TESTING THE NANOPARTICLE-SUPPORT ADHESION USING SCANNING FORCE MICROSCOPY

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An increasing number of products involving nanoparticles (NPs) attached to a surface are being developed, such as cosmetic foundation powders containing NPs to fill tiny blemishes or industrial catalysts containing Pt NPs dispersed on porous oxide supports. If the NPs fall off the surface or get washed away after a short period of usage the functionality of the product would be impaired. In addition, safety issues may be raised if the NPs are released to the environment. To ensure the reliability and safety of such products, the strength of the adhesion between the NPs and the support surface needs to be tested. Owing to its high spatial resolution as well as the direct mechanical tip-sample interactions, Scanning Force Microscopy (SFM/AFM) is a promising tool for such nanomechanical testing. Recently, Eppler et al. [1] demonstrated this approach for a model catalyst containing arrays of Pt NPs.

To explore the potential of the approach and to develop a deeper insight into the interactions between SFM-tip and NPs, we investigated arrays of W-NPs deposited on a surface of template-stripped gold. The W-NPs were generated by means of Electron Beam Deposition (EBD) involving $W(CO)_6$ as a precursor gas. The interparticle distance was ~280 nm, and the dwell time of the electron beam was used as a parameter to generate NPs of various sizes. With beam dwell times in the ms range, the height of the NPs was in the range between 2 and 5 nm. One array for each dwell time value was generated, with each array extended over 100x100 microns^2.

Using microcantilevers of ~60 pN/nm stiffness, the arrays of NPs were imaged in contact mode. Starting from low values, the normal force was successively increased to find the critical force from which on NPs are detached from the supporting surface. For NPs of a 2 ms beam exposure time, the critical force was found to be ~45 nN. Scanning at this force resulted in complete removal of the NPs (Fig. 1). These results are discussed in terms of the various forces acting at the interfaces tip/NP and NP/surface.

Additional information is available from the lateral force images. In particular, they show tracks that can be attributed to the movement of loose particles as induced by the scanning tip. Such events result in increased lateral forces. The loose NPs tend to pile up along the edges of the scan area. In the course of subsequent scans of expanded scan range some of these loose particles are moved towards the edges of the new scan area.

Also the issue of quantification of lateral forces was addressed. A modification of Varenberg's wedge technique [2] for the determination of the torsional calibration coefficient was studied. Employing Focused Ion Beam (FIB) etching, shallow edges of ~20° slope angle were generated in order to ensure a stable condition of the feedback when scanning across the edges. As compared to the initial slopes, the lateral force profiles show extended plateaus, thus allowing for a more reliable evaluation of the lateral forces measured on the slope.

References:

[1] A.S. Eppler, G. Rupprechter, E.A. Anderson, G.A. Somorjai, J. Phys. Chem. B **104** (2000) 7286.
[2] M. Varenberg, I. Etsion, G. Halperin, Rev. Sci. Instr. **74** (2003) 3362.

Figures:

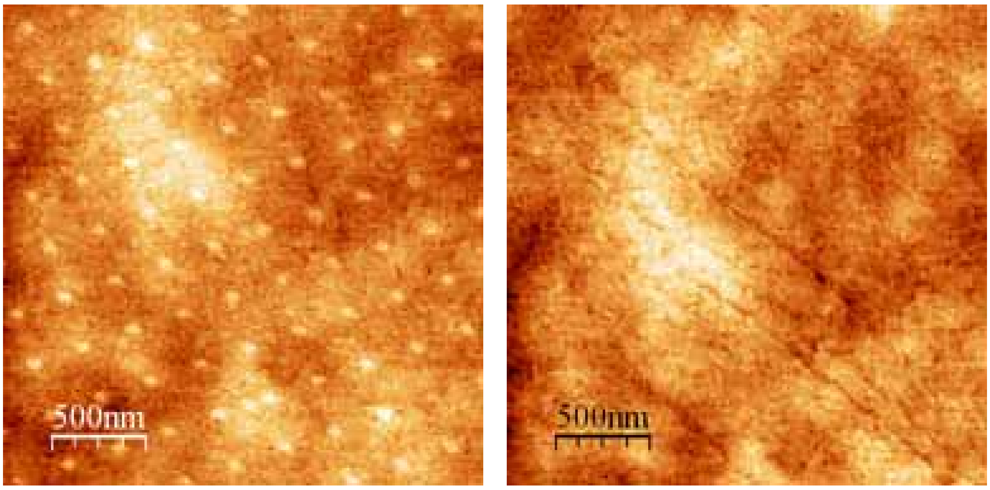

Fig. 1: Topography images of an array of W-nanoparticles, measured with normal forces of ~3 nN and ~45 nN, respectively. Total height 5.2 nm and 4.2 nm, respectively. Scan range 2.5 microns.