

## MEng project CHESS-12: Adsorption of Nanoparticles at Modified Surfaces

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The attachment of inorganic nanoparticles to surfaces is a fundamental problem underlying coating and printing techniques and also of paramount importance for electronic devices, such as solar cells and light-emitting diodes. The structure of the nanoparticle layer plays an important role in the device performance [Alivisatos].

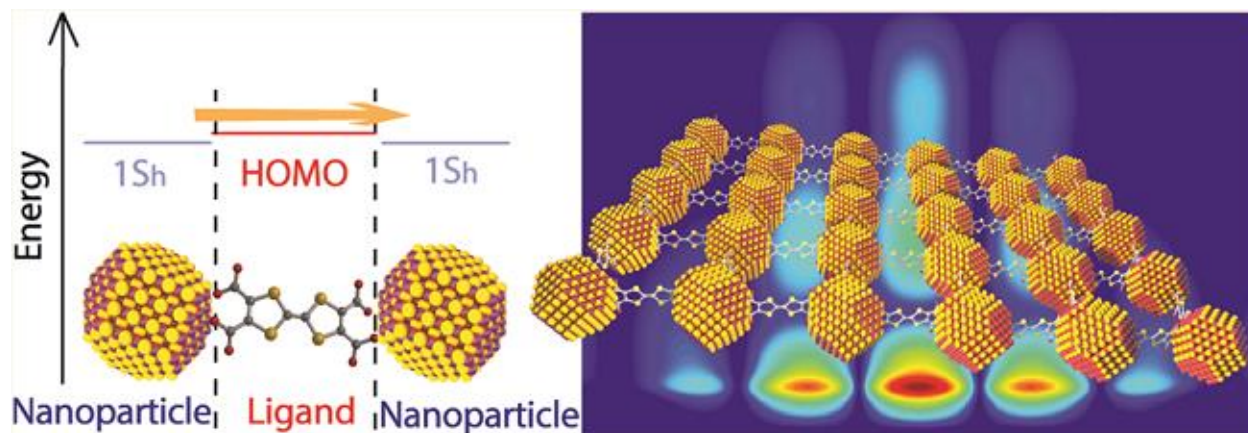


Figure 1: Ordered PbS nanoparticle array with bifunctional linker on a wafer surface forming a field-effect transistor [Alivisatos].

There are multiple facets to the adsorption of soft materials to surfaces: first of all there is the van-der-Waals attraction between nanoparticles and the substrate which can be understood within the Hamaker model [Hamaker]. Then there is the surface energy of the silica substrate (i.e. silicon wafers covered with native oxide, glass slides, or silica-coated quartz oscillators) which can be modified using self-assembled monolayers [Willner]. These can be either neutral, such as octadecyl trichlorosilane (OTS) or methyl- polyethyleneglykolsilane (mPEG) , or functional, such as aminopropyl triethoxysilane (APTES) or phenyl trichlorosilane (PTS). We would like to characterize the Langmuir isotherms and the adsorption kinetics [Park]. Goal would be to prepare monolayer and sub-monolayer systems in equilibrium with the solution phase in a controlled way. The effect of a neutral functional layer can be understood as a spacer that keeps nanoparticles further away from the substrate, and thus reduces the van-der-Waals attraction of the particles to adsorb on the substrate. When the adsorption energy becomes smaller than the mean thermal energy  $kT$  per particle, adsorption from solution should be much reduced. We would like to find this threshold.

Nanoparticles will be obtained from the Hanrath lab. We will apply quartz-crystal microbalance and dissipation (QCM-D) [Park, Johannsmann] at CHESS using a recently acquired Biolin Q-Sense instrument, which also permits to control the substrate temperature. A pilot study showed that iron oxide particles of about 10 nm diameter absorb well at room temperature in equilibrium with the solution. We would

like to obtain more detailed information, how the adsorption depends on the particle size and the functional layer. It would also be very interesting to find out, at what temperature nanoparticles desorb as a function of their size and thus determine their binding energy.

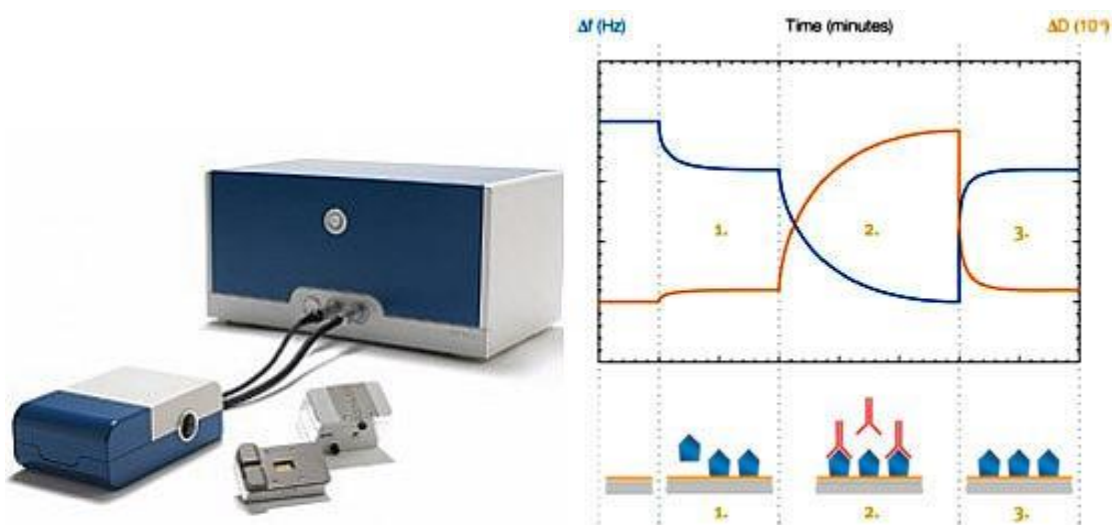


Figure 2: Q-Sense QCM-D system with sensor and controller (left). Typical QCM-D scan: 1. absorption of a linker molecule, 2. absorption of an elongated molecule, 3. rinsing and removal of elongated molecule. Note the shifts in frequency related to the mass uptake and in dissipation related to the interaction of attached molecules with the liquid.

We will complement these measurements with grazing-incidence small-angle x-ray scattering (GISAXS) at CHESS D1 beamline to characterize the adsorption, conformation, and self-assembly of nanoparticles on clean or modified silicon oxide surfaces. The project student