Nanotomography & Nanomaterials Group

Phd topics available
(priority on topics 1-3, other topics beyond 1-8 are available as well, subject to discussions):

1. Looking inside Materials: Nanotomography and 3D Nanometrology

Supervisors: G Möbus et al.

Nanomaterials are intrinsically 3-dimensional materials, as their properties depend on surface-proximity and confinement, also referred to as low-dimensional matter. Imaging of surfaces or simple planar cross-sections is therefore no longer sufficient. In this project we develop new acquisition sequences and new data reconstruction procedures for applying the established method of computed axial tomography (CAT) to nanomaterials, where objects are rotated under irradiation around an axis, with special emphasis on 3D chemical and structural mapping. State-of-the-art aberration corrected electron microscopy is available for projection imaging. Applications will comprise e.g. nanoparticles, nanoparticle arrays, nanocomposites, and functional nanotips and porous materials.
[1] Journal of Nanoparticle Research12 (3) , pp. 1045-1053. Three-dimensional characterization of multiply twinned nanoparticles by high-angle tilt series of lattice images and tomography

2. Nanopatterning for the engineering of novel functional devices and surfaces by irradiation through nano-channel masks

Supervisors: G Möbus et al.

The synthesis of thin membranes with periodically arranged transparent pores is at the centre of this project. Such masks can be penetrated by electrons, low-energy ions (e.g. FIB), or high-energy ion irradiation in accelerators. By combining specific masks and specific substrate surfaces, pattern transfer can be achieved in various ways, such as to generate a sputtering pattern, a surface activation pattern, or an ion implantation pattern below the surface. The project will explore the mechanisms of charged particle penetration through narrow nanochannels and the impact on substrates of different chemistry. Ultimately the aim would be to generate functional arrays of nano-dots or nanoparticles on and inside a substrate with advanced optical, chemical or magnetic properties. Prospective applications include nano-circuitry, nano-optics, and pattern generation for nanoscale templating.
[1] Physical Chemistry Chemical Physics, 15, 2013, 4291-4296 Nanopatterning by ion implantation through nanoporous alumina masks

3. Synthesis and atomic resolution characterisation of catalytically active oxide nanoparticle architectures

Supervisors: G Möbus et al.

The shape and size of nanoparticles is crucial for their application in surface-specific reaction environments, such as for catalysis. However, nanoparticles need to be arranged in specific ways with respect to each other and the support they are attached to, which influences further their overall surface/volume ratio and accessibility. In this project synthesis of oxide nanoparticles is examined and mechanisms how they attach to each other to form

systematic 1D and 3D structures (beyond random agglomerates) are explored. Atomic resolution examination of surfaces by aberration corrected TEM and EELS are the main experimental methods.
[1] ACS Nano*, **2012**, 6 (1), pp 421–430. Cationic Surface Reconstructions on Cerium Oxide Nanocrystals: An Aberration-Corrected HRTEM Study*

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4. Irradiation induced synthesis of nanoparticles

Supervisors: G Möbus

Selected compound materials can serve as precursors for the electron beam induced reduction into pure metals. Using carefully chosen irradiation conditions the reduction process can be used for the fabrication of metallic nanoparticles via a diffusion, nucleation and growth process. Of particular interest is the local fabrication of Al, Ag, and Bi nanostructures, as well as of ferromagnetic metals, e.g. Ni and Co.
The study will examine:
- Synthesis of individual particles and nanorods by live observation via in-situ TEM
- Mass fabrication of thousands of nanoparticles on a support film
- Metal grain crystallisation in nanocomposites and fabrication of agglomerated architectures of nanoparticles
- Fabrication of metal nanobeads and study of planar defects in fcc-nanostructures
The fabrication will be accompanied by extensive high-resolution imaging and spectroscopy, especially concerning the plasmon resonance of the freshly fabricated particles, with respect to prospective applications in nanooptics.

5. Generation of functional nanoparticles/nanopore composites with high surface area.

Supervisors: G Möbus

Nanoparticles of e.g. cerium oxide have recently attracted high levels of attention due to their very wide range of applications, e.g. for catalysis, fuel cells, solar cells, UV absorbers, and biomedical additives. Apart from using particles in solution or dry powders, an interesting group of morphologies is particles attached to or embedded in porous support structures. The project will explore both the direct and simultaneous synthesis of ceria into pores from liquid precursors, as well as the infiltration of pre-fabricated particles into porous materials. Anodic aluminium oxide and nanoporous glasses will be the host materials considered. Transmission electron microscopy for imaging and spectroscopy will form the essential part of the post-synthesis part of the project.

6. Nanoscale imaging and analysis of hydroxyapatite nanostructures.

Supervisors: G Möbus, F Claeyssens
(A topic can be formulated in this area upon request, subject to confirmation with collaborators)

7. High-resolution local chemistry analysis via EELS spectroscopy for oxide glasses and ceramics.

Supervisors: G Möbus and R.J. Hand

Physical and chemical properties of glasses and ceramics often depend on the coordination and valence states of functional doping atoms or other functional cations. In this project, the technique of electron energy loss spectroscopy in the electron microscope is used to spatially map the distribution of coordination and valence parameters in a selection of glasses and glass nanocomposites, mainly derived from the field of immobilisation science (vitrification of radionuclides). Solubility limits, crystallisation sequences, and annealing processes of multi-component borosilicate glasses will be explored, as they turn into glasscomposite materials by nanoscale precipitation. Metrological analysis of the threedimensional particle distribution in the glass matrix will form an essential part of the project.

8. Aberration corrected transmission electron microscopy of nanoparticles.

Supervisors: G Möbus

Latest progress in imaging technology with electron microscopes allows to image nanoparticles and other nanoobjects with atomic resolution in the thinnest areas of the object, such as corners, edges, projected surfaces, etc… The importance of these capabilities is in visualising surface reconstructions, local changes of lattice constants, depletion of layers (e.g. oxygen), stability of facets against irradiation induced displacements, and surface redox-chemistry changes, in order to predict and assess the functional surface activity for the particles in service, e.g. as catalysts.
The project is available in three flavours, depending of advanced knowledge and interest of the student:
(i) An experimental version of the project, comprising specimen preparation for a variety of interesting nanoparticles, imaging with atomic resolution,
video recording of live materials morphology alterations, and spectroscopy for local chemical analysis.
(ii) A theoretical version of the project, based on computer simulations, can be offered, with the main aim of understanding and reproducing the complex wave-optical image formation process in the modern aberration corrected TEM. Special image postprocessing
routines to extract e.g. atomic positions from image intensity distributions will be another essential part.
(iii) Any combination of experimental and theoretical work is also available.