratio of the (complex) voltage to the (complex) current. The experimental impedance is then either used qualitatively or analysed with a model. The models, in turn, may range from equivalent circuits consisting of electrical passive components (resistors, capacitors, inductances and others) or detailed mathematical models based on kinetic and transport equations. Equivalent circuits are not always easy to interpret, and to some extent the ambiguities inherent in the impedance method are more prone to causing problems of interpretation than when relying on explicit mathematical models.

Modelling of porous electrodes, and their impedance in particular, thus play an important role in the interpretation of experimental data. The models initially proposed for simple processes such as double-layer charging and faradaic reaction has later been extended to include transport processes in the electrolyte phase and also intercalation processes in the electrode phase. This is of significance for characterising technologically important systems such as those of metal hydride and Li-ion batteries. Another area of current interest is porous, nanostructured, semiconducting electrodes for applications in photovoltaic cells.

The NTNU group is currently developing impedance models for complex electrode systems and methods based on them for application in a range of the group’s activities, including water electrolysis and intercalation batteries. A recent example is an analytical impedance model for porous intercalation electrodes in which the electrode matrix has mixed ionic and electronic conductivity.

The work is partly done in collaboration with SINTEF, and is funded through various sources including the Research Council of Norway and NTNU.

Svein Sunde, Lars-Erik Owe, Fride Vullum, Carl-Erik Foss and Ann-Mari Svensson (SINTEF)
Degradation of PEM fuel cells

Fuel cells are electrochemical devices that convert the chemical energy in oxygen and a fuel, such as hydrogen, directly to electrical energy without the need for equipment like turbines and generators. Fuel cells are primarily classified according to the membrane employed to separate the cathode and anode, and according to the temperature range as low-temperature (alkaline fuel cells and polymer-electrolyte membrane [PEM] fuel cells – PEMFCs), intermediate temperature (phosphoric acid fuel cells), and high-temperature fuel cells (molten carbonate and solid oxide fuel cells). PEMFCs are particularly attractive for vehicle traction.

Degradation of polymer electrolyte membrane fuel cells (PEMFCs) is one of the main obstacles before the technology is ready for mass market introduction. PEMFCs need to demonstrate lifetimes of several thousands of hours before they will appeal to car owners. High production costs combined with relatively short lifetime therefore results in a total lifetime cost that currently prevents commercialization. Known causes of degradation of a PEMFC include chemical and physical membrane degradation, damage to the cell caused by subfreezing conditions, poisoning by fuel impurities, particle growth or dissolution of the finely dispersed Pt catalyst usually employed, and corrosion of the porous carbon material on which the Pt electrocatalyst is supported. A significant contribution to the overall fuel cell degradation is loss of electrochemically active platinum area from the fuel cell cathode during operation at high potentials. This loss of Pt catalyst area can take place as an Ostwald ripening process where smaller particles are dissolved and redeposited on larger particles, which will lead to the growth of larger particles at the expense of smaller particles. Other mechanisms are coalescence via crystal migration on the carbon surface, detachment of particles from the carbon support or dissolution and subsequent migration of soluble Pt species into the membrane material where it is chemically reduced. An understanding of these phenomena and how to mitigate them is a key factor for increasing the lifetime of PEMFCs.

Knowledge of how different impurities affect PEMFC durability is another prerequisite for optimal selection of materials for PEMFC systems and for determining necessary fuel quality requirements. Chloride is among the contaminants that have been identified in fuel cells during operation and is suggested to originate from impurities in coolants used or de-ionised water. Other origins of chloride impurities can be from operating a fuel cell in a marine environment where chloride will be present or when using co-product hydrogen from the chlor-alkali industry as fuel.

The electrochemical energy group at NTNU collaborates with SINTEF in studies of PEMFC degradation. In this project the purpose was to demonstrate the application of employing an electrochemical quartz balance (EQCM) to study the degradation of a carbon-supported platinum PEMFC catalysts exposed to small amounts of chloride in an electrochemical cell (Fig. 1). So far such degradation studies have been applied to smooth Pt electrodes only, purporting to emulate the real, supported catalyst. Our results showed, however, that significant quantitative error will appear in terms of degradation rates if measurements based on such smooth platinized platinum electrodes are used to predict the degradation rates of the real catalyst. The project also established EQCM as a method for performing EQCM measurements on real electrocatalysts.

The degradation activity has been funded by the Research Council of Norway, partly through the Nordic Council of Ministers (N-INNER programme), and NTNU.

Axel Ofstad, José Luis Gomez de la Fuente, Frode Seland, Steffen Møller-Holst [SINTEF], Magnus Thomassen [SINTEF], Mahdi Darab and Svein Sunde
One of the main environmental and economical challenges facing the metallurgical industry is fugitive emissions of both materials and energy. A recent example is the metal/mineral producing companies Celsa, Fesil and SMA Minerals in the Mo i Rana industrial park, which were placed under strict control from the Norwegian environmental authorities (SFT) between March 8 and June 6, 2007, due to increased dust emissions to air with unknown origin. These companies were enforced to reduce production by a total of 20% on days with high measured aerial dust concentrations, until the cause and origin of the increased emissions were clarified. In addition to the environmental effects of the dust emissions on the community, the economic effects for the companies in terms of lost production were significant.

The process industry in Norway is generally subjected to an extensive regulation that describes the relationship between the emissions from the plants and their effect on the community. Stricter emission regulations will however only be effective if an understanding of the mechanisms of fugitive emission generation exists and is coupled with new technical solutions to measure emissions and deal with the related process problems. Hence, innovation in terms of both process operation and equipment design aimed at reducing and/or capturing emissions, as well as techniques and tools for measuring the emissions, are crucial.

In the competence project (KMB) “FUME” – a partnership between SINTEF, NTNU and the Norwegian Ferroalloys Industry, and co-funded by the Norwegian Research Council, the primary objective is to develop in-depth competence in the area of fugitive emissions of materials (gas, dust/particles etc) to internal and external environment and energy (both low and high temperature) – in the Norwegian ferroalloys industry. The acquired competence will be applied to reduce emissions:

- through direct process improvements based on a fundamental understanding of emission generation mechanisms.
- through improvement of equipment for emission reduction and capture with respect to the working environment.
- and to better utilise low- and high temperature waste energy in integrated process solutions (district household heating, fish farming, bio-refineries etc).

The emissions from a ferroalloys plant may be grouped into fugitive or directed/concentrated emissions. Directed emissions are for example emissions from a stack, i.e. from a limited area where it is reasonably easy to establish strategies for emission reductions. Fugitive emissions on the other hand are less defined and emitted over larger areas. These emissions may be particles from dust/soot, aerosols (liquid droplets and gases) or steam. Examples of fugitive emissions from the ferroalloys industry are; dusting from handling of raw materials (transport, weighing, charging), smoke from the furnace during charging and tapping, and dust emissions during product handling (liquid metal/slag, crushing, and packaging).

Recent industrial measurement campaigns carried out in the project have successfully correlated NO$_x$ formation to SiO gassing and oxidation. The rate of silicon oxidation during metal refining - one of the main contributors to plant dust formation - has also been quantified and correlated to oxygen access to the liquid silicon surface.
Photo of the top of a ladle with silicon being refined, showing the dynamic nature of the silicon surface and the air above.

SEM-image of collected fume from the refining, 50 k magnification.
Quasi Natural Consolidation (QNC) is an environmentally friendly technology for water proofing of tunnels and sand stabilization of loose oil field reservoirs prone for sand production during oil recovery. A critical step in the technology is under patent protection both in Norway and internationally by Temasi AS with Terje Østvold as inventor. This technology has been qualified for the Gullfaks Field through laboratory core testing by Terje Østvold and Statoil. A meeting was held between the Gullfaks asset, Terje Østvold and M-I SWACO in August 2009 to discuss the execution of a field trial in well C-15. A 19 meter vertical section of this well having a perforated liner in a homogenous sand pack was selected for treatment due to its non-complex completion nature.

Until recently the technology had only been tested in the lab, but in October last year the method was applied in this well. Two consolidation treatments were bull headed into the formation with a 20 hrs curing period between the 1st and 2nd treatment and the active components were pre-mixed chemical solutions that were blended during the pumping sequence.

Each of the treatments consisted of:
1. A calcium nitrate and urea water solution of equal Ca\(^{2+}\) and urea concentrations (0.83 mole/l) having a volume of 34 m\(^3\).
2. Urease catalyst (20 g/l) water solution (Temasi catalyst) with a volume of 4 m\(^3\).

See the photo for preparation of solutions before shipment to platform. After mixing and pumping these fluids after preflush to clean up and cool the near well bore reservoir, 5500 kg CaCO\(_3\) had precipitated in a volume of 150 m\(^3\) of the near well bore region reaching 1.6 m from the well centre. A reduction of 2.8 vol% of the free volume in between the sand grains was now occupied by the precipitated CaCO\(_3\).

The method worked, and no sand production was observed after treatment, but due to a pressure decline in the reservoir it was not possible to increase well production to water and oil rates higher than before the treatment. Time will show if a slow dissolution of the precipitated CaCO\(_3\) will enhance well production.

Terje Østvold

Photo: Leif Olav Jerang / NTNU

Preparing solutions for sand consolidation on Gullfaks well C15 at Coast Center Base AS, Ågotnes, Sotra.
A technique for in-situ high resolution imaging of solidification microstructures by synchrotron X-radiation has been developed in a cooperation between NTNU and SINTEF over a period of about 10 years.

This technique has been used to study dendritic and eutectic growth of aluminium alloys. One of the potential applications of the images is validation of dendrite growth models. The first step to do this is to develop a model that accurately simulates the development of the dendritic structure in the experiment. This has been done in a PhD project in cooperation with University of Iowa, USA. A new meso-scale phase field model has been developed that has been validated against columnar dendritic growth of Al-Cu alloys. Figure 1 shows X-ray images of dendrites compared to the predicted structure development.

**Figure 1:**
Predicted (left) and observed (right) microstructure development in Al-30wt%Cu alloy.
It can be seen that the model accurately predicts the general features of the microstructure including the overgrowth and elimination of one of the four primary dendrite arms. A problem that can severely complicate the modeling work is that convection is sometime present in the experiment. A severe example of this can be seen in Figure 2. The work has resulted in a PhD thesis that was successfully defended in January 2011.

*Figure 2:
Liquid convection in Al-20wt% Cu alloy.*
The structure of dislocation clusters – as revealed by transmission electron microscopy (TEM)

The presence of dislocations in silicon solar cells reduces the conversion of solar energy to electric power. It is therefore an important task to avoid or reduce the formation of dislocations in wafers for solar cells. In multicrystalline silicon cast by unidirectional solidification the density of dislocations is normally low at the bottom but increases towards the top. The number of dislocations does not increase all over a wafer but often in clusters with a very high density. The parts of cells having such clusters will often not produce electric power at all.

When etching polished wafers the dislocations reaching the surface may be seen as etch pits because the etching is faster at the end of a dislocation than in its surroundings. The white dots in Figure 1 are etch pits being about 1 μm in size.

Mechanisms behind the formation of dislocation clusters have been studied at Department of Materials Science and Engineering (DMSE) for some time by using optical light microscopy and scanning electron microscopy (SEM) on etched wafers. This has now been extended to TEM investigations.

In Figure 1a typical dislocation cluster on an etched wafer is shown by using SEM. The surrounding grains have a much lower dislocation density. In certain directions the etch pits line up in lines where it is difficult to reveal the individual pits.

Normally slip in silicon is expected to take place on {111} planes. However, the dislocation etch pits do not line up on traces between {111} planes at the wafer surface but rather along traces between {110} planes and the wafer surface, Figure 2.

TEM specimens are cut from a selected area of the specimen shown in Figure 1 and thinned down by ion milling. In Figure 3, a part of a dislocation array – three
straight dislocation segments - is seen in four different incident beam directions. The dislocation segments are presented in Figure 4, red lines. The dislocations are seen to lie in [211] directions in parallel [1-1-1] planes. Their Burgers’ vector is $b = 1 / 2 [101]$ and their ends are seen to line up in [-211] directions.

The dislocation line directions may be a result of image forces. The interface between melt and solid during solidification is most likely a (111) plane, see Figure 4. A dislocation moving in a [1-1-1] plane may have a pure screw character. By the influence of image forces the dislocation may move in the [10-1] plane being normal to (111) and thus reduce its length and energy.

The dislocation structures in the etch pit lines may be formed by either 1) Frank-Read mechanisms operating in a (110) plane or 2) rearrangements of dislocations belonging to the same slip system into sub-boundarys. The effect of image forces created at the interface will in both cases be important, but slip on (110) planes is only necessary in 1).

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Figure 3:
TEM bright field (BF) images (a) - (c) and dark field image, $g = -220$ (d) of a segment of one of the dislocation arrays. The dislocation line direction is found to be [-211].

Figure 4:
Schematic illustration of the dislocation configuration as observed by TEM. Thompson tetrahedron is shown in (a).
Silicon solar cells are made from wafers being about 0.16 – 0.20 mm thick. The slicing of wafers from the ingot is done by wire sawing in which a slurry consisting of hard SiC particles and polyetylen glycol is transported on a wire into the sawing area as shown in Figure 1. The wire sawing process is a type of grinding explained by the rolling-indentation theory in which the hard SiC particles make indentations causing chipping. To study the indentations in detail hardness indentations using Vickers and Knoop indenters have been performed on a (100) surface of a single crystal, see Figure 2.

Figure 1: The set-up in a wire saw (top) and details of the process (middle and bottom).

Figure 2: Sketch of shape of Vickers and Knoop (bottom) indenters relative to [100] direction.
The hardness tests have been done by using loads up to 500 gram and with varying the angle, $\alpha$, between the diagonal of the indenter and the [100] direction.

At low loads cracks are seen to start from the corners of the indents. At higher loads chipping is observed (Fig. 3). The amount of chipping and the shape of the chips vary with the orientation of the indenter diagonal relative to the [100] direction: At loads up to 100 gram the number of chips formed are much higher when the angle $\alpha$ is small than when it is near to 45°, Figures 4 and 5.

At room temperature and atmospherical pressure silicon has a diamond crystal structure. Silicon is brittle at these conditions. When loading silicon the crystal structure may change to ductile crystal structures with a higher density.

