NTNU
Faculty for Natural Sciences
Dept of Physics
Dept of Materials Science and Engineering

TEM Gemini Centre

SINTEF
Materials and Chemistry
Dept of Synthesis and Properties

Project work / Master/Diploma topics in the TEM Gemini Centre, Autumn 2013

As a physics/nanotechnology project or diploma student in the transmission electron microscopy (TEM) group you can take an active part in one of the exciting research projects which require finest scale material characterisation. You work together with a PhD student, a SINTEF research team or one of our external collaborators to achieve a common goal. The work can have an applied character and be very practical, or theoretical to support experimental activities within the group. Also a combination of practical and theoretical work is a possibility. In all projects the TEM or input from TEM is used to understand the structure of a material down to the atomic level and relate this to important macroscopic properties of the materials.

2013 is a special year for the TEM group as we will install and start to use 3 new NORTEM instruments! This upgrade and extension will give new possibilities for advanced materials characterization and novel experimental solid state physics using electrons. We will use this year to build competence and students will have the unique opportunity to be among the first to learn to use the latest generation of TEMs!!

Examples of student projects which are available for the fall semester 2013 and in which you can participate are:

- Developing and characterising of new aluminium alloys
- Studies of nanostructures in functional oxides
- Analyses of catalyst materials for future applications
- Studies of solar cell materials (Si, thin films, quantum dots & nanowires)
- Simulation, quantification and image processing of TEM data.

These projects are described in more detail in the next pages. Earlier, several student projects have led to publications [1-7]. Due to high demand on the research facilities and the intensive supervising we want to give, we can take in max 4 students this semester.

People working in the TEM group – on microscopes, with sample preparation and simulations.

We offer:

- Choice of a project that fits your interests and background.
- Training in operating advanced and modern scientific equipment or/and simulation and quantification software (theoretical/modelling).
- Weekly meetings with a supervisor during the project.
- Being part of a large and dynamic scientific consortium.
- Possibility in extending the project (to diploma/PhD) or getting a summer job.

You are encouraged to contact one of us if you like to hear more details on a specific project, other available projects, options in academia or industry after a diploma in TEM or possibilities to incorporate own research ideas related to TEM. For more information on the current activities within the group, group members, equipment and recent publications, see the TEM Gemini Centre homepage: **http://www.ntnu.edu/geminicentre/tem**.



Contacts:

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John Walmsley (Room D4-113, Tel.

References:

[1] E. A. Mørtsell, A. M. Muggerud, Y. Li, and R. Holmestad, "Dispersion Hardening Effect of Dispersoids in 3xxx Al Alloys With Varying Manganese", Proceedings of 13th International Conference on Aluminum Alloys: ICAA13,

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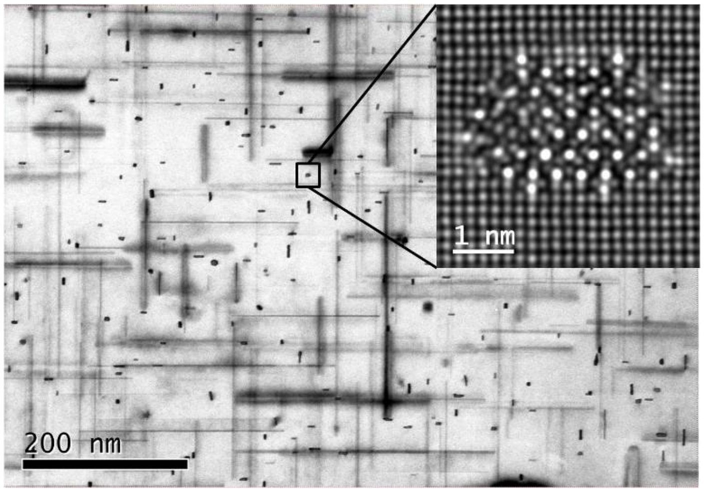
Nano-structure characterization for aluminium alloys development



Motivation:
In studies of light metal alloys there are challenges when it comes to establishing relations between the nano-structure and the mechanical properties, as for example strength and ductility. In Al-Mg-Si/Ge-(Cu) alloys, which are industrially relevant due to their superior mechanical properties (high strength /weight ratio and good corrosion properties), the hardness increase is due to precipitation of nanometre-sized metastable phases that form from solid solution during heat treatment.

