QUANTITATIVE DETERMINATION OF THE MOBILITY AND SLIDING FRICTION FORCE OF GAS PHASE DEPOSITED NANOPARTICLES FROM THEIR AGGLOMERATION BEHAVIOR

Ute Queitsch[1], Alfred Hucht[2], Bernd Rellinghaus[1] and Ludwig Schultz[1]
1 Organization, Address, City, Country
[1]IFW Dresden, P.O. Box 270116 D-01171, Germany
[2]Universität Duisburg-Essen, Lotharstr. 1, 47057 Duisburg

u.queitsch@ifw-dresden.de

As combined efforts of industrial and basic research push the dimensions of future devices, machines and concepts down to the nanoscale a fundamental understanding and a molecular-level control of the involved mechanisms and interactions is crucial for the ultimate realization of these technological advancements. As the dimensions are reduced, surface forces increasingly gain importance for the overall system behaviour and tribological properties as friction, wear and lubrication limit the reachable degree of miniaturization for moving nanocomponents as for example in nano-electromechanical systems (NEMS). Due to the small dimensions direct measurements of e.g. included forces or surface potentials are challenging and either afford extensive experimental setups [1,2] which only allow for quantitative information when complex contact mechanics are included, or research is restricted to MD simulations which are limited in terms of complexity of the treated problems and to the confined computing resources [3,4].

We have developed a fast and easy method for the quantitative determination of the mobility and sliding friction force of gas phase deposited nanoparticles on amorphous carbon by simple image analysis. This is done by a combination of experimental studies on the agglomeration behaviour of gas phase deposited nanoparticles on surfaces with simulations on the Brownian diffusion of these particles.

Nanoparticles tend to agglomerate. Here 5nm sized FePt nanoparticles are deposited from the gas phase on aC substrates. As shown in Figure 1 (a) the fraction of agglomerated particles increases with increasing particle density. This is partly due to the statistical arrival of the particles. The according fraction is simulated and depicted as a blue curve. The experimentally derived agglomeration (plotted as symbols) is clearly higher than this purely random agglomeration. This means, the nanoparticles have to be mobile after deposition. In order to determine the nanoparticle mobility we assumed Brownian particle diffusion in two dimensions, described by

$$\left\langle r(t)^2 \right\rangle = 4Dt$$

with the diffusion constant $D = 10^{-12} m^2/s$, taken from the literature [5,6]. With a constant rate of $F_d = 10^6/s$ we randomly deposited particles on a substrate with dimensions LxL and periodic boundary conditions. After deposition, the particles are allowed to move randomly on the surface for a limited time t_d, after which they are assumed to have exhausted their initial kinetic energy by friction effects. Furthermore, the particles are blocked immediately when they agglomerate with another particle. Adjusting the unknown diffusion time t_d to the experimentally observed agglomeration rates revealed, that the particles diffuse for about 10µs (equivalent to 40 nm) after deposition (Figure 1b). Assuming, the initial kinetic energy (in the order of 3eV/ particle) is completely transferred to frictional effects, which is realistic at this low kinetic energy (soft landing), we determine the sliding friction force F to be in the order of 10^{-1}nN which is in well agreement with previous results of SFA or FFM studies.

The presented method is applicable for all mobile nanostructures on arbitrary substrates.
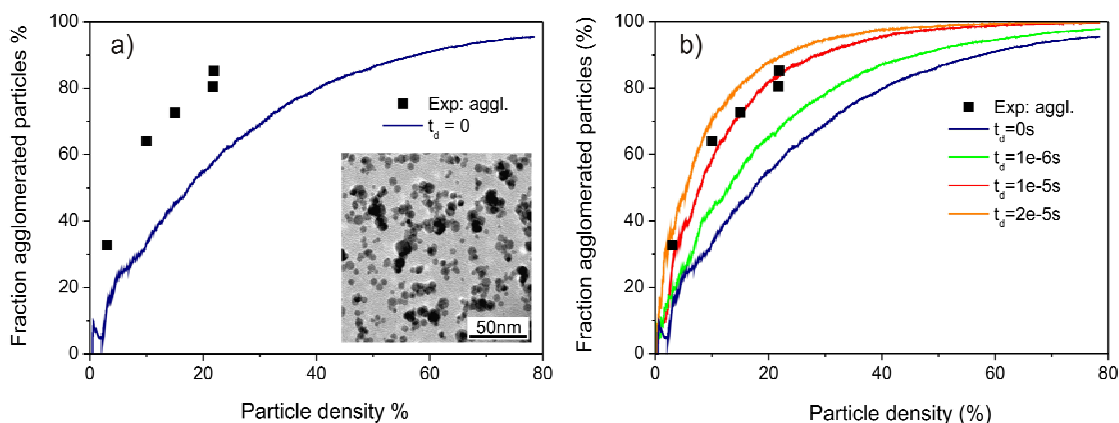
Figure 1: *a)*: Fraction of agglomeration vs. the nanoparticle density as derived from experiment and simulation. *b):* Calculated agglomeration vs. density curves for particles which are deposited at random positions at the substrate and are then allowed to diffuse to diffuse on the surface by a limited time t_d.

References:

[1] CM. Mate, GM. McClellan, R. Erlandson and S. Chiang, *Phys. Rev. Lett*., **59**, (1987), 1942

[2] UD. Schwarz, O. Zwörner, P. Köster and R. Wiesendanger, Phys. Rev. B, 56, (1997), 6987

[3] U. Landmann, WD. Luedtke, NA. Burnhamn and RJ. Colton, *Science*, **248,** (1990), 454

[4] P. Deltour, JL. Barrat and P. Jensen, *Phys. Rev. Lett.*, **78**, (1997), 4597

[5] L. Bardotti, P. Jensen, A. Hoareau, M. Treilleux and B. Cabaud, *Phys. Rev. Lett*., **73**, (1995), 4694

[6] J. Chen and KY., Chan, Molecular Simulation, 31, (2005), 527