![Figure 3: Knoop indent with chipping on one side. Note the ductile-like structure in the bottom of the indent.](image)

![Figure 4: The tendency to chipping as a function of $\alpha$ and load.](image)

![Figure 5: The tendency to chipping as a function of $\alpha$ and load.](image)
The variations in chipping may be explained by the phase transformations. On loading the indenter may cause phase transformation and dislocation formation near to the indent. Upon unloading dislocations may relax depending on the microstructure. When the angle $\alpha = 45^\circ$ the number of activated slip systems may be small during loading and the amount of relaxation is substantial. This may be seen as a staircase structure at the indent surface, see Figure 6. If $\alpha = 0$ the number of activated slip systems may be higher making relaxation more difficult when unloading. In this case the dislocations may be stored and cause internal stresses when the crystal structure change back to the diamond structure and causing severe chipping, Figure 7.

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Figure 6:
At $\alpha = 50^\circ$ cracking from the corners are seen at a load of 100g (left). At 300 g chips are formed outside the Vickers indent. Note the staircase structure inside the indent.

Figure 7:
At $\alpha = 5^\circ$ and a load of 300 g the chipping becomes more severe. Note the change in shape of the chips.


EXTRACTIVE METALLURGY


INORGANIC CHEMISTRY


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Electronic structure of multiferroic BiFeO$_3$ and related compounds: Electron energy loss spectroscopy and density functional study.

Toprak, M.S.; Darab, M.; Syvertsen, G.E.; Muhammed, M.:
Synthesis of nanostructured BSCF by oxalate co-precipitation - As potential cathode material for solid oxide fuels cells.

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Øye, H.A.; Brekken, H.; Nygaard, L.:
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PHYSICAL METALLURGY

Bellmann, M.P.; Meese, E.A.; Arnberg, L.:
Impurity segregation in directional solidified multicrystalline silicon.

Brynjulfson, I.; Bakken, A.; Tangstad, M.; Arnberg, L.:
Influence of oxidation on the wetting behavior of liquid silicon on Si$_3$N$_4$-coated substrates.

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Solar grade silicon feedstock.

Chen, Y.; Li, Y.; Walmsley, J.C.; Dumoulin, S.; Skaret, P.C.; Roven, H.J.:
Microstructure evolution of commercial pure titanium during equal channel angular pressing.

Chen, Y.; Li, Y.; Walmsley, J.C.; Dumoulin, S.; Roven, H.J.:
Deformation structures of pure titanium during shear deformation.

Cui, J.; Roven, H.J.:
Degreasing of aluminum turnings and implications for solid state recycling.

Cui, J.; Roven, H.J.:
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Mesoscopic simulation of dendritic growth observed in X-ray video microscopy during directional solidification of Al–Cu alloys.

Denys, R.V.; Poletaev, A.A.; Solberg, J.K.; Tarasov, B.P.; Yartys, V.:
LaMg$_{11}$ with a giant unit cell synthesized by hydrogen metallurgy: Crystal structure and hydrogenation behavior.

Dispinar, D.; Akhtar, S.; Nordmark, A.; Di Sabatino, M.; Arnberg, L.:
Degassing, hydrogen and porosity phenomena in A356.

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A 3D Monte Carlo study of the effect of grain boundary anisotropy and particles on the size distribution of grains after recrystallisation and grain growth.

Furu, J.; Buchholz, A.; Bergstrøm, T. H.; Mathiesen, K.:
Heating and melting of single Al ingots in an aluminium melting furnace.

Ganesan, S.M.; Moe, P.T.; Vinothkumar, P.; Audestad, J.I.; Solberg, B.; Solberg, J.K.; Burnell-Gray, J.S.; Rudd, W.:
Establishment of heat treatment cycles for forge welded API L80 tubular joints.

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Matrix coherency strain and hardening of Al-Mg-Si.

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The effect of deformation on the work hardening behaviour after aging of two commercial Al-Mg-Si alloys.

Li, Y.; Chen, Y.; Walmsley, J.C.; Mathiesen, R.; Dumoulin, S.; Roven, H.J.:
Faceted interfacial structure of (1011) twins in Ti formed during equal channel angular pressing.


CONFERENCE PROCEEDINGS, OTHER REPORTS AND PUBLICATIONS


LABORATORIES AND EQUIPMENT

METALLOGRAPHY LABORATORY

Professor Jan Ketil Solberg has overall scientific responsibility for the lab. Senior Engineer Pål Ulseth and Staff Engineer Torild Krogsdal are responsible for the daily management. **Location:** AGV2: E-508, E-514, E-514A and E-520.

**Equipment (description and specification)**

The laboratory consists of equipment for sampling, metallographic preparation, documentation and characterization of prepared surfaces in general for light microscopy but also for SEM and TEM. Hardness testing. Classical metallographic preparation equipment: Abrasive cutting, grinding and polishing. Mounting press, grinding and polishing machines, semiautomatic preparation machines. Equipment for marking, precision cutting, ultrasonic cleaning and drying. We do electrolytic polishing of specimens to be examined in SEM / TEM. Several light microscopes with digital cameras with accompanying software for image analysis. Micro and macro hardness testers. Sigmascope for measuring electrical resistance.

HEAT TREATMENT LABORATORY

Professor Jan Ketil Solberg has overall scientific responsibility for the lab. Senior Engineer Pål Ulseth is responsible for the daily management. **Location:** AGV2: A-441 and “Smeltehallen”.

**Equipment (description and specification)**

The laboratory is equipped with furnaces to heat treat materials. 4 muffle furnaces: Naberterm T > 1100°C, Naberterm T > 1280°C, Naberterm T > 1100°C air circulated and Heraus T > 750°C air circulated. Tube furnaces T > 1000 °C. 10 saltbaths for 300-600°C heat treatment and 5 oilbaths for the temperature range RT - 200°C. Abrasive cutting: 3 Discotomes.

ELECTRON MICROSCOPE LABORATORY

Professor Jarle Hjelen and Professor Jan Ketil Solberg have overall scientific responsibility for the lab. Close cooperation with the Department of Geology and Mineral Resources Engineering. **Location:** AGV2: F-361, F-362, F-369, F-370 and F-373.

**Equipment (description and specification)**

The laboratory is equipped with several electron microscopes; SEM, FESEM, LVSEM, FIB, TEM and EPMA, as well as equipment for preparing specimens for these microscopes. JEM-2010 TEM with Oxford ISIS EDS, Gatan GIF200 Electron energy loss analysis: Characterization of crystal structure and micro/nano structures down to atomic level. FEI, FIB200: Preparation of specimens for SEM/EBSD and TEM. JEOL JXA-8500F EPMA, microprobe analyzer with 5 WDS and JED EDS: Determination of local chemical composition and microstructures down to nano level. Zeiss ULTRA 55 Limited Edition FESEM with EDAX Pegasus XM2 EDS system, in-situ tensile sub stage (including moduls for heating and cooling), NORDIF UF-1000 EBSD detector: high resolution electron imaging, crystal orientation mapping, X-ray microanalysis, in-situ deformation at temperatures between - 60 ºC and + 750ºC. Zeiss SUPRA 55 VP LVFESEM with Bruker 800 EDS system, NORDIF CD-200 EBSD with large area EBSD mapping function: high resolution electron imaging, X-ray microanalysis, EBSD mapping of large Si wafers. Hitachi SU-6600 FESEM with Bruker EDS, CL and NORDIF UF-1000 off-line EBSD system: high current FESEM for fast EDS and EBSD acquisition. 2 Jeol JSM 840 SEMs, one is equipped with an in-house made nano soldering unit, the other with a dedicated on-line NORDIF EBSD system for Si wafer characterisation.

MECHANICAL TESTING/FORMABILITY LABORATORY

Professor Hans Jørgen Roven and Professor Bjørn Holmedal (rolling and hot torsion) have overall scientific responsibility for the lab. Location: AGV2: E-112, E-S004, E-S008 and A-K047.

Equipment (description and specification)
The laboratory is equipped with modern units for tensile testing, fatigue, fracture toughness, compression, bending, simple shear, accelerated creep, superplastic properties, multi-scale measurements, nanostructuring metals by severe plastic deformation (ECAP), formability tests, extrusion, forging, special pressure tests at high T, mechanical refinement of metals, hydroforming at room temperature and cold rolling and hot torsion testing. For mechanical characterization of metals and materials: Two servohydraulic computerized universal test machines (100 kN in tension/compression): MTS 810 and MTS 880. The forming, formability and nanostructuring units include 1 manual hydraulic press (60 tons) and 1 computerized servohydraulic MTS 1000 kN press with a second biaxial servohydraulic actuator (100 kN). The press units have special tools for nanostructuring of metals such as equal channel angular pressing (ECAP), continuous ECAP, double axis ECAP, high pressure torsion (HPT), but also special dies for hydroforming, formability testing and backward extrusion. Strain analyses and forming limit diagrams (FLDs) can be established based on automatic 3D strain analyses (ASAME) or digital speckle correlation analyses (DSCA). There are also special units for new extrusion technologies. The cold rolling mills are 1 servohydraulic one-stand (maximum 150 mm width) and 1 electricity powered small scale mill. A servohydraulic hot torsion unit is internally constructed and has computerized control and data acquisition.

METAL SOLIDIFICATION/CASTING LABORATORY

Professor Lars Arnberg has overall scientific responsibility for the lab. Location: AGV2: K-007 and access to SINTEF Foundry laboratory, Richard Birkelands vei.

Equipment (description and specification)
The laboratory has equipment for solidification experiments and aluminium alloy production. 3 resistance furnaces for melting 1–5 kg metal at temperature up to 1000°C. Computer equipment: Software for recording temperature during solidification. Melt viscosimeter: The equipment is used to measure rheological properties of partly solidified metal up to 1000°C. The foundry has an induction furnace for iron and steel with 100 kg capacity, a drop coil induction furnace and a resistance furnace for melting 100 kg of aluminium with rotary degassing equipment. There is also a low pressure casting unit with 150 kg melt capacity. The lab also has sand moulding facilities including core shooter and a sand/resin mixing unit. Melt diagnostic equipment includes ALSPEC H hydrogen analyser PODFA, reduced pressure test and computer logging facilities.

SOLAR SILICON SOLIDIFICATION LABORATORY

Professor Lars Arnberg has overall scientific responsibility for the lab. Location: AGV2: GM-103.

Equipment (description and specification)
The Heliosi-laboratory is a clean room class 10 000 (particles/foot³) and equipped for crystallization of high purity PV Si. Bridgman pilot scale furnace type Crystalox DS 250 for directional solidification of silicon ingots up to 12 kg Si. Typical size: Diameter: 250 mm, height: 100-120 mm. Equipment for protective crucibles coating including automatic coating and a muffle furnace for firing of the coating.

CHARACTERIZATION OF SILICON – SOLAR CELL MATERIALS LABORATORY

Associate Professor Marisa Di Sabatino and Research Scientist Gaute Stokkan have overall scientific responsibility for the lab. Location: AGV2: GM-110, GM-104 and E-418.

Equipment (description and specification)
The laboratory consists of different activities of material characterization. Carrier lifetime measurements: QSSPC (quasi steady state photoconductance) and CDI (carrier density imaging). PVScan 6000: Maps dislocation density on etched surfaces over large areas. Infrared radiography: Shows inclusions and cracks in silicon. LBIC (Light Beam Induced Current): Local short circuit current of solar cells. Furnaces for high temperature annealing in protective atmosphere, T < 1400°C: Studies of stability of microstructure during annealing/cooling. GDMS (glow discharge mass spectrometer): Trace element analysis in Si and Al Concentrations down to ~ 1 ppb. FPP (four point probe) resistivity measurements: Control of resistivity and doping level. FTIR (Fourier transform infrared spectroscopy): Measures concentration of oxygen and carbon in silicon. Suns-Voc: Estimates IV-curves during and after cell processing.
SILICON SOLAR CELL – ETCHING LABORATORY

Associate Professor Marisa Di Sabatino and Research Scientist Gaute Stokkan have overall scientific responsibility for the lab. **Location:** AGV2: E-114.

**Equipment (description and specification)**


PROCESS METALLURGY/METALS PRODUCTION LABORATORY

Professor Merete Tangstad, Professor Leiv Kolbeinsen, Professor Ragnhild Aune and Associate Professor Gabriella Tranell have overall scientific responsibility for the lab. **Location:** AGV2: GM-118, E-118, E-204, E-214, ”Smeltehallen”, K-013, K-020 and K-03x.

**Equipment (description and specification)**


DIFFRACTOMETER LABORATORY

Professor Bjørn Holmedal has overall scientific responsibility for the lab. **Location:** AGV2: A-347.

**Equipment (description and specification)**

The laboratory is equipped with a diffractometer, an instrument for measuring X-ray diffraction. In addition there is software for analyzing the metal texture, i.e. the statistical distribution of crystal orientations in a metal (pole figures, orientation distribution function (odf)). X-ray diffractometer: Siemens D5000. Texture software: Bruker.

CHEMISTRY BUILDING II STUDENTLABORATORY


**Equipment (description and specification)**

The laboratories are used for laboratory courses in general chemistry for 1st grade students, and are equipped with general equipment and instrumentation for this activity. 50 pH- meters, 9 spectrophotometers, 90 volt meters, 12 power regulators, 9 drying cupboards, 12 centrifuges, 12 analytical balances and 6 balances.
LABORATORY FOR CERAMIC SCIENCE AND ENGINEERING

Professor Mari-Ann Einarsrud has overall scientific responsibility for the lab. Location: Chemistry building II: 001, 008, 011, 018, 022, 032B, 035, 107, 119 and 125. AGV2: Hot press laboratory.

**Equipment (description and specification)**
The laboratory consists of equipment for ceramics processing and engineering: powder synthesis, powder handling, green body formation, firing and machining of ceramics. It is also equipped for the preparation of ceramic thin films and coatings. Spray pyrolyser: Pilot scale equipment for the manufacture of ceramic oxide powders, capacity of 10 kg per day. Wet chemical synthesis of ceramic and inorganic materials: Chemical synthesis equipment, ultrasonic bath, ultrasonic finger, rotavapor, autoclave for hydrothermal synthesis, autoclave for super critical drying, centrifuge, incubator. Handling, dispersion and milling of powder: Viscometer, ball mill, planetary mill, attrition mill, drying cupboard. Manufacturing of films of ceramic and inorganic materials on substrates: Dip coaters, spray coaters, spin coater. Equipment for manufacture of green bodies of ceramic materials: Presses, laminating press, extruder, tapecaster. Drying, calcination and firing of ceramic materials: Chamber furnaces, tube furnaces, high temperature furnaces, hot presses, clean room furnaces. Grinding and polishing: Polishing equipment, grinding equipment, cutting tools.

LABORATORY FOR CERAMIC SCIENCE AND ENGINEERING, CHARACTERIZATION

Professor Kjell Wiik has overall scientific responsibility for the lab. Location: Chemistry building II: 014, 018, 032B, 034B, 103 and 107. Perleporten: Lab.