What will the student do in the project:
The student will do experimental testing of mechanical properties (such as hardness) with different heat treatments and alloy compositions, and complementary nanostructure studies on the TEM. The heat treatment and hardness measurements will be done at the Department of Materials Technology and Engineering.

Required from the student:
Background in materials physics (solid state physics) and interest in materials science would be an advantage. We need a student interested in experimental work, and working independently in a larger group of scientists.

Other aspects:
We are many people working on aluminium alloys in the TEM group, we work in close collaboration with SINTEF and Hydro Auminium, and the students will participate in project meetings in this consortium at Sunndalsøra and Trondheim. Students get their own problem which fits well into the rest of the work done. Within this field there are possibilities for continuation as a PhD student.

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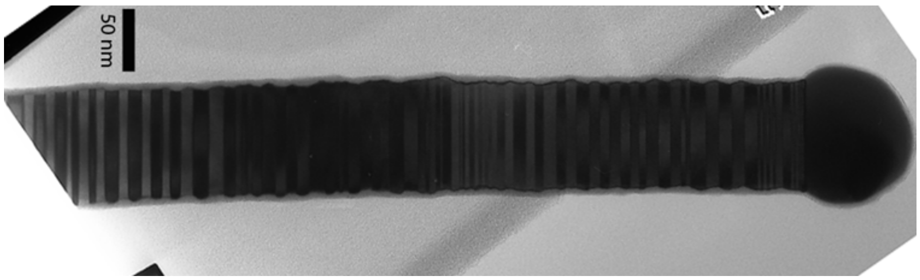
Structural characterization of heterostructured semiconducting nanowires

Motivation:

III-V semiconductor nanowires with high quality are grown Department of Electronics and Telecommunications (IET) for future application in optical devices (laser) and solar cells. Because of their small size, nanowires have to be studied by characterisation techniques with a high resolution as for example TEM.



What will the student do in the project:

You will study a batch of nanowires with interesting optoelectric properties. Especially the relation between optical & electric properties to the crystal structure / lattice defects/composition as determined by TEM are important. You will learn to use basic TEM techniques as electron diffraction and high resolution imaging techniques. SEM and STEM work within NTNU Nanolab could be part of the project. Your own characterization results are relevant to optimize growth and nanowire-based devices.

Required from the student:

Interest in experimental work using the TEM. Join weekly project meetings with academics and other project students that grow the nanowires. You should be able to clearly communicate and relate your results to others in the project and understand what feedback they expect from your TEM work.

Other aspects:

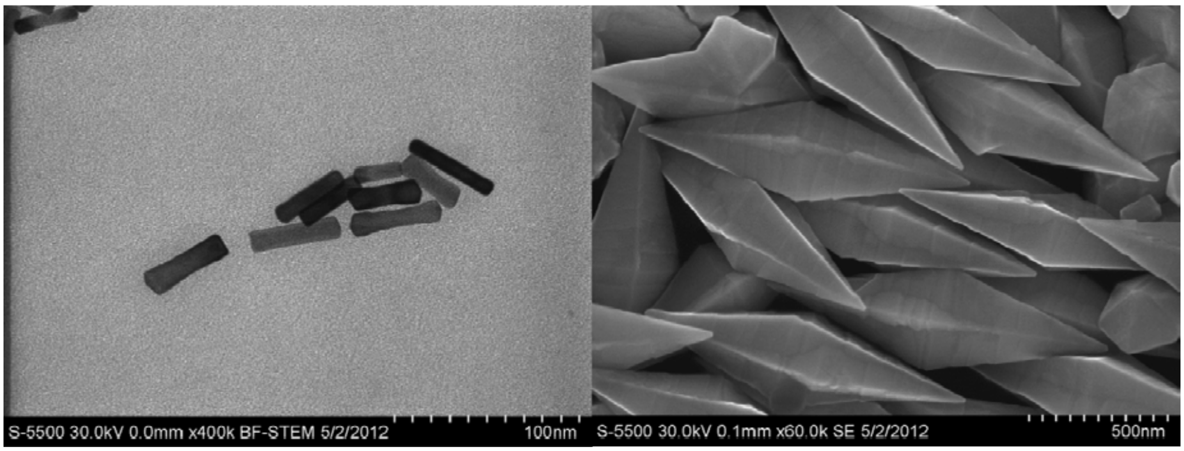
The field of semiconductor nanowires, fundamental understanding and application of them in devices had an enormous growth in the last years. We had already 8 project/diploma students working on TEM of semiconducting nanowires. Results of students' work are published afterwards. The research is interdisciplinary and a key example of nanotechnology at NTNU. The obtained practical skills can be applied in the study of other nanostructures.

