Microsc. Microanal. Vol. 13 Suppl. 3 (2007) 266.

The Structure of Gold Nanoparticles on Different Substrates Studied by Aberration Corrected High Resolution Transmission Electron Microscopy

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The interface between metallic nanoparticle and a substrate determines the particles function e.g. electric contact or magnetic storage device in the case of particles made of magnetic transition metals; the shape of the particle and its facets determines its function and efficiency as catalyst.
Therefore the structure has to be determined at the atomic level before the structure-properties-relationship can be unravelled.

The resolution limiting imperfections of the circularity (astigmatism and coma) and refraction strength (spherical aberration) of magnetic lenses have been overcome by the use of corrector elements (C_S-corrector) attached to the microscope column as additional lenses. The latest generation of aberration corrected transmission electron microscopes (TEM) opens up for the first time the look into the sub-Ångström region without artefacts such as focus delocalisation.

In this study we are investigating by aberration corrected TEM the morphology and interface microstructure of gold nanoparticles (3 to 5nm in diameter) on Si, MgO, rutile (TiO_2) and sapphire (Al_2O_3) to explore the interaction between the nanoparticles and substrates as well as the particle shapes and facets. The particles have been deposited on the substrate using dip coating of metal-salt loaded micelles. Oxygen and hydrogen plasma removed the organic compounds and reduced the metal-salt into solid metals. Cross-section TEM samples were prepared using mechanical grinding, dimpling and polishing followed by low angle, low energy argon ion etching. The TEM investigations were carried out using an objective lens corrected FEI Titan 80-300 TEM operating at accelerating voltages of 80kV and 300kV.

First results show a distinct interaction between Au and different substrates. As an example the C_S-corrected HRTEM image of an Au-nanoparticle on TiO_2 [110] is shown in Fig.1. The image (Fig.1) is recorded with negative spherical aberration (C_S=-4µm) and focus close to zero (f=6nm) and all higher aberrations equal to zero within the errors of measurements. The local fast Fourier transforms (FFT) of Au-particle and substrate (1b), substrate only (1c) and Au only (1d) are shown; the corresponding lattice fringes are indexed. For the case of TiO_2 (rutile) the following orientations relationships have been found: 111_{Au} // 110_{TiO2} and 110_{Au} // 200_{TiO2}. Filtered images of particle together with substrate and the particle itself are shown in Fig.1e,f. The particle contains pronounced {110} facets along the [111] projection as shown in the Fourier filtered image Fig 1.f.

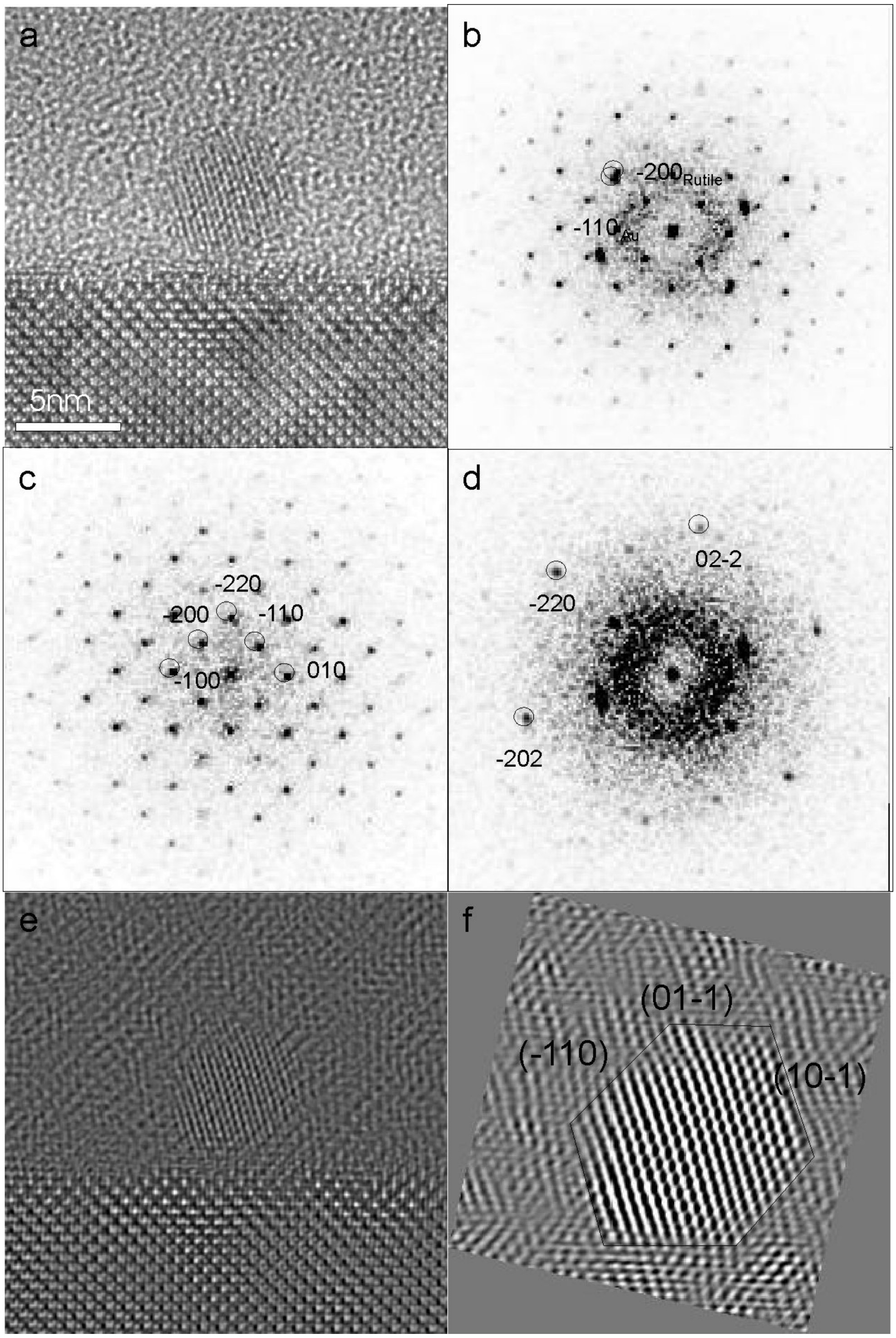

Fig.1. Au nanoparticle on rutile (TiO_2).
(a) Experimental CS-corrected HRTEM image. (b,c,d) Locally calculated FFT showing reflections of particle and substrate (b), substrate (only) particle only (d). (e) Fourier filtered image of particle and substrate (f) Fourier filtered image of the partilcle showing its facets.

This work has been supported by the DFG Collaborate Research Centre SFB 569.