**Equipment (description and specification)**
The laboratory is equipped for the characterization of microstructural, thermal, physical, structural and mechanical properties of ceramics. Mechanical testing: Biaxial tester, beam bending of gels to measure mechanical strength and permeability, equipment for 4-points bending test and creep test of ceramic materials at temperatures up to 1100 degrees under controlled atmosphere. Thermal analysis: Thermogravimetric analysis equipment (TGA), thermogravimetric analysis equipment with attached mass spectrometer, differential thermoanalysis equipment (DTA, DSC), and dilatometers. Particle size/surface: Nitrogen adsorption equipment for measuring of surface area and pore size, particle size analyser, and He pycnometer. Transport and dielectric properties: Equipment for measuring electrical conductivity and conductivity relaxation, measuring of gas permeability, characterisation of fuel cells and characterisation of dielectric and piezoelectric properties (Ferrotester). Spectroscopy: FTIR and UV-Vis instruments.

LABORATORY FOR POWDER X-RAY DIFFRACTION

Professor Tor Grande has overall scientific responsibility for the lab. Responsible departments are Department of Materials Science and Engineering and SINTEF Materials and Chemistry. Location: Chemistry building II: 113.

**Equipment (description and specification)**
The laboratory is equipped with four X-ray diffractometers for quantitative and qualitative X-ray diffraction of powder, films and monoliths at ambient temperature as well as low and high temperature under controlled atmosphere. Siemens D5005, unit A: High resolution diffractometer (θ-2θ) with primary monochromator for CuKα1 radiation, scintillator detector. Siemens D5005, unit B: Diffractometer with secondary monochromator, scintillator detector and PSD detector, 40 position sample changer, high temperature camera and sample holder for capillary geometry, Göbel mirror and Soller slits for grazing incidence measurements. Bruker D8 Focus: Diffractometer with PSD detector ([LynxEye]), 9 position sample changer. Bruker D8 Advance: Diffractometer with PSD detector (Vänlec-1), 9 position sample changer, high temperature camera, low temperature camera.

LABORATORY FOR ELECTRON MICROSCOPY IN CHEMISTRY BUILDING II

Professor Mari-Ann Einarsrud has overall scientific responsibility for the lab. Location: Chemistry building II: 033.

**Equipment (description and specification)**
LABORATORY FOR ELECTROCHEMICAL ENERGY TECHNOLOGY

Professor Svein Sunde and Associate Professor Frode Seland have overall scientific responsibility for the lab. **Location:** Chemistry Building II: 225, 223, 219, 215, 207, 201 and 014.

**Equipment (description and specification)**
The laboratory contains equipment for electrochemical measurements, synthesis and applied fuel cell work. Two **UNilab MBrAun glove boxes**: One for storage of special compounds and chemicals, and one for assembly and characterization of Li-ion batteries. One electrochemical set-up for experiments in controlled atmosphere (Par 273A with Solartron 1250 frequency analyzer). Cleaning of glass ware and preparation of electrolytes: Dish washer, hydrogen peroxide bath, hot plate, fume hood and MilliQ water installation (denoized water). Synthesis of electrocatalysts: Tubular furnace, ultrasonic bath, heating cabinet, technical scales, centrifuge, Zeta potential measuring equipment, PZC - auto titration equipment, stations for drying electrodes and electrode preparation. Standard Electrochemical measurement set-ups: Potentiostats, arbitrary function generators, computers with special software, water baths. Standard Electrochemical measurement set-ups for elevated temperature: Potentiostats, arbitrary function generators, computers with special software, autoclaves and heating cabinets. Electrochemical measurement set-up for rotating (ring) disk electrode: Potentiostats, shafts and electrodes of various compounds and design (Pine inst. Tacussel/Radiometer). Electrochemical measurement for impedance spectroscopy: Potentiostats, sine-wave generators, frequency response analyzers, computers with specialised software. Electrochemical quartz crystal microbalance: Potentiostats, frequency counter, faraday cage of special design and functionality (including reference quartz crystal), computer with specialised software. Spraying of electrodes and MEA preparation: Manual air brush of various sizes, automatic computer controlled spray stations, screen print, hot press, heating cabinets and analytical scale in an “environmental room”. Fuel cell activity: Three individual low temperature PEMFC test stations with load box, data loggers, humidifiers, flow controls, temperature controls, etc. Test station for high temperature PEMFC activity for small organic molecules including evaporator. Stack testing station, Sintalyzer, Ion chromatograph. Photoelectrochemistry: Potentiostats with arbitrary function generator and computer with specialised software. High power Xenon lamp, monochromator, lock-in amplifier, chopper. UV-vis. FTIR.

LABORATORY FOR ELECTROCHEMICAL SCANNING PROBE MICROSCOPY (AFM/STM)

Professor Svein Sunde has overall scientific responsibility for the lab. **Location:** Chemistry building II: 003A.

**Equipment (description and specification)**
The laboratory contains two atomic force microscopy / scanning probe microscopy installations [Agilent (2009) and Veeco] with electrochemical cell/environmental chamber, potentiostat and function generator for electrochemical measurements. Agilent SPM: Sample holders, SPM scanners, electrochemical cell and environmental chamber, air floating tables for noise rejections, ancillary hardware for operating the installations. Veeco SPM: Sample holders, SPM scanners, electrochemical cell, air floating tables for noise rejections, ancillary hardware for operating the installations.

LABORATORY FOR CORROSION AND SURFACE TECHNOLOGY

Professor Kemal Nisancioglu and Professor Geir Martin Haarberg have overall scientific responsibility for the laboratory. **Location:** Chemistry building II: 001, 307, 313, 321 and 323.

**Equipment (description and specification)**
Laboratories are organised both for teaching and research. Specimen preparation, metallography, optical microscopy, electrochemical testing and characterization, video equipment synchronised with electrochemical polarization equipment. Surface treatment and aqueous electrolysis: Etching, anodizing, metal deposition and winning, electroplating and polishing. Hydrogen penetration and diffusion in metals. Standardised corrosion testing: Autoclave testing, stress corrosion cracking, salt spray testing. Metallographic equipment [grinding/polishing], digital light microscope, various electrochemical testing/characterisation equipment, hydrogen-diffusion cells [Davenathan/Stachurski], autoclaves for corrosion tests at high pressure/temperature, tensioner for tension corrosion tests, salt spray cabinet, furnaces for heat treatment of samples and various workshop tools for cutting, sawing, drilling etc for sample preparation.

ELECTROLYSIS LABORATORY IN CHEMISTRY BUILDING II

Responsible scientific employee is Professor Geir Martin Haarberg. **Location:** Chemistry building II: 413 and 419.

**Equipment (description and specification)**
Glove box [Braun]: Dry argon atmosphere, and vacuum pump in room 419. Glove box [Vac]: High temperature furnace for experiments in salt melts, room 413. Additional furnaces: For experiments in salt melts up to 1000 °C, both traditional tube furnaces with water cooling, and “gold film” furnaces. Oil bath and teflon cell: With rotating electrode for studies of Fe-precipitation from hydroxide electrolytes at temperatures up to 120 °C. Vacuum equipment: With glassware and connections for salt treatment included vacuum pumps and diffusion pump. Electrochemical measuring equipment: Potentiostats with impedance measuring equipment.
LABORATORY FOR ELECTROLYSIS IN PILOTPLANT FACILITY

Professor Geir Martin Haarberg and Head of Department Arne Petter Ratvik have overall scientific responsibility for the lab. Location: Chemistry building 5 ground floor.

Equipment (description and specification)
High temperature furnaces, gas outlets (argon) and watercooling system, a small workshop for sawing and preparation of equipment for high temperature experiments, a storage room for equipment for high temperature experiments and chemicals, apparatus for the manufacture of anodes for aluminium electrolysis, apparatus with vacuum pump for manufacture of waterfree AlF3, some large furnaces for special experiments are situated in the ground floor, and electrochemical measuring equipment, mainly potentiostats with impedance measuring equipment.

CARBON LABORATORY

Head of Department Arne Petter Ratvik has overall scientific responsibility for the lab. Location: Chemistry Building II: 303 and Chemistry Hall: 101, 101C, 160, 164 and storage room 054.

Equipment (description and specification)
<table>
<thead>
<tr>
<th>Speaker</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>January 21</strong></td>
<td></td>
</tr>
<tr>
<td>Dr. Petr Krtil, Senior Scientist J. Heyrovsky Institute of Physical Chemistry, Prague, Czech Republic.</td>
<td>Structural aspects of electrocatalyst design.</td>
</tr>
<tr>
<td><strong>February 5</strong></td>
<td></td>
</tr>
<tr>
<td>Researcher Mikhail Tsyplkin, Department of Materials Science and Engineering, NTNU.</td>
<td>Nanocrystalline Ir-oxide based anode electrocatalyst for PEM water electrolyser.</td>
</tr>
<tr>
<td><strong>February 12</strong></td>
<td></td>
</tr>
<tr>
<td>PhD Per Martin Rørvik, Department of Materials Science and Engineering, NTNU.</td>
<td>Annealing effect on the domain orientation in PbTiO$_3$ nanorods.</td>
</tr>
<tr>
<td><strong>February 19</strong></td>
<td></td>
</tr>
<tr>
<td>Professor Heiko Hessenkemper, Technische Universität Bergakademie Freiberg, Germany.</td>
<td>New glass concepts for solar energy.</td>
</tr>
<tr>
<td><strong>February 26</strong></td>
<td></td>
</tr>
<tr>
<td>PhD student Mahdi Darab, Department of Materials Science and Engineering, NTNU.</td>
<td>Synthesis and characterization of platinum/carbon electrocatalysts using different techniques.</td>
</tr>
<tr>
<td><strong>March 5</strong></td>
<td></td>
</tr>
<tr>
<td>Researcher Ana Maria Martinez, SINTEF Materials and Chemistry.</td>
<td>Electrodeposition of Si thin films from ionic liquids.</td>
</tr>
<tr>
<td><strong>March 12</strong></td>
<td></td>
</tr>
<tr>
<td>Professor Kjell Wiik, Department of Materials Science and Engineering, NTNU.</td>
<td>Membrane materials for oxygen and syn-gas production.</td>
</tr>
<tr>
<td><strong>March 19</strong></td>
<td></td>
</tr>
<tr>
<td>PhD Sverre Magnus Selbach, Department of Materials Science and Engineering, NTNU.</td>
<td>Local and average structure of inorganic nanoparticles.</td>
</tr>
<tr>
<td><strong>April 16</strong></td>
<td></td>
</tr>
<tr>
<td>PhD student Lars-Erik Owe, Department of Materials Science and Engineering, NTNU.</td>
<td>The effect of the electrolyte on the electrochemical properties of anodically formed iridium oxide.</td>
</tr>
<tr>
<td><strong>April 23</strong></td>
<td></td>
</tr>
<tr>
<td>Adjunct Professor Asbjørn Solheim, Department of Materials Science and Engineering, NTNU.</td>
<td>Aluminium electrolysis – from Söderberg anodes to CO$_2$-free aluminium production.</td>
</tr>
<tr>
<td><strong>April 30</strong></td>
<td></td>
</tr>
<tr>
<td>PhD student Magnus Rotan, Department of Materials Science and Engineering, NTNU.</td>
<td>Phase composition, microstructure and resistance to attrition of alumina-based supports for Fischer-Tropsch catalysts.</td>
</tr>
<tr>
<td><strong>May 7</strong></td>
<td></td>
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<tr>
<td>PhD student Jiregna Hirko Foggi, Department of Materials Science and Engineering, NTNU.</td>
<td>Lifetime modelling of overhead power lines exposed to marine atmosphere.</td>
</tr>
<tr>
<td><strong>May 12</strong></td>
<td></td>
</tr>
<tr>
<td>Researcher Shuihua Tang, Department of Materials Science and Engineering, NTNU.</td>
<td>Effect of methanol on the electrochemical behaviour of a Pt/C catalyst layer.</td>
</tr>
<tr>
<td><strong>September 10</strong></td>
<td></td>
</tr>
<tr>
<td>Professor Richard Haverkamp, School of Engineering and Advanced Technology, Massey University, Palmerston North, New Zealand.</td>
<td>Hard and soft materials. Three recent synchrotron and atomic force microscope studies: Sheep, nanoparticles and single molecule manipulation.</td>
</tr>
<tr>
<td><strong>September 17</strong></td>
<td></td>
</tr>
<tr>
<td>PhD student Hasan Güleryüz, Department of Materials Science and Engineering, NTNU.</td>
<td>Measurement of forces between silica surfaces by colloidal probe AFM technique.</td>
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<tr>
<td>Date</td>
<td>Speaker</td>
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<tr>
<td>September 24</td>
<td><strong>Professor emeritus Arne Espelund</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>October 1</td>
<td><strong>PhD Jonas Gurauskis</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>October 8</td>
<td><strong>Dr. Vanessa Gil Hernandez</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>October 15</td>
<td><strong>Professor emeritus Terje Østvold</strong>, Department of Materials Science and Engineering, NTNU.</td>
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<tr>
<td>October 29</td>
<td><strong>PhD student Morten Tjelta</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>November 5</td>
<td><strong>PhD student Esma Senel</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>November 12</td>
<td><strong>Associate Professor Fride Vullum-Bruer</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>November 19</td>
<td><strong>Professor Ragnhild E. Aune</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>November 26</td>
<td><strong>PhD student Juan Tan</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>December 3</td>
<td><strong>PhD student Heiko Gaertner</strong>, Department of Materials Science and Engineering, NTNU.</td>
</tr>
<tr>
<td>December 10</td>
<td><strong>PhD Odne Burheim</strong>, Department of Chemistry, NTNU.</td>
</tr>
</tbody>
</table>