Contact persons: Ton van Helvoort (IFY, a.helvoort@ntnu.no). Other key people in the project: Vidar Fauske (IFY, vidar.fauske@ntnu.no), Helge Weman (IET) and Bjørn-Ove Fimland (IET).

TEM study of Shaped-controlled Gold nanoparticles

Motivation:

Gold nanoparticles with a distinct specific morphology can easily be made by a seed mediated approach in the presence binary surfactants. To further optimize the synthesis, the relation between crystal structure, facets, growth direction and process conditions need to be better understood. Due to the size, electron microscopy would be the tool of choice for this task.



What will the student do in the project:

You will study different batches of Au nanoparticles using TEM. By characterizing morphology and crystal structure, you will assist to optimize the control of specific morphologies. You will learn and apply basic TEM techniques as electron diffraction and high resolution imaging techniques. SEM and STEM work within NTNU Nanolab could be part of the project.

Required from the student:

Interest in experimental work on nanoparticles and synthesis aspects. Student should be able to work independently and clearly communicate results to others in the project, both physicists and chemists.

Other aspects:

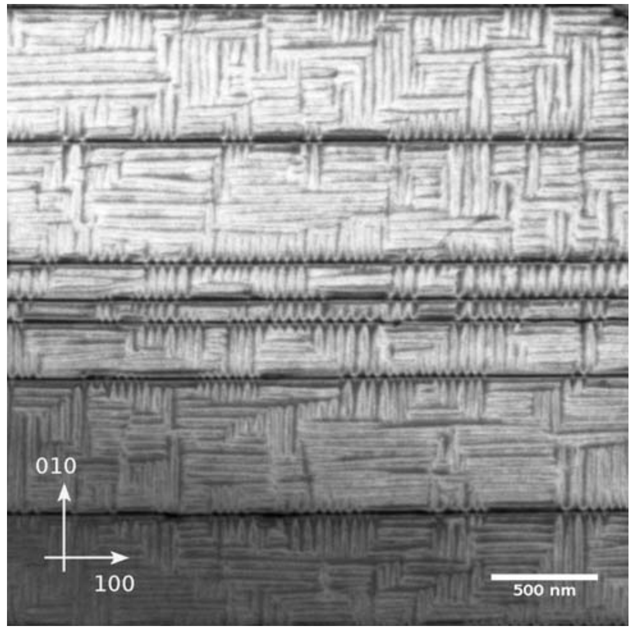
The gold nanoparticles are made at NTNU Department of Chemical engineering and initial characterization is done at NTNU Nanolab. The student has the opportunity to be involved in all aspects of the project. The obtained practical skills can be applied in the study of other nanostructures.