*Multiple twinnings in pure Ti processed by room temperature ECAP.*
<table>
<thead>
<tr>
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</table>
| **January 21**  
Dr. Petr Krtil, Senior Scientist J. Heyrovsky Institute of Physical Chemistry, Prague, Czech Republic. | Structural aspects of electrocatalyst design. |
| **February 5**  
Dr. Dimitry Kozodaev, NT-MDT Europe, The Netherlands. | Integrated multifunctional systems based on the atomic force microscopy for advanced materials. |
| **February 11**  
Professor Arne Kristian Dahle, University of Queensland, Australia. | Understanding and controlling eutectic reactions in Al-Si alloys. |
| **February 11**  
Dr. Giulio Timelli, University of Padova, Italy. | Aluminium foundry: From traditional to innovative processes. |
| **February 19**  
Professor Heiko Hessenkemper, Technische Universität Bergakademie Freiberg, Germany. | New glass concepts for solar energy. |
| **March 18**  
Professor Marija Kosec, Electronic Ceramics Department Jozef Stefan Institute Ljubljana, Slovenia. | Mechanically activated solid state synthesis of ceramic materials: From lead free piezoelectrics to transparent conductive oxides. |
| **June 24**  
Professor Geoff Scamans, Brunel Centre for Advanced Solidification Technology, Brunel University, United Kingdom. | Aluminium sustainability: Cans to cars. |
| **September 10**  
Professor Richard Haverkamp, School of Engineering and Advanced Technology, Massey University, Palmerston North, New Zealand. | Hard and soft materials. Three recent synchrotron and atomic force microscope studies: Sheep, nanoparticles and single molecule manipulation. |
| **September 14**  
Professor emeritus David Embury, formerly Professor at McMaster University, Canada. | Fracture of metals defining useful limits. |
| **September 16**  
Professor emeritus David Embury, formerly Professor at McMaster University, Canada. | Developing microstructures to produce ultrahigh strength metallic materials. |
| **October 15**  
Dr. Ole Runar Myhr, Hydro, Norway. | Process chain simulations in manufacturing of aluminium automotive components. |
| **October 15**  
Dr. Øystein Hop, Hydro, Norway. | Harnessing the sun – aluminium for the solar industry. |
| **October 28**  
Dr. Andreas Afseth, Alcan Centre de Recherches de Voreppe, France. | Functional aluminium surfaces for solar energy conversion. |
STAFF

SCIENTIFIC STAFF

Professor, PhD Lars Arnberg
Professor, PhD Ragnhild Elizabeth Aune
Professor emeritus Jon Arne Bakken
Professor, Dr.ing. Mari-Ann Einarsrud
Professor emeritus, Dr.ing. Thorvald Abel Engh
Professor emeritus Arne Wang Espelund
Professor, Dr.ing. Tor Grande
Professor, Dr.ing. Øystein Grong
Professor, Dr.scient. Jarle Hjelen
Professor, Dr.scient. Bjørn Holmedal
Lecturer, Sigrid Hakvåg, from June 21, 2010
Professor, Dr.ing. Geir Martin Haarberg
Adjunct Professor, Dr.ing. Ola Jensrud
Adjunct Professor, Dr.ing. Harald Justnes
Adjunct Professor, PhD Morten Karlsen, from September 1, 2010
Professor, Dr.ing. Leiv Kolbeinsen
Associate Professor, Dr.ing. Hilde Lea Lein
Professor, Dr.philos. Otto Lohne
Adjunct Professor, Dr.ing. Odd-Arne Lorentsen, from March 1, 2010
Associate Professor, PhD Marisa Di Sabatino Lundberg, from June 1, 2010
Professor, Dr.ing. Knut Marthinsen
Adjunct Professor, PhD Mohammed M’Hamdi
Professor emeritus, M.Sc.Eng. Ketil Motzfeldt
Professor emeritus, PhD Erik Nes
Professor, PhD Kemal Nisancioglu
Professor emeritus Sverre Olsen
Adjunct Professor, Dr.ing. Knut Arne Paulsen
Adjunct Professor, Dr.techn. Oddvin Reiso
Adjunct Professor, Dr.ing. Christian Rosenkilde
Professor emeritus, Dr.techn. Terkel Rosenqvist
Professor, Dr.techn. Hans Jørgen Roven
Professor emeritus, Dr.techn. Nils Ryum
Associate Professor, PhD Frode Seland
Associate Professor, PhD Sverre Magnus Selbach, to June 30, 2010
Professor, Dr.philos Jan Ketil Solberg
Adjunct Professor, Asbjørn Solheim, from March 1, 2010
Professor, Dr.techn. Svein Sunde
Adjunct Professor, Dr.ing. Morten Sørlie
Professor, Dr.ing. Merete Tangstad
Professor emeritus, Dr.techn. Jomar Thonstad
Associate Professor, PhD Gabriella Tranell
Professor emeritus Reidar Tunold
Professor emeritus Johan Kristian Tuset
Adjunct Professor, Dr.ing. Halvard Tveit
Associate Professor, PhD Fride Vullum-Bruer
Professor, Dr.ing. Kjell Wiik
Adjunct Professor, PhD Volodmyr Yartys
Professor, Dr.ing. Martin Ystenes
Professor emeritus, Dr.techn. Terje Østvold
Adjunct Associate Professor, Dr.ing. Eivind Johannes Øvrelid
Professor emeritus, Dr.techn. Harald Arnjot Øye

TECHNICAL STAFF

Senior Engineer Elin Harboe Albertsen
Senior Engineer Jan Arve Baatnes, to February 7, 2010
Senior Engineer Harald Holm
Chief Engineer Eli Beate Larsen
Senior Engineer Solveig Louise Sørli Jonassen, from November 1, 2010
Senior Engineer Torild Krogstad
Senior Engineer Tor Arild Nilsen
Senior Engineer Kjell Rekke
Chief Engineer Morten Raanes
Senior Engineer Pål Skaret
Senior Engineer May Grete Sætran
Chief Engineer Julian Tolchard
Chief Engineer Pål Ulseth
Engineer Gunn Torill Wikdahl
Chief Engineer Yingda Yu

ADMINISTRATIVE STAFF

Higher Executive Officer Martha Bjerknes
Executive Officer Elsa Mari Florhaug, 50 % position
Head of Administration Trond Einar Hagen
Senior Secretary from February 1, 2010
Higher Executive Officer Unni Keiseraas
Higher Executive Officer Elin Synnøve Isaksen Kaasen, from September 10, 2010
Higher Executive Officer Brit Wenche Meland
Executive Officer Hilde Martinsen Nordsø
Head of Department, Dr.ing. Arne Petter Ratvik
Senior Secretary Åse Lill Salomonsen to June 30, 2010
RESEARCH SCIENTISTS

PhD Julien Degoulange, to January 14, 2010
M.Sc. Carl Erik Lie Foss, to January 24, 2010
M.Sc. Maria Psarrou, from February 23, 2010
PhD Jafar Safarian-Dastjerdi, from September 12, 2010
Dr.ing. Gaute Stokkan
PhD Shuihua Tang, to September 29, 2010
PhD Mikhail Tsykin
PhD Harald Vestel, 75 % position

GUEST PROFESSORS/RESEARCHERS

M.Sc. Zuriñe Amodarain, from April to June, 2010
M.Sc. Sarah Bernardis
M.Sc. Rosemary Cox-Galhotra, from August 19 to December 23, 2010
Professor Richard Haverkamp, from May to August, 2010
M.Sc. Reza Khabazbehesht, from June 1, 2010
PhD Pietrzyk Stanislaw, from August 15 to September 17, 2010
M.Sc. Dongming Yao, from September 1, 2010

POST DOCTORAL FELLOWS

PhD Shahid Akhtar
PhD Martin Bellmann, to September 1, 2010
PhD Dmitry Bokach
PhD Yongjun Chen
PhD Annika Eriksson
PhD Snorre Fjeldbo
PhD Vanesa Gil Hernández, from July 7, 2010
PhD Rajiv Girsi, to August 27, 2010
PhD José Luis Gómez
Dr.ing. Sverre Gulbrandsen-Dahl, 50 % position
PhD Jonas Gurauskis, from June 7, 2010
PhD Emmanuel Hersent, from May 1, 2010
PhD Bin Lin, from August 18, 2010
PhD Erlend Fjøsne Nordstrand
PhD Stanka Tomovic Petrovic, 50 % position
PhD Per Martin Rervik, to August 31, 2010
PhD Jafar Safarian-Dastjerdi, to September 11, 2010
PhD Sverre Magnus Selbach, from July 1, 2010
PhD Kati Tschöpe, from August 6, 2010
PhD Zhaoheui Wang, from August 16, 2010

SCIENTIFIC ASSISTANTS

Leiv Olav Jøsang
Darcy Wayne Stevens, from May 25, 2010
Kira Turkova, 30 % position

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Sarina Bao
Jirang Cui
Per Kristian Dahlstrøm
Mahdi Darab
Carl Erik Lie Foss, from January 25, 2010
Heiko Gaertner
Sidse Meli Hanetho
Astri Bjørnetun Haugen
Liudmila Igorevna Ilyukhina
Lars Klemet Jakobsson
Nils Eivind Kamfjord
Egil Krystad, from August 25, 2010
Eirin Kvalheim
Ørjan Fossmark Lohne
Chiara Modanese
Peyman Mohseni
Mari Kirkebøen Næss
Lars-Erik Owe
Malin Sletnes
Dmitry Slizowskij
Sapthagireesh Subbarayan
Tor Olav Loveng Sunde
Guttorm Ernst Syvertsen
Sophie Beatrice Weber
Øyvind Østrem

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Mustafa Balci
Markus Bernhardt, from August 30, 2010
Marte Bjørnsdotter
Yacine Boulfrad
Ingvild Margrete Brynjulfson
Thomas Brynjulfson, from August 1, 2010
Sindre Bunkholt, from August 23, 2010
Xinzi Chen, from August 18, 2010
Elena Dal Martello
Tobias Alexander Danner, from August 30, 2010
Pierre Delaleau, to October 10, 2010
Torunn Ervik
Jiregna Hirko Foggi
David Franke
Jørgen Furu
Kenji Kawaguchi
STAFF

Mark William Kennedy
Hasan Güeryüz
Terje Hals
Mehdi Kadkhodabeigi
Nils Eivind Kamfjord
Maulid Kivambe
Ole Sigmund Kjos, August 8, 2010
Jeffery Kline
Michal Kolar
Michal Ksiazek
Köksal Kurt
Elizaveta Kuznetsova
Thomas Ludwig, from September 15, 2010
Tomas Manik, from August 30, 2010
Bronislav Novák, from August 16, 2010
Piotr Ochal
Vinothkumar Palanisamy
Bo Qin, from November 22, 2010
Stian Seim
Esma Senel
Suwarno Suwarno
Katharina Teichmann
Morten Tjelta
Kati Tschöpe, to August 5, 2010
Knut Omdal Tveito, from August 17, 2010
G. Nagaraj Vinayagam
Zhaohui Wang, to August 15, 2010
Ning Wang, from January 17, 2010
Saijun Xiao
Qinglong Zhao, from February 22, 2010
Haitao Zhou
Agnieszka Zlotorowicz
Vegard Øygarden

UNDERGRADUATE ASSISTANTS

Spring semester
Olav Kigen Bjering
Kim Blommedal
Tarjei Bondevik
Thomas Brynjulfesen
Kristian Engen Eide
Kai Erik Ekstrøm
Kari Forthun
Trond Arne Hassel
Halvor Hoen Hersleth
Guttorm André Hoff
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Jens Kristian Holmen
Håvard Husby
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Steinar Jørstad
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Aleksander Kolstad
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Åse Ervik
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Thea Cecilie Gjøstvang
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Johan Kolstø Sønstabaø
Eivind Bruun Thorstensen
Asbjørn Ulvestad
Ole Jørgen Østensen
Åsne Århus

SUMMER STUDENTS

Inger Marie Bjørnevik
Wu Chen
Stian Gurrik
Anne-Jorunn Hausken
Kjetil Hyllestad
Håkon Trygve Strøm Jørgensen
Roald Bræck Leer
Håvard Mølnås
Anne Kirsti Noren
Anne Marthe Nynmark
Gerhard Olsen
Petter Ottesen
Jonas Hovde Pedersen
Henrik Roven
Trygve Schanche
Rajat Sharma
Camilla Sommerseth
Ali Tabeshian
Phung Hieu Dinh Tran
David Fjøsne Traaen
Buhle Sinaye Xakalashe
Shuang Zhang

APPRENTICE

John Michael Love, to July 28, 2010

DEPARTMENT MANAGEMENT

Sofie Drågen
Arne Petter Ratvik (head)
Øystein Grong
Trond Einar Hagen
Lars-Erik Owe
Geir Martin Haarberg
Eli Beate Jakobsen
Leiv Kolbeinsen
Ørjan Fossmark Lohne
Gabriella Tranell (deputy head)
Ragne Marie Skarå/Line Teigen Døssland
Pål Ulseth

DEPARTMENT BOARD

Sofie Drågen
Trond Furu
Lars-Erik Owe
Arne Petter Ratvik (head)
Morten Raanes
Ragne Marie Skarå/Line Teigen Døssland
Rudie Spooren
Svein Sunde

SUBSTITUTES

Brit Wenche Meland
Merete Tangstad
Morten Tjelta
Aud Wærnes
GRADUATE STUDIES

PhD Degrees

During 2010, 91 PhD students have worked at Department of Materials Science and Engineering. 10 students have been awarded the degree PhD:


Major subject: Electrochemistry.
Dr. lecture: Application of carbon nanofibres and nanotubes as electrocatalyst supports in fuel cells.
Thesis advisor: Professor, Dr.techn. Svein Sunde.
Examination committee: Prof. dr. Frank Albert de Bruijin, University of Groningen, Faculty of Mathematics & Natural Sciences, Groningen, The Netherlands. Professor Eivind M. Skou, Institute of Chemical Engineering, Biotechnology and Environmental Technology, University of Southern Denmark, Odense, Denmark. Professor, Dr.ing. Kjell Wiik (chair).

Summary: The PhD thesis deals with the degradation of polymer-electrolyte membrane fuel cells (PEMFCs). The thesis work, partly performed at Los Alamos National Laboratories in USA in collaboration with Dr. Rod Borup, and partly at NTNU in collaboration with SINTEF, describes the influence of operating conditions on catalys and catalyst support degradation as well as the influence of chloride on catalyst degradation (see "Degradation of PEM fuel cells").


Major subject: Extractive metallurgy.
Dr. lecture: Chinese Steel Industry – Past, Present and Future.
Thesis advisor: Professor, Dr.ing. Lev Kolbeinsen.
Co-supervisor: Associate Professor, PhD Gabriella Tranell.
Examination committee: Provost and Senior Vice President for Academic Affairs Alan W. Cramb, Illionis Institute of Technology (IIT), Department of Mechanical, Materials & Aerospace Engineering, Chicago, USA. Product Manager Tore-Andre Skjervheim, Elkem Bjølvefossen AS, Ålvik, Norway. Professor, Dr.ing. Merete Tangstad (chair).

Summary: DISvaDRI aims at development of special addition alloys for steels that contain a fine dispersion of effective seed crystals, and promote grain refinement during steel solidification. Metallic materials with small grain sizes usually have improved mechanical properties, which depend upon the characteristics of the solidification microstructure. It is well known that some non-metallic inclusions dispersing in steels can act as heterogeneous nucleation sites for various precipitates such as sulphides, nitrides and carbides. Multiphase particles are beneficial to catalyse formation of intragranular ferrite crystal during phase transformation which creates a finer grained microstructure, and consequently improve mechanical properties of steel. These beneficial inclusions are named dispersoids. Utilisation of dispersoids in steel metallurgy requires the controlled addition of the dispersoids to the steel, which can take place by employing an alloy containing a large number density of the desired dispersoids.

The dispersoid alloy could be considered as a "smart master alloy", and directly added into the liquid steel. In this thesis work, both natural ilmenite ore and mixture of magnetite ore and cerium dioxide were used to produce smart master alloys. Several parameters were tested such as particle size and pellet size, reducing temperature and time, reducing agents, and gas composition and gas flow rates.


Major subject: Inorganic chemistry.
Dr. lecture: Smart materials – the application of ferroic materials.
Thesis advisor: Professor, Dr.ing. Tor Grande.
Co-supervisor: Professor, Dr.ing. Mari-Ann Einarsrud.
Examination committee: Professor, PhD Marija Kosec, Department of Chemistry and Biochemistry, Div. Electronic Ceramics, J. Stefan Institute, Ljubljana, Slovenia. Dr.ing. Eirik Hagen, Norsk Hydro AS, Porsgrunn, Norway. Professor, Dr.ing. Martin Ystenes (chair).
This work is on the fabrication of textured lead-free piezoelectric materials based on materials $K_{x}Na_{1-x}NbO_{3}$ (KNN). Textured KNN materials with high degree preferential grain orientation have the potential to possess piezoelectric properties comparable to single crystals. The aim of the work was to obtain a high degree of texture or preferential grain orientation by so-called template assisted grain growth mechanism. This method relies on the use of a combination of fine grained powder and single crystal templates particles with same composition and crystal structure. First, a spray pyrolysis process to synthesise fine, homogeneous sub-micron powders of KNN was established. Secondly, a molten salt synthesis route to fabricate single crystal KNN templates with either needle or plate like morphology was developed. The route consisted of two steps. The first step was to synthesis anisotropic single crystals with compositions $K_{4}Nb_{6}O_{17}$, $K_{2}Nb_{4}O_{11}$ or $KNb_{3}O_{8}$. Secondly, these single crystals were converted to KNN single crystals with the same morphology by a molten salt route. The crystal growth mechanisms giving anisotropic morphology and the mechanism for conversion from non-perovskite to perovskite template crystals were presented. Finally, textured KNN materials were fabricated by a modified tape-casting technique. A slurry of the sub-micron KNN powder and single crystal KNN template needle-like templates were prepared and preferential orientation of the template particles were obtained by a modified tape caster using hydrodynamics to orient the template particles. High degree of grain orientation in dense KNN ceramics was demonstrated.


Major subject: Electrochemistry.
Dr. lecture: Chlorine electrolysis.
Thesis advisor: Professor, Dr.techn. Svein Sunde.
Examination committee: Professor, PhD Karel Bouzek, Institute for Chemical Technology Prague, Department of Inorganic Technology, Czech Republic. Principal Engineer Chlorine, Dr.ing. Egil Rasten, INEOS Norge AS, Technology and Projects, Porsgrunn, Norway. Professor, Dr.ing. Signe Kjelstrup, Department of Chemistry, NTNU (chair).

Summary: The PhD thesis dealt with water electrolysis employing polymer electrolyte membranes (PEMWE). The advantages compared to classical alkaline WE are among other things high purity, high current densities, and low energy consumption. A problem associated with PEMWE, however, is the high anodic overpotential for oxygen evolution due to the acidic environment in the membrane. Lervik’s thesis investigates among other things the influence of the electrolyte on the catalyst performance, and also the characterisation of the catalysts with impedance analysis. The work also shows that the electronic structure of the nanostructured version of iridium oxide, a relevant electrocatalytic material for the oxygen-evolution reaction in PEMWE, is different from other iridium oxides such as anodic iridium oxide films (AIROF). Yet, when properly normalised they have the same electrocatalytic activity, a result of fundamental importance.


Major subject: Electrochemistry.
Dr. lecture: Corrosion in geothermal energy utilisation.
Thesis advisor: Professor, PhD Kemal Nisancioglu.
Co-supervisor: Senior Researcher, Dr.ing. Otto Lunder, SINTEF Materials and Chemistry.
Examination committee: Professor, PhD Geoff Scamans, Brunel Centre for Advanced Solidification Technology, Brunel University, UK. Senior Adviser, Dr.ing. Astrid Bjørgum, SINTEF Materials and Chemistry, Norway. Professor, Dr.techn. Svein Sunde (chair).

Summary: In order to achieve the desired strength, AlMgSi (6000-series) alloys are often alloyed with either small (fraction of a wt%) Cu or excess Si in relation to that required to form Mg2Si amounts of Si. However, these elements have also been reported to introduce susceptibility to intergranular corrosion (IGC), depending on the applied thermomechanical processing. There is disagreement in the literature and between major aluminium companies whether Cu or excess Si is most harmful for IGC susceptibility, and the IGC mechanism of 6000-series alloys in this context is not well understood. This work investigates the effect of composition and thermomechanical history on IGC susceptibility systematically and by use of advanced characterisation methods and sheds light on the mechanism of IGC in 6000-series alloys in general.
The results show that Cu-free alloys are not susceptible to IGC. Excess Si causes superficial IGC, which is not deemed to be harmful to the integrity of the aluminium structure. In the presence of a small fraction of a percent of Cu, high IGC susceptibility is introduced in the underaged condition by segregation of a few nanometer thick Cu-rich film along the grain boundaries. Galvanic coupling between the Cu film and the solute depleted zone along the grain boundary gives rapid IGC propagation. In the maximum hard T6 temper, the material becomes coincidentally resistant to all forms of localised corrosion by coarsening of the grain boundary Cu into discrete AlMgSiCu phases. Further coarsening by overaging leads to pitting corrosion.


Major subject: Physical metallurgy.

Dr. lecture: Aluminium recycling - industrial opportunities and metallurgical challenges.

Thesis advisor: Professor, PhD Lars Arnberg.

Co-supervisors: Marisa Di Sabatino, SINTEF Materials and Chemistry.

Examination committee: Professor, Dr.ing. Arne Kristian Dahl, Materials Engineering, The University of Queensland, Australia.

Summary: In the past few decades numerous studies on microporosity formation have been reported. However, several aspects of this subject are not fully understood. The motivation behind Shahid Akhtar’s doctoral thesis was to improve the knowledge of porosity formation and its effect on the mechanical properties of aluminium castings. The study concentrated on the effect of hydrogen and oxide defects on microporosity of aluminium-silicon alloy castings. The main focus of the work was to control the variables during melt preparation, casting and solidification and keep the experimental variations at minimum. The data obtained from Shahid Akhtar’s work where casting variables were controlled in a highly reproducible way has been used for evaluating the results of simulated microporosity distributions using recently developed state-of-art modelling approaches. The knowledge gained was also applied in an industrial foundry for routine melt quality control, and the cause of a high rejection rate was successfully identified and reduced.


Major subject: Electrochemistry.

Dr. lecture: Electrochemical production of rare earth metals and alloys.

Thesis advisor: Professor, Dr.ing. Geir Martin Haarberg.

Co-supervisors: Ana Maria Martinez, SINTEF Materials and Chemistry.

Examination committee: Professor Hongmin Zhu, University of Science and Technology Beijing, China.

Professor Toru H. Okabe, Institute of Industrial Science, The University of Tokyo, Japan.

Professor Emeritus, Dr.techn. Jomar Thonstad (chair).

Summary: The background for the work was that the current production process for titanium is very costly, labour intensive and energy demanding. In Norway we have many titanium rich raw materials, such as ilmenite and rutile, combined with a high competence and long tradition for metal production by electrolysis.

The chosen method for investigating a new electrochemical process was based on preparing titanium oxycarbide anodes by reducing and purifying titanium containing slag, followed by oxidising the anode to form dissolved titanium ions to be reduced at the cathode to produce titanium metal. The oxycarbide anode behaviour was studied in molten NaCl-KCl and NaCl-Na_3AlF_6 at temperatures around 800 °C. The existence of several different valencies of dissolved titanium complexes caused problems in establishing a procedure for efficient deposition of good quality titanium. Preliminary attempts to use a liquid alloy cathode based on Bi, Sn and Zn were promising.


Major subject: Electrochemistry.

Dr. lecture: Corrosion Fatigue of Aluminium Alloys.

Thesis advisor: Professor, PhD Kemal Nisancioglu.

Co-supervisor: Professor, Dr.philos Jan Ketil Solberg.

Examination committee: Professor Tekn. Dr. Jinshan Pan, Kungliga Tekniska högskolan, Stockholm, Sweden.

Dr. ing. Andreas Afseth, R&D Leader, Functional Surfaces, France.

Associate Professor, Dr.ing. Hilde Lea Lein (chair).
Summary: Lead is present as a trace element in most commercial alloys because it is a natural constituent of the bauxite ore. Bismuth may also be present, although not yet documented, because of its close proximity to Pb in the periodic table. Despite their presence at the ppm level, Pb and Bi segregate to the surface of the alloy by heat treatment at 600°C, a temperature of practical interest in relation to brazing and welding. The thesis investigates the mechanism of segregation of Pb and Bi to the surface of aluminium by heat treatment and the resulting changes in the electrochemical and corrosion properties of model binary AlPb and AlBi alloys. The effect of a third element, such as Cu, Fe, Mn, Zn or Si, commonly found as impurity element or alloyed with aluminium to improve mechanical properties, is also investigated.

Pb and Bi were shown to segregate in the form of nanosize metal particles and film, the latter at the oxide-metal interface, because the elements are unstable in the aluminium lattice due to their large atomic size. This result is in disagreement with the well-known phase diagrams for the AlPb and AlBi systems. Film segregation destabilizes the protective oxide leading to electrochemical activation of the aluminium surface in chloride environment. The particulate segregations do not have a similar effect. Activation has a detrimental effect in causing galvanic and filiform corrosion on aluminium. The effect is reduced by the added presence of noble elements Fe, Mn, Si and especially Cu. The effect can be exploited in reducing pitting corrosion susceptibility and production of active aluminium anodes for cathodic protection and Al/air batteries and electrolytically etched aluminium capacitors.

Zhaohui Wang: **Aging of Si,N-bonded SiC sidewall materials in Hall-Héroult cells - Material characterization and computer simulation.**


Major subject: **Inorganic chemistry.**

Dr. lecture: Intercalation mechanisms and compounds of graphite and related materials.

Thesis advisor: Professor, Dr.ing. Tor Grande.

Examination committee: Professor Mario Fafard, Université Laval, Québec, Canada.

Dr.ing. Ole-Jacob Siljan, Hydro Aluminium, Porsgrunn, Norway.

Head of Department, Dr.ing. Arne Petter Ratvik (chair).

Summary: Si,N-bonded SiC materials have become the state of the art sidewall materials in aluminium electrolysis cells due to high thermal conductivity and high oxidation resistance compared to carbon materials. Although the materials has a high chemical stability, the materials age over time and this work aimed to investigate the mechanisms leading to degradation and to develop models based on finite element method to simulate the degradation of the sidewall. First, a thorough characterization of both pristine and used sidewall materials was carried out. It was found that the degradation in the upper part of the sidewall was dominated by oxidation leading to formation of SiO or SiON. The oxidation process resulted in increased porosity, detachment of SiC grains and reduced mechanical strength. On the other hand the lower part of the sidewall the oxidation was accompanied by the diffusion of sodium into the sidewall resulting in the formation of sodium silicate phases. The reaction caused a decrease in the porosity and a reduced thermal conductivity of the material. The thermal conductivity of these porous materials was thoroughly discussed taking into account effects of microstructure related features such as grain-boundary resistance pore-shape and pore-orientation factor. The diffusion of sodium through the cathode to the sidewall was simulated yielding quantitative agreement with the amount of sodium found in spent pot lining. The simulation established that diffusion of sodium is dominated by solid state diffusion in the cathode, while in the sidewall diffusion take place by diffusion of gaseous sodium.

Kati Tschöpe: **Degradation of cathode lining in Hall-Héroult cells - Autopsies and FEM simulations.**


Major subject: **Inorganic chemistry.**

Dr. lecture: Characterization of carbon materials with emphasis on cathode materials.

Thesis advisor: Professor, Dr.ing. Tor Grande.

Examination committee: Dr. Fred Brunk, Dr. C. Otto GmbH, Bochum, Germany.

Dr.ing. Ole-Jacob Siljan, Hydro Aluminium, Porsgrunn, Norway.

Head of Department, Dr.ing. Arne Petter Ratvik (chair).