Contact persons: Ton van Helvoort (IFY, a.helvoort@ntnu.no). Other key people in the project: Gurvinder Singh (IKP, gurvinder.singh@ntnu.no), Wilhelm Glomm (IKP, wilhelm.r.glomm@ntnu.no)

TEM characterization of oxide thin films

Motivation:

Oxide materials show superior optical, magnetic, dielectric, piezoelectric, and electric conduction (superconductivity, ionic conductivity, semiconductivity) properties, as well as excellent mechanical performance, which make them an important and promising class of functional materials. In the oxide electronics group at Department of Electronics and Telecommunications they have currently large focus on the effect of interfaces on ferroelectric and piezoelectric materials. The goal is to understand how interfaces can be used to control properties for applications within sensor technologies. Recently they have started to study how to utilize the 2-dimensional-electron gas at the interface between $SrTiO_3$ and $LaAlO_3$. Another system is the colossal magneto resistant material $(La,Sr)MnO_3$. The thin films are grown by the Pulsed Laser Deposition (PLD) technique.



What will the student do in the project:

Study the crystal structure and the coherence in the thin films using TEM, and correlate this with properties. An important aspect here is to make good cross section samples, and TEM sample preparation will be a considerable part of the work.

Required from the student:

We seek students with background from physics or nanotechnology. Interest in solid state physics and electronics is needed. We need a student interested in experimental work, and working independently. Accuracy and patience are needed for the sample preparation work.

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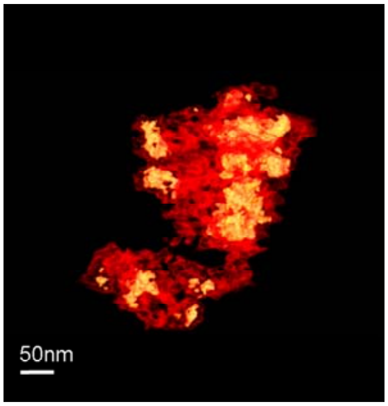
Nanoscale TEM studies of catalyst systems



Three dimensional reconstruction of Co-oxide nanoparticles (yellow) distributed in a porous alumina substrate (red).

Motivation

Supported metal nanoparticles which are used many important catalytic processes. We have a strong cooperation with the Department of Chemical Engineering who work with a wide range of catalyst and related systems. To understand, design and develop these systems it is increasingly important to have an atomic-scale understanding of their microstructure. Brand new TEM instruments will be installed in Trondheim during 2013 and we would like to explore the possibilities that these offer for imaging and analysis.

What the student will do in the project:

Besides acquiring data, emphasis will be placed on analysing data quantitatively and developing techniques and procedures, both for data acquisition and processing. One example of this would be in electron tomography tilt-series that can be used to study materials that show complexity in three dimensions on the nanometre-scale.

Other details:

TEM will be part of a multidisciplinary activity, including synthesis and testing, with which it willl be corrdinated through planning and regular meetings. Several possible projects are available and it will be an objective to include results in journal publications.

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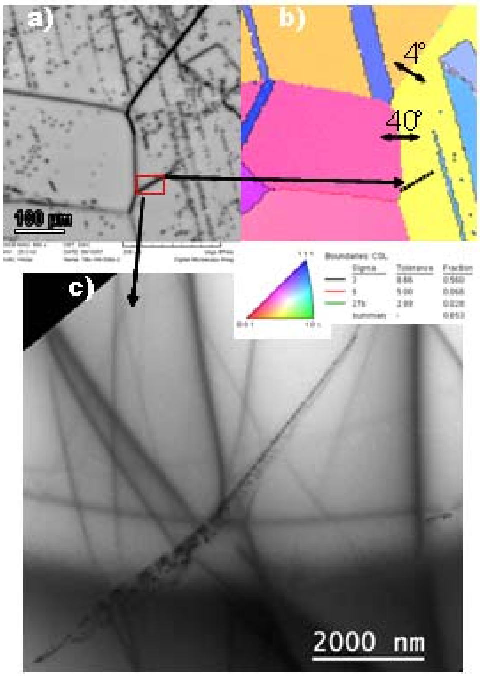
TEM investigations of microstructure in silicon solar cell materials