Summary: The chemical degradation of cathode lining in aluminium electrolysis cells has been a subject of research in several decades. The aging of the cathode lining will over time change the thermal balance of the cell and possibly lead to failure. The objective of this work was to confirm degradation mechanisms proposed previously and to develop finite element method simulation of the cathode lining to possibly find a qualitative explanation for the well known cathode heave phenomenon. Autopsies of spent pot lining confirmed the common understanding of the dominant chemical reactions taking place in the refractory lining. The characterization of the spent pot lining materials further revealed that the actual sequence of materials found from the bottom of carbon cathode and further into the refractory lining reflected both the reactions which had taken place due to the penetration of bath component.
through the cathode, but also the reverse thermal gradient introduced during cooling of the spent cathode lining. Moreover, two reactions fronts in the refractory lining were demonstrated, the first was due to the diffusion of elemental sodium diffusing through the carbon cathode and the second due to the penetration of the molten bath. A modified reaction mechanism for the chemical degradation of the refractory lining was presented and a degradation map due to sodium attach was constructed. A two dimensional finite element method simulation of the cathode lining was developed. First the evolution of the thermal gradient in the lining was simulated based on physical data of the lining materials. Secondly, the mechanical stresses build up in the lining due to the thermal gradients were simulated. The effect of chemical expansion due to sodium intercalation in the carbon cathode was also investigated. The work show that the driving force for the heaving of cathode with a high degree of graphitization is mainly due to the thermal gradient in the lining.
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<tr>
<td>Magnus Rotan</td>
<td>Phase composition, microstructure and resistance to attrition of alumina-based supports for Fischer-Tropsch catalysts.</td>
</tr>
<tr>
<td>Espen Andre Rudberg</td>
<td>Oxygen exchange on functional oxide membranes.</td>
</tr>
<tr>
<td>Stein Rervik</td>
<td>Migration effects in prebaked anodes.</td>
</tr>
<tr>
<td>Stian Seim</td>
<td>Slag properties and phase relations in the Ti-industry.</td>
</tr>
<tr>
<td>Esma Senel</td>
<td>Effect of trace elements on surface properties of aluminium alloys.</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
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<tr>
<td>-----------------------------</td>
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<tr>
<td>Malin Sletnes</td>
<td>Wet chemical based methods for deposition of quantum dot structures and production of hybrid materials for enhanced solar cell efficiency.</td>
</tr>
<tr>
<td>Dmitry Slizowskii</td>
<td>Use of waste materials for ferromanganese production.</td>
</tr>
<tr>
<td>Karl Gunnar Solheim</td>
<td>The effect of microstructure on the properties of 13%Cr flowlines in operation.</td>
</tr>
<tr>
<td>Isac Sorin</td>
<td>Metal powder project - “metal printing process”.</td>
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<tr>
<td>Sapthagireesh Subbarayan</td>
<td>Nanostructuring of light metals; aluminium-magnesium bi-materials.</td>
</tr>
<tr>
<td>Tor Olav Leveng Sunde</td>
<td>Thin films of transparent conducting oxides by wet chemical methods.</td>
</tr>
<tr>
<td>Suwarno Suwarno</td>
<td>Metal hydrides for hydrogen sorption enhanced reactor.</td>
</tr>
<tr>
<td>Guttorm Ernst Syvertsen</td>
<td>Synthesis and characterisation of nanostructured fuel cells based on proton conductors.</td>
</tr>
<tr>
<td>Juan Tan</td>
<td>Segregation of surface activating trace elements indium and tin by heat treatment of model aluminium alloys.</td>
</tr>
<tr>
<td>Katharina Teichmann</td>
<td>The effect of deformation on the precipitation behaviour of Al-Mg-Si-alloys.</td>
</tr>
<tr>
<td>Morten Tjelta</td>
<td>Photoelectrochemical characterization of semiconductor electrodes.</td>
</tr>
<tr>
<td>Knut Omdal Tveito</td>
<td>Modelling of macrosegregation formation during Direct-Chill casting of aluminium alloys – influence of grain transport and deformations.</td>
</tr>
<tr>
<td>Ning Wang</td>
<td>Softening behaviour of recycle based aluminium alloys during iso-thermal and non-isothermal annealing and concurrent precipitation.</td>
</tr>
<tr>
<td>Sophie Beatrice Weber</td>
<td>Ceramic thermal barrier coatings.</td>
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<tr>
<td>Saijun Xiao</td>
<td>Gas anode for metal electrowinning.</td>
</tr>
<tr>
<td>Qinglong Zhao</td>
<td>The influence of Mn, Fe and Si on work hardening of aluminium alloys.</td>
</tr>
<tr>
<td>Haitao Zhou</td>
<td>Synthesis and characterization of nanostructured materials for improved capacity in Li-ion batteries.</td>
</tr>
<tr>
<td>Agnieszka Zlotorowicz</td>
<td>Electro catalysts for novel high-temperature PEM water electrolysis.</td>
</tr>
<tr>
<td>Øyvind Østrem</td>
<td>Cathode wear in industrial aluminium electrolysis cells.</td>
</tr>
<tr>
<td>Vegar Øygarden</td>
<td>Chemical compatibility, degradation and performance of cathode material in proton conducting fuel cells.</td>
</tr>
<tr>
<td>UiF Roar Aakenes</td>
<td>Industrialising of the Hymen Bonding method – from prototype to commercial process.</td>
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</table>
### PhD projects co-supervised in other departments

<table>
<thead>
<tr>
<th>Name and Title</th>
<th>Thesis advisor</th>
</tr>
</thead>
</table>
| **Sarah Bernardis**  
Engineering impurity behaviour on the micron-scale in metallurgical-grade silicon production. | Kenneth Russel, Tonio Buonassisi  
(Massachusetts Institute of Technology, Boston, USA) and Marisa Di Sabatino. |
| **Tina Kristiansen**  
Aerogels; a new class of materials for catalytic applications. | David Graham Nicholson (Department of Chemistry, NTNU) and Mari-Anns Einarssrud. |
| **Jinbao Lin**  
SPD by CEC of magnesium alloys. | Qudong Wang (Shanghai Jiao Tong University, China) and Hans Jørgen Roven. |
| **Efstathios Ntafalias**  
Investigation on the possibility to control water permeability of concrete. | Petros G. Koutsoukos (Department of Chemical Engineering, University of Patras, Patras, Greece) and Terje Østvold. |
| **Maria Psarrou**  
Protecting soil from water erosion through precipitation of calcium phosphate. | Petros G. Koutsoukos (Department of Chemical Engineering, University of Patras, Patras, Greece) and Terje Østvold. |
| **Peter Schmidt**  
Hollow castings produced by LPDC. | Jürgen Bast (T. U. Bergakademie, Freiberg, Germany) and Lars Arnberg. |
| **Anna Smirnova**  
Hydrogen diffusion in super martensitic 13% Cr and X70 pipeline steels. | Roy Johnsen (Department of Engineering Design and Materials) and Kemal Nisancioglu. |
| **Joalet Steenkamp**  
Lining materials in the manganese industry. | Chris Pistorius (Carnegie Mellon University, Pittsburgh, USA) and Merete Tangstad. |
| **Ragnhild Kjæstad Sæterli**  
Electronic structure of thermoelectric and ferroelectric materials – Advanced transmission electron microscopy studies. | Randi Holmestad (Department of Physics, NTNU) and Knut Marthinsen. |
| **Nuria Tavera Valero**  
Corrosion by degradation products in amine-based CO₂ capture units. | Hallvard Svendsen (Department of Chemical Engineering, NTNU) and Kemal Nisancioglu. |
| **Ida Westermann**  
Work hardening behaviour of age-hardenable Al-Zn-Mg-(Cu) alloys. | Odd Sture Hopperstad (Department of Structural Engineering, NTNU), Bjørn Holmedal and Knut Marthinsen. |
| **Fredrik Widerøe**  
Novel extrusion technology and simulations. | Torgeir Welo (Department of Engineering Design and Materials, NTNU) and Hans Jørgen Roven. |
| **Zhipeng Zeng**  
Study on the ECAP process for commercially pure titanium. | Stefan Jonsson (Department of Materials Science and Engineering, KTH, Stockholm, Sweden) and Hans Jørgen Roven. |

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*Photo: Terje Hals  
Cross-section of aluminium profile produced by new innovation technology (screw extrusion of aluminium).*
COURSE PROGRAM

Descriptions of the courses offered at the Department of Materials Science and Engineering are included in the University Course Catalogue that can be obtained from Student and Academic Section, NTNU. The present survey lists the courses given by our scientific staff.

<table>
<thead>
<tr>
<th>Course no.</th>
<th>Semester</th>
<th>Title</th>
<th>Credits in parenthesis</th>
<th>Lectures and exercise coordinators</th>
<th>Passed/Started</th>
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<tbody>
<tr>
<td>TMT4106</td>
<td>S</td>
<td>General Chemistry (7.5)</td>
<td>M. Ystenes</td>
<td>187/224</td>
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<tr>
<td>TMT4110</td>
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<td>I. Kaus, T. Mokkelbost</td>
<td>121/142</td>
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<tr>
<td>TMT4120</td>
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<td>T. Grande</td>
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<tr>
<td>TMT4130</td>
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<td>M.-A. Einarsrud</td>
<td>91/96</td>
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<tr>
<td>TMT4166</td>
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<td>Experimental Materials- and Electro Chemistry (7.5)</td>
<td>F. Seland, K. Wiik, G.M. Haarberg</td>
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<tr>
<td>TMT4175</td>
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<td>Materials Technology 2 (7.5)</td>
<td>Ø. Grong, K. Marthinsen, O. Lohne</td>
<td>30/30</td>
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<tr>
<td>TMT4206</td>
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<td>R.E. Aune</td>
<td>19/23</td>
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<tr>
<td>TMT4208</td>
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<tr>
<td>TMT4210</td>
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<td>Material and Process Modelling (7.5)</td>
<td>K. Marthinsen</td>
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<td>TMT4215</td>
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<td>Casting (7.5)</td>
<td>L. Arnberg</td>
<td>27/28</td>
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<td>TMT4245</td>
<td>S</td>
<td>Functional Materials (7.5)</td>
<td>F. Vullum-Bruer</td>
<td>21/24</td>
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<tr>
<td>TMT4252</td>
<td>S</td>
<td>Electrochemistry (7.5)</td>
<td>G.M. Haarberg</td>
<td>38/44</td>
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<tr>
<td>TMT4260</td>
<td>S</td>
<td>Phase Transformations in Metals (7.5)</td>
<td>K. Marthinsen, Ø. Grong</td>
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<tr>
<td>TMT4266</td>
<td>S</td>
<td>Materials Techn.-Forming Light Metals (7.5)</td>
<td>B. Holmedal, O. Jensrud, O. Reiso</td>
<td>7/8</td>
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<tr>
<td>TMT4275</td>
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<td>Thermodynamics and Phasediagrams (7.5)</td>
<td>M. Tangstad</td>
<td>25/27</td>
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<tr>
<td>TMT4285</td>
<td>S</td>
<td>Hydrogen Techn., Fuel/Solar Cells (7.5)</td>
<td>S. Sunde</td>
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<tr>
<td>TMT4300</td>
<td>S</td>
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<td>J.K. Solberg, J. Hjelen</td>
<td>45/50</td>
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<tr>
<td>TMT4500</td>
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<td>Materials Technology, special project (15.0)</td>
<td>Several teachers at the department</td>
<td>12/13</td>
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<tr>
<td>TMT4850</td>
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<td>Experts in Team (7.5)</td>
<td>L. Kolbeinsen</td>
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<tr>
<td>TMT4900</td>
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<td>Master thesis, Spec. in Materials Chemistry and Energy Techn. (30.0)</td>
<td>Several teachers at the department</td>
<td>12/12</td>
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<tr>
<td>TMT4905</td>
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<td>Master thesis, Materials Techn. (30.0)</td>
<td>Several teachers at the department</td>
<td>27/27</td>
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<tr>
<td>TMT5100</td>
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<td>Electrolysis of Light Metals 2 (7.5)</td>
<td>K.A. Paulsen</td>
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<tr>
<td>TMT4100</td>
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<td>TMT4112</td>
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<td>K. Wiik</td>
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<tr>
<td>TMT4115</td>
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<td>T. Grande</td>
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<tr>
<td>TMT4122</td>
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<td>General and Organic Chemistry Laboratory Course (7.5)</td>
<td>S. Hakvåg, H.L. Lein</td>
<td>81/82</td>
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<tr>
<td>TMT4145</td>
<td>A</td>
<td>Ceramic Engineering (7.5)</td>
<td>M.-A. Einarsrud</td>
<td>36/36</td>
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<tr>
<td>TMT4155</td>
<td>A</td>
<td>Heterogen Equilibria/Phase Diagrams (7.5)</td>
<td>T. Grande, M. Tangstad, A. Solheim</td>
<td>65/74</td>
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<tr>
<td>TMT4171</td>
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<td>Materials Technology 1 (7.5)</td>
<td>G. Tranell, H.J. Roven, L. Arnberg</td>
<td>30/30</td>
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<tr>
<td>TMT4185</td>
<td>A</td>
<td>Materials Technology (7.5)</td>
<td>L. Arnberg, Ø. Grong, M. Di Sabatino, B. Holmedal</td>
<td>78/81</td>
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<tr>
<td>TMT4190</td>
<td>A</td>
<td>Applied Materials Technology (7.5)</td>
<td>O. Lohne, K.H. Holthe</td>
<td>24/27</td>
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<tr>
<td>TMT4222</td>
<td>A</td>
<td>Mechanical Properties of Metals 1 (7.5)</td>
<td>B. Holmedal</td>
<td>18/20</td>
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<tr>
<td>TMT4240</td>
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<td>Microstructure and Properties of Metals (7.5)</td>
<td>J.K. Solberg</td>
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<td>Code</td>
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<td>F. Seland, G.M. Haarberg</td>
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<td>TMT4255</td>
<td>A</td>
<td>Corrosion and Corrosion Protection (7.5)</td>
<td>K. Nisancioglu, R. Johnsen</td>
<td>47/48</td>
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<tr>
<td>TMT4260</td>
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<td>Phase Transformations in Metals (7.5)</td>
<td>K. Marthinsen, Ø. Grong</td>
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<td>TMT4280</td>
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<td>Extractive Metallurgy (7.5)</td>
<td>L. Kolbeinsen</td>
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<tr>
<td>TMT4292</td>
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<td>Materials- and Surface Chemistry (7.5)</td>
<td>S. Sunde, K. Wiik</td>
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<tr>
<td>TMT4305</td>
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<td>Electrometallurgy (7.5)</td>
<td>G. Tranell, M. Tangstad, H. Tveit</td>
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<td>TMT4320</td>
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<td>Nanomaterials (7.5)</td>
<td>F. Vullum-Bruer</td>
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<tr>
<td>TMT4325</td>
<td>A</td>
<td>Refining and Recycling of Metals (7.5)</td>
<td>R.E. Aune</td>
<td>14/14</td>
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<tr>
<td>TMT4500</td>
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<td>Several teachers at the department</td>
<td>38/38</td>
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<td>Several teachers at the department</td>
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<tr>
<td>MT8107</td>
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<td>Semiconductor Electrochemistry (11.0)</td>
<td>S. Sunde</td>
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<tr>
<td>MT8201</td>
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<td>Advanced Electrometallurgy (7.5)</td>
<td>G. Tranell, M. Tangstad</td>
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<tr>
<td>MT8207</td>
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<td>Electron Microscopy (7.5)</td>
<td>J.K. Solberg</td>
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<td>MT8216</td>
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<td>Recrystallization and Texture (7.5)</td>
<td>K. Marthinsen</td>
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<td>MT8301</td>
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<td>Carbon Materials Technology (7.5)</td>
<td>M. Særlie</td>
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<tr>
<td>MT8306</td>
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<td>Cement Semestry (7.5)</td>
<td>H. Justnes</td>
<td>10/10</td>
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<td>MT8308</td>
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<td>T. Grande</td>
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<td>MT8108</td>
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<td>Mass Transfer (7.5)</td>
<td>K. Nisancioglu</td>
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<td>MT8205</td>
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<td>Ø. Grong</td>
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<tr>
<td>MT8210</td>
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<td>L. Arnberg</td>
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<td>MT8213</td>
<td>A</td>
<td>Modelling and Simulation of Materials Microstructure and Properties (7.5)</td>
<td>K. Marthinsen</td>
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<td>MT8215</td>
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<td>Dislocation Theory Applied to Thermo-Mechanical Treatments of Metals (7.5)</td>
<td>B. Holmedal</td>
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<td>MT8307</td>
<td>A</td>
<td>Thermodynamics of Materials (7.5)</td>
<td>T. Grande</td>
<td>14/14</td>
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</tbody>
</table>
M.Sc. STUDENTS

Master of Science in Materials Technology (5 years)

Autumn semester
3rd year
Martin Alm
Jo Aunemo
Randi Berggren
Kim Blommedal
Ingeborg Brede
Magnus Bru
Aleksander Coucheron
Lars Eriksen
Kristian Fallrø
Espen Fanavoll
Trond Arne Hassel
Erik Hem
Øystein Høgsand
Audun Johanson
Kristian Berg Keilen
Pernille Kildahl
Thomas Loland
Thong Nguyen
Bodil Pedersen
Trygve Schanche
Jaran Sele
Per Fredrik Tunestam
Asbjørn Ulvestad
Tobias André Eidsør Viken

4th year
Arya Bastiko
Audun Bilsbak
Erik Bjartnes
Ann Kristin Bjerkelund
Jan Gaute Frydendahl
Preben Kjos Gabrielsen
Stian Gurrik
Kristoffer Werner Hansen
Thomas Holm
Hans Husby
Torunn Hjulstad Iversen
Hedda Nordby Krogstad
Kristian Larsen
Thomas Larsen
Martin Borlaug Mathisen
Gunnar Sande
Aleksander Rudolf Stoss
Espen Oldeide Strandheim
Erlend Sælberg
Astri Samme
Andreas Torstensen
Jørund Yangskåsen

5th year
Eirik Belland
Tor Arne Buberg
Jens Erik Davidsen
Sofie Drågen
Solveig Egtvedt
Anne-Jorunn Enstad
Ruth Oltedal Herikstad
Håkon Trygve Strøm Jørgensen
Steinar Jørstad
Steinar Lauvdal
BJarte Åsveit Nygård
Petter Ottesen
Jonas Hovde Pedersen
Mads Reiten
Trine Viveke Salvesen

Graduated Master of Technology students

Spring semester
Patrick Alknes
Vegard Andersen
Svein Prestrud Astad
Olav Kigen Bjerring
Lars-Petter Bjørkeng
Tor Henning Bjørnå
Kristian Karlsen Brede
Thomas Brynjulfson
Sindre Bunkholt
Kristian Nyborg Dahl
Ørjan Aronsen Ellingsen
Alexander Rise Gallala
Ann Leni Haugstad
Kristoffer Klægvetd
Amund Nordli Løvik
Ingeborg Johannesen Odland
Richard Havgå Nilssen
Richard Havgå Ringstad
Christoffer Boots Demez Rosario
Eirik Andersen Rotevatn
Magnus Skjellerudsvåen
Gunstein Skomedal
Hans Magne Torseth
Knut Omdal Tveito

Master of Science in Chemistry and Biotechnology, Specialization in Materials Chemistry and Energy Technology

Autumn semester
3rd year
Kjetil Andersen
Elin Schonhovd Dæhlen
Dehila Eide
Kari Forthun
Kristine Mari Lund Hansen
Marius Hansen
Kenneth Hole
Hanne Ekeberg Hove
Håvard Husby
Catalina Musinio
Silje Kathrin Nedsdal
Henriette Sæd Næss
Eva Rise
Siri Marie Skaftun
Sandra Helen Skjærø
Belma Talic
Anne Elisabeth Thorstensen
Sophie Caroline Utne
Tormod Østmo

4th year
Helene Bjerke
Kristin Roberta Brandt
Lene Marie Lysgaard Bristel
Marthe Emilie Melandse Buan
Tone Beate Heiaas Bukholm
Line Teigen Døssland
Øystein Gullbrekken
Cathrine Selina Holager
Lise Jemblie
Ingrid Krummen
Dan Sætre Lagergren
Ingrid Mattson
Christine Måinichen
Anne Marthe Nymark
Gerhard Henning Olsen
Mari Lovise Torp
Marius Sunde
Arne Hetland Tvedt
Stine Lund Walø
Sandra Wika
5th year
Inga Askestad
Inger Marie Bjørnevik
Kai Erik Ekstrøm
Jarl Erik Morsund Flatøy
Øystein Gretting
Ragnhild Helene Gulbrandsen
Håkon A. Holm Gundersen
Sigrid Lædre
Håvard Melnäs
Anita Reksten
Kristian Grøtta Skorpen
Halldan Kristoffer Småbråten
Camilla Sommerseth
Øyvind Sunde Sortland
Jørgen Svendby
Magnus Weberg
Espen Tjønneland Wefring
Ole Jørgen Østensen
Åsne Århus

Graduated Master of Technology students
Spring semester
Henrik Klitgaard Bostad
Torbjørn Cederløv
Ingelin Clausen Endsjø
Helle Ervik Fossheim
Mette Grorud
Victoria Leivestad
Urd Sæther Olden
Solveig Røjkjær
Marianne Charlotte Simonsen
Ragne Marie Skarra
Ingrid Stamnes
Henrik Åsheim

Master of Technology in Materials Technology (2 years)
(Master Programme in Materials Technology for Engineers)
Autumn semester
1st year
Stig Rune Berg
Morten Dahlstrøm
Jonas Einan
Martin Fossum
Christian Grødahl

Graduated Master of Technology students
Spring semester
Johanna Hansen
Phillip Juven
Vivian Koen
Lasse Roaas
Truls Sætran
Trond Erik Tollefsen
Petter Wibe
Petter Gire Døhlie (part time)
Anders Welde Gjennes (part time)

2nd year
Eivind Strand Dahle
Knut Ove Dahle
Atle Korsnes Lian
Marius Slagsvold

Graduated Master of Technology students
Spring semester
Line Sunde Lilleby
Zeinab Sharifi

Master of Science Program in Silicon and Ferroalloy Production
Autumn semester
1st year
Nicholas Smith
Shawn Wilson (Canada) (part time)

Graduated Master of Technology students
Spring semester
Joseph Prince Armoo (Ghana)
Thomas Hartmut Ludwig (Germany)

Master of Science Program in Light Metals Production
Autumn semester
1st year
Maureen Bangu Isiko (Uganda)
Dian Mughni Fe Muhaimin (Indonesia)
Ahmet Oguz Tezel (Turkey)
Shuang Zhang (China)

Graduated Master of Technology students
Spring semester
Stephen Caesar Lobo (Canada)
# Electrochemistry

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<tr>
<td>Henrik Klitgaard Bostad</td>
<td>Professor Geir Martin Haarberg</td>
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<tr>
<td>Electrochemical production of carbon nanotubes from molten salts and their use in lithium-ion batteries.</td>
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<td>Ingelein Clausen Endsjo</td>
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<tr>
<td>High temperature PEM fuel cell for direct conversion of small organic molecules for electrical energy.</td>
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<td>Kristoffer Kløgetvedt</td>
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<td>Effect of lead, tin, magnesium and gallium on anodic activation of aluminium alloys.</td>
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<tr>
<td>Mette Grorud</td>
<td>Professor Svein Sunde</td>
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<td>Synthesis and characterization of electrocatalysts for oxidation of small organic molecules in fuel cells.</td>
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<td>Professor Kemal Nisancioglu</td>
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<td>AC corrosion of pipeline steel.</td>
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<tr>
<td>Solveig Rørkjær</td>
<td>Professor Svein Sunde</td>
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<td>Porous silicon as rear side reflectors for very thin silicon solar cells.</td>
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<td>Torstein Skarsgard</td>
<td>Associate Professor Frode Seland</td>
</tr>
<tr>
<td>Ingrid Stamnes</td>
<td>Professor Kemal Nisancioglu</td>
</tr>
<tr>
<td>AC corrosion of pipeline steel.</td>
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<tr>
<td>Henrik Åsheim</td>
<td>Professor Geir Martin Haarberg</td>
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<td>Cathodic deposition of titanium in chloride melts.</td>
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# Extractive Metallurgy

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<td>Eirik Andersen Rotevatn</td>
<td>Professor Merete Tangstad</td>
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<td>Gunstein Skomedal</td>
<td>Adjunct Associate Professor Eivind Øvrelid</td>
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<tr>
<td>Effect of slurry parameters on material removal rate and surface quality in multi wire sawing of silicon wafers.</td>
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<td>Magnus Skjellerudsvæen</td>
<td>Professor Ragnhild E. Aune</td>
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<td>Zr&lt;sub&gt;55&lt;/sub&gt;Cu&lt;sub&gt;30&lt;/sub&gt;Ni&lt;sub&gt;30&lt;/sub&gt;Al&lt;sub&gt;10&lt;/sub&gt; bulk materials metallic glass – preparation of amorphous metal and the possibility of its application as articulating surface material in an artificial hip joint.</td>
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# Inorganic Chemistry

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<td>Torbjørn Cederlev</td>
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<td>Title</td>
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<td>Amund Nordli Løvik</td>
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<td><strong>Supervisor</strong></td>
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<td>Svein Prestrud Astad</td>
<td>Investigation of M-A constituent and crack growth in an arctic steel.</td>
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<tr>
<td>Olav Kigen Bjering</td>
<td>In situ EBSD-characterisation of crack propagation in a HSLA steel at -60 °C.</td>
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<tr>
<td>Tor Henning Bjørnå</td>
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<tr>
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<tr>
<td>Joseph Prince Armoo</td>
<td>Professor Geir Martin Haarberg</td>
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<tr>
<td>Thomas Hartmut Ludwig</td>
<td>Professor Lars Arnberg</td>
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<td>Stephen Ceasar Lobo</td>
<td>Professor Leiv Kolbeinsen</td>
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**MASTER OF SCIENCE PROGRAMME IN LIGHT METALS PRODUCTION**

**MASTER OF SCIENCE PROGRAMME IN SILICON AND FERROALLOY PRODUCTION**

From the competition “Best knife” among students taking the course TMT4190 Applied Materials Technology (fall 2010). Fredrik Haakonsen is responsible for the presentation.
EXTRACURRICULAR ACTIVITIES,
Honours, Participation in Courses, Conferences, Lectures and Study Visits

Lars Arnberg
Lars Arnberg is an Affiliate Professor at the Department of Mechanical Engineering, Worcester Polytechnic Institute, USA.

IMT Solidification and Casting Group Seminar, Oppdal, Sweden, March 11-12, 2010.

NADIA Final project meeting Brescia, Italy, April 14-15, 2010.


TU Bergakademie Freiberg, Germany, June 3-4, 2010. Opponents on two PhD dissertations.

EUMRS, Strasbourg, France, June 7-11, 2010.

FME project meeting, Porsgrunn, Norway, August 24, 2010.


Osaka University, Japan, September 23, 2010.


Tohoku University, Japan, September 28-29, 2010. Project discussions.

EnginSoft, Padova, Italy, October, 4-5, 2010. Project discussions.

CSSC4, Taipei, Taiwan, October 26-29, 2010. Invited lecture on: “Comparison of ingot- and solar cell properties between a compensated and an electronic grade silicon feedstock”.

University of Queensland, Australia, November 22-26, 2010. Invited lecture on: “Materials research at NTNU: Aluminium solidification imaging solar cell silicon development”.

Elena Dal Martello

Marisa Di Sabatino


SEEIT workshop, Freiburg, Germany, September 30, 2010. Presentation on: “Norwegian University of Science and Technology – Education and Research strategies”.

Norwegian - German Group Seminar on Solar Cell Silicon, Trondheim, Norway, October 4-6, 2010. Presentation on: “Research on PV-Si crystallization and characterization laboratories at IMT/NTNU”.


“Party of Five”-Meeting on the CHINOR framework, Shanghai, China, October 20-22, 2010. Presentation on: “NTNU’s research work in the area of silicon solar cells”.

Xiamen University, Xiamen, China, October 24-26, 2010. Visit and seminar.


Mari-Ann Einarsrud


Evaluation of Chemistry in Norway, DNVA, Oslo, Norway, June 1, 2010.


Arne Espelund
Røros Rotary, Røros, Norway, February 11, 2010. Presentation on: “Røros og Ågordo”.

Trondhjems polytekniske forening, Trondheim, Norway, February, 17, 2010. Presentation on: “Kobbersmelting i Trøndelag”.

“Jernhelg” arranged by Nore og Uvdal kommune, Numedal, Norway, June 5-6, 2010. Presentation, inspection and more.


Røros, Norway, August 18, 2010. Guide at an excursion to a medieval bloomery in Røros, arranged by the local historical association.

Næs Jernverksmuseum, Tvedestrand, Norway, August 26, 2010. Presentation on: “Jernet i Telemark”.

Vitforum, NTNU, Trondheim, Norway, August 31, 2010. Presentation on: “Eldre jernalder i Trøndelag”.

Stiklestad, Norway, October 6, 2010. Lecture at Stiklestad National Museum about the Heglesvollen site, followed by a field trip one week later.

Rørosmuseet, Røros, Norway, October 10, 2010. Presentation on: “Røros og de andre kobberverka i Norge”.

NTNU, Trondheim, Norway, October 22, 2010. Lectures about carbon control in early ironmaking at seminars among chemists and physicists, arranged by Professor emeritus R. Tunold and Professor K. Olaussen.


Visited anew the copper city Ågordo in Italy in order to develop cooperation with the museum in Røros.

Hired by the museum in Røros with the aim to improve the presentation of science and technology. Suggestions delivered in December.

Field trip with Selbu and Tydal Historielag to the Roman age bloomery at Blesterbekken in Tydal.

With Meråker Historielag to the copper smelting site from the 14th century Kopperå and to the ruins of Gilså hytte from recent centuries.

Geir Martin Haarberg


National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA, February 23, 2010. Oral presentation. Study visit.


Hasan Güleryüz


Université de Franche-Comté, Besançon, France, May 19 - June 6, 2010. Study visit.

Stockholm University, Stockholm, Sweden, November 29 - December 4, 2010. Study visit.

Jarle Hjelen


JEOL, Eching, Germany, August 9-10, 2010. Visit.

RISØ DTU, National Laboratory for Sustainable Energy, Materials Research Division, Riso, Denmark, August 12, 2010. Presentation on: “EBSD activities at DMSE”.


Department of Materials Science and Engineering, NTNU, Trondheim, Norway. Administrated the purchase and installation of a high current field emission scanning electron microscope, Hitachi SU-6600. The equipment was installed in December 2010.