a) EBIC, b) SEM c) TEM

Motivation:
Supply of silicon is one of the bottlenecks of the photovoltaic industry. Cost and energy payback time for the silicon production can be significantly reduced through the so-called metallurgical production route. The disadvantage is that the resulting material often contains higher level of impurities and crystal defects which reduce the efficiency of silicon solar cells, by introducing recombination centres for electrons and holes in the bulk. To improve the silicon wafer production, it is important to understand how defects are formed and where other phases are nucleated and grown during solidification and cooling, and how this affects the lifetime. Another aspect is the interfaces and contacts in the produced cells. The structure at nanoscale of these contacts has to be studied in detail down to nanoscale to understand the properties and efficiency of Si solar cells. There is interest in the study of both multicrystalline and single-crystal solar Si.

What will the student do in the project:
Light microscopy and scanning electron microscopy techniques will be combined with TEM to study grain boundaries, dislocations and particles in the same material, Interfaces and contacts will be studied in TEM. The student will learn to use basic TEM techniques, and collaborate with other students at IMT who will do/have done most of the other experiments.

Required from the student:
Interest in experimental work and a background in solid state physics or functional materials is an advantage.

Other aspects:
There is a large activity at Gløshaugen on silicon solar cell materials, this includes participation in a nationally Centre for Environmental-friendly Energy Research (FME) and the student will have the possibility to join this activity, with participation in regular meetings, etc.

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Data processing of electron microscope experimental results

Motivation:

Electron microscopes are able to collect multiple and large data sets simultaneously. This could be an image, series of images or spectra. Because of better microscopes, detectors and computing power available to TEM users, post-acquisition processing beyond what standard TEM software packages becomes more elaborate, but also more rewarding. Example areas where there is a need as well as current developments:

- Compositional mapping by EDX (Note: we will get the most efficient detection systems on the market within NorTEM, however analytical software for mining these is not yet well developed. Also we will have different suppliers, so data set compatibility/one-common user interface needs to be addressed. We consider here building our own routines using Python).
- Electron energy loss spectroscopy fine structure (ELNES). Detailed analysis using for example FEFF8 or Hyperspy is considered. (Note: NorTEM will get faster EELS detectors and improved energy resolution. Probing the electronic structure by ELNES will be a focus in many of the different materials systems we work on)
- Electron tomography: three dimensional tomographic reconstruction exploiting the scattering intensity of electrons when a sample volume has been imaged over a range of orientations. (Note: the three NorTEM machines will all have tomography option, making the technique accessible to a broader group of user than to date).
- Statistical analysis an improved representation of EDX and EELS spectra: Principle components analysis (PCA) or MSA is getting routine data processing for (noisy) spectra, however not yet implemented in acquisition software. Here existing routines in Hyperspy (based on Phyton) or Matlab could form the basis of the project work.
- Strain analysis: Image processing to extract strain variation is important in different fields we work on as for example semiconductors and alloy design.
- Atomic resolved HAADF STEM image simulations and quantifications: Acquiring atomic resolved HAADF STEM where the intensity of an atomic column can reflect the average atomic number, would allow mapping composition on the atomic scale. Quantification was successfully used for precipitates in Al-alloys and heterostructured nanowires. We want to extend the routines to other materials systems and implement them on the new NorTEM microscopes.

What will the student do in the project?:

The student will work with new and existing data sets related to one of the techniques listed above. He/she will develop data analysing routine that harvest more from a given data set. Such routines should be made available in commonly used TEM user software in a user-friendly way, so an average user of the facility could benefit.

Required from the student:

An interest in using and developing software tools is required. The student has to understanding after the project how different datasets are build-up based on how the microscopes or detector acquire signals. Further he/she has to understand and address to the requirements an average TEM user has regarding data processing software. Good communication and interaction with scientific and academic staff and PhD students.

Other aspects:

The intention is that final results will form a part of ongoing research programmes and contribute to a publishable result. Related to this there might be a summer job offered.

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