EXTRACURRICULAR ACTIVITIES


Xiamen, China, October 25, 2010. Study visit. Oral presentation.


Shanghai Chongqing, China, May 2010. Study visit with NTNU delegation. Visits and oral presentations at East China University of Science and Technology, Shanghai and Donghua University, Shanghai.

Kyoto and Tokyo, Japan, June 2010. Study visit with NTNU group.

Shanghai and Beijing, China, July - August, 2010. Study visit.

2nd International Round Table on Titanium Production by Electrolysis, Tromsø - Trondheim, Norway, September 19-22, 2010. Chairman and co-author.

Tokyo, Kyoto and Hyuga, Japan. Study visit and attending workshop in Hyuga. Two oral presentations.


Eli Beate Larsen

"IØ6501 Strategi og ledelse", NTNU Videre, Trondheim, Norway, Fall semester 2010. Course.

Otto Lohne

Meeting with Minister Trond Giske, NTNU, Trondheim, Norway, February 12, 2010. Presentation on: "Solar cell research at NTNU/SINTEF" (by Torstein Haarberg, SINTEF and Otto Lohne, NTNU).


Advisory board meeting, Arctic Energy Partners, Trondheim, Norway, April 12, 2010. Presentation on: "Solar cells – from quantity to quality".

"Ideas about wire sawing", Saw & slurry fundamentals – REC workshop, Porsgrunn, Norway, April 21, 2010.

Received a prize for research and teaching on silicon solar cell materials from Elkems forskningsfond on the PROSIN-conference in Kristiansand, Norway, May 26–27, 2010.


Knut Marthinsen

Member of the International Committee for the Joint International Conferences on Recrystallization and Grain Growth (ReX&GG), the International Committee for the International Conferences of Aluminium Alloys (ICAA) and member of the International Advisory Committee for THERMEC conferences (International Conference on Processing and Manufacturing of Advanced Materials).

Member (NTNU’s representative) in the Steering Committee for the BIP NFR projects “Nucleation Control for Optimized properties” and RIRA (Remelting and Inclusion Refining of Aluminium) and the NFR KMB project “Defect Engineering for Crystalline Silicon Solar Cells”.

Leader of the focus area “Light Materials” under the Strategic Area Materials (TSO Materials) at NTNU, and Deputy member to the Board of Research and PhD education at the Faculty of Natural Sciences and Technology, NTNU.

Project Leader for Strategic University Program (SUP): Innovation in light metals processing and manufacture involving the use of severe plastic deformation for nano-structuring, mechanical alloying and interfacial bonding (Improvement), a collaboration project between Dept. of Materials Science and Engineering (DMSE), Dept. of Physics (IFY), NTNU, and SINTEF Materials and Chemistry (2009-2013).

Participation in the NFR KMB MoReAL (Remelting and Inclusion Refining of Aluminium) bi-annual project meeting at NTNU/SINTEF March 3, 2010.

Participation at the NFR BIP KK (Nucleation Control for Optimized properties) project meeting at SINTEF Raufoss Manufacturing March 18-19, 2010.

Participation in the NTNU’s delegation (incl. NTNU Rectorate, Research leaders and Professors from NTNU’s strategic areas) to China, May-June, 2010, in connection with the World Expo 2010 in Shanghai, and to promote research and educational cooperation with key partner universities in China.

Seminar and discussions with key personell within the Materials Field at Shanghai Jiatong University, China, May 27, 2010. Presentation of the Department of Materials Science and Engineering, NTNU and own research interests and activities.

Seminar and discussions with key personell within the Materials Field at Chongqing University, China, May 31, 2010. Presentation of the Department of Materials Science and Engineering, NTNU, light metals research at NTNU/SINTEF and own research interests and activities.

Seminar and discussions with key personell at the Department of Materials Science and Engineering, Tsinghua University, Beijing, China, June 2, 2010. Presentation of the Department of Materials Science and Engineering, NTNU and own research interests and activities.
Visit to and strategic discussions with relevant key personnel at GRINM (General Res Inst. of Non-ferrous Metals), Beijing, China, June 3, 2010.

Visit to and strategic discussions with relevant key personnel at Univ. of Science and Technology, Beijing [USTB], China, June 3, 2010.

KMB BILAT (The Norwegian-Japanese Al-Mg-Si precipitation project) project seminar at Hydro AI, R&D Sunndal, Norway and at NTNU, Trondheim, Norway, June 6-8, 2010 in connection with visits of Prof. Sato (Tokyo Tech.), Prof. Matsuda and Prof. Ikeno (Toyama Univ.) to Hydro and NTNU/SINTEF.

Participation at the NFR BIP KK (Nucleation Control for Optimized properties) project meeting at Hydro AI, R&D Center, Sunndalsøra, Norway, June 14-15, 2010.

Hosting the BIP RIRA (Remelting and Inclusion Refining of Aluminium) bi-annual project meeting at NTNU/SINTEF, Trondheim, Norway, June 29-30, 2010.


Participation at the 12th International Conference on Aluminium Alloys [ICAA12], Yokohama, Japan, September 5-9, 2010. Participation in the International Committee meeting September 7, 2010 with a presentation of the NTNU/SINTEF candidacy to host ICAA14 in Trondheim in 2014. Co-author to five papers that was presented at the conference.

KMB BILAT (The Norwegian-Japanese Al-Mg-Si precipitation project) project seminar in Hakone, Japan, September 10-11, 2010.

Participation in the NFR KMB MoReAL [Remelting and Inclusion Refining of Aluminium] bi-annual project meeting at NTNU/SINTEF, Trondheim, Norway, October 7, 2010.

Participation in the NFR BIP RIRA [Remelting and Inclusion Refining of Aluminium] bi-annual project meeting at NTNU/SINTEF, Trondheim, Norway, November 24-25, 2010.

Participation in the SPD SUP Improvement workshop at “Hurtigruta” [Coastal liner] and in Kristiansund, Norway, December 14-15, 2010.


Referee for several renowned international journals in materials science and engineering with a peer review system.

Chiara Modanese

University of Milano Bicocca, Dept. Materials Science, Milano, Italy, October - November 2010. Study visit (experiments).

Kemal Nisancioglu

Kogakuin University, Tokyo, Japan, September 4, 2010. Invited lecture: “Significance of trace element segregation in corrosion of aluminium alloys”.

Visit to Prof. Ken’ichi Shimizu labs, Keio University, Yokohama, Japan, September 7, 2010.

Anodizers Research Conference, Kogakuin University, Tokyo, Japan, September 8, 2010. Invited lecture: “Nanofilm copper segregation as cause of intercrystalline corrosion of AlMgSi alloys”.

International Conference on Aluminium Alloys [ICAA12], Yokohama, Japan, September 5-9, 2010. Keynote lecture entitled: “Significance of trace element segregation in corrosion of aluminium alloys”.


Lars-Erik Owe
WELTEM project meeting, Trondheim, Norway, January 28-29, 2010.


Primolyzer-WELTEMP Workshop, DTU, Copenhagen, Denmark, November 16, 2010. Talk on: “Electro catalysts for PEM water electrolysers”.

Stian Seim
Department of Mining and Materials Engineering, McGill University, Montreal, Canada, April 12 – June 28, 2010. Study visit.

Sverre Magnus Selbach


Electroceramics XII, Trondheim, Norway, June 13-16, 2010. Lecture on: “Crystal structure and phase diagram of
oxygen hyperstoichiometric BiFe$_x$Mn$_{3-\delta}$O$_{3+\delta}$.

IMRCC XIX, Mexican Materials Research Society, Cancun, Mexico, August 15-19, 2010. Invited lecture on: “Point defects in BiFe$_x$Mn$_{3-\delta}$O$_{3+\delta}$ and Pb$_{x}$TiO$_{3-\delta}$: implications for thin films”.


Materials Research Society Fall Meeting 2010, Boston, MA, USA, November 29 - December 3, 2010. Poster on: “Phase diagram of oxygen hyperstoichiometric BiFe$_x$Mn$_{3-\delta}$O$_{3+\delta}$”.

Materials Research Society Fall Meeting 2010, Boston, MA, USA, November 29 - December 3, 2010. Invited lecture on: “Thermal expansion, chemical expansion, ferroelasticity and valence state of Mn in Sr-sbustituted LaMnO$_{3+\delta}$”.

Jan Ketil Solberg
Reviewer for International Journal of Impact Engineering.

Reviewer for Journal of Alloys and Compounds.

Administrator, Adjunct Professor position in Steel Materials, NTNU, Department of Materials Science and Engineering, Trondheim, Norway.


Statoil, Rotvoll, Norway, January 26, June 29 and August 27, 2010. Status meetings in Renergi-BIP project “An integrated process for hydrogen production and generation”.


REC, Singapore, March 24, 2010. Study visit, excursion leader for 3rd class master students.

Schlumberger, Singapore, March 25, 2010. Study visit, excursion leader for 3rd class master students.

Hydro Aluminium, Malaysia, March 26, 2010. Study visit, excursion leader for 3rd class master students.

Tor Olav Løveng Sunde


Guttorm Syvertsen


California Institute of Technology (Caltech), Pasadena, California, USA, August 11 - November 24, 2010. Study visit under the supervision of Prof. S. M. Haile, of the Solid State and Electroceramics Research Group.


Juan Tan


Workshop in modelling possibilities applied to trace element studies in Aluminium and it’s alloys, Trondheim, Norway, October 21, 2010. Lecture on: “Tin segregation by heat treatment”.


Jomar Thonstad
TMS Annual Meeting, Seattle, Washington, USA, February 14-18, 2010. Presentation on: “Terminating anode effects by lowering and raising the anodes. – A closer look at the mechanism.”
Slovak Technical University, Bratislava, Slovakia, April 22 and November 5, 2010. Project meetings.


AGH – University of Science and Technology, Krakow, Poland, June 14 and November 8, 2010. Project meetings.

Fride Vullum-Bruer

Sophie Weber

Kjell Wiik


Member Organizing committee Electroceramics XII-Conference, NTNU, Trondheim, Norway, June 13-16, 2010.

EULANEST-066 (European–Latin American Network for Science and Technology), Lisbon, Portugal, June 25-26, 2010. Project presentation (Project partner 5). Lecture on: "Energy conversion from renewable sources in solid oxide cells".

Terje Østvold
Project meetings with Statoil, Stjørdal and Rotvoll, Norway, on varying research projects January 11, February 4, March 11, September 9, 2010.

Project and board meetings related to "Sand Stabilisation and Water Proofing of Tunnels". This project is operated by the spin-off company Impermeable AS where Terje Østvold is the manager. Radcon Scandinavia, Oslo Norway, January 17, February 22, June 4, November 8, December 28, 2010. Project meetings.

International MultiScale courses.
2. Exprogroup AS Haugesund, September 7-9, 2010.
   a) For the corrosion group at Cenpes, November 10-12, 2010.
   b) At Petrobras University, Rio de Janeiro, November 29 - December 3, 2010.


Project meetings with Det Norske Oljeselskap, WeST group, and DuPont on steel surfacem treatment to avoid scale formation in oil wells, Trondheim, Norway, February 9 and March 11, 2010.

21st International Oil Field Chemistry Symposium, Geilo, Norway, March 14-17, 2010. Member of committee and session Chairman. Presentation on: "Understanding CaCO$_3$ precipitation during oil recovery".

Project meetings with Statoil and SINTEF Petroleum Research, on the understanding of scale formation under turbulent flow conditions, Stjørdal, Norway, May 4, 2010 and Bergen, Norway, October 6, 2010.

Project meetings with Statoil on sand stabilization, Stjørdal, Norway, May 4, August 17 and September 14, 2010.

Project meeting with STATOIL and M-I SWACO, May 4, 2010. Planning sand consolidation with the QNC technology developed by Impermeable AS and Temasi AS for well C15 on the Gullfaks Field.

Project meeting with Lundin Norway on scale prediction for the Krabbe Field. May 6 and June 3, 2010.

10th SRE International Conference on Oilfield Scale, Aberdeen, UK, May 26-27, 2010. Presentation on: "Re-development of the Frøy Field: Selection of the injection water".

ICE-HT, FORTH Patras, Greece, June 14-23, 2010. Study visit.

Project meetings with M-I SWACO on sand stabilization, Dynea, Lillestrøm, Norway, August 28, 2010.

Herriot-Watt University, Edinburgh, Scotland, on a "Distinguished Visiting Fellowship from The Royal Academy of Engineering" granted to Terje Østvold. Modelling reservoir reactions during water flooding in order to enhance oil recovery. September 13-24, 2010. Study visit.

Terje Østvold is a member of the TEKNA Oil field chemistry symposium board. Meeting in Oslo, Norway, October 19, 2010.


Consulting in Rio de Janeiro at Petrobras Research Centre with Francisco de Rosario from Petrobras, Prof. J. F. Cajaiba da Silvand, University Federal Do Rio de Janeiro, Institute of Chemistry and Prof. R. Damasceno, Institute of Cheistry, NAB on cooperation NTNU-SINTEF-Petrobras and the two research institutions. December 17, 2010.
The editor thanks

Johnsen for collecting the administrative data and taking care of the process of printing the report.

Skipsnes AS for printing.

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Annual report for
Department of Materials Science and Engineering
Norwegian University of Science and Technology
NO-7491 Trondheim, Norway
Internet address: http://www.ntnu.edu/mse

EXTRACURRICULAR ACTIVITIES

Cooperation with SINTEF Petroleum Research. Project meetings and reporting on running projects. A series of meetings during the year at Statfjord, Rovnoy and Sjøsuldsfjorden, Norway.

Harald A. Bye

Harald A. Bye is Chairman of the Technical Committee, ISO / TC 226 (Materials for the Aluminium Industry).


The Norwegian Academy of Technological Sciences, Oslo, Norway, March 6, 2010. Industrial Council Meeting.


Non-Ferrous Metals - 2010, Krasnoyarsk, Russia, September 2-4, 2010. Lecture on: “Power failure, temporary pot shutdown, restart and repair”.

Alstahaug Torgrett, Mosjøen, Norway, October 5-6, 2010. Judge.


Norsk Standard, Oslo, Norway, November 17, 2010. Project meeting, ISO.

Vegar Øygarden

NorFERM symposium, Storeås Gjestegård, Kongsvinger, Norway, April 12-14, 2010. Presentation on: “Symposium on high temperature proton and mixed proton electron conductors for future energy technologies”.


Summer School: Ceramics membranes for green chemical production and clean power generation, Valencia, Spain, September 8-10, 2010.

Photo: Pål Ulseth.
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 to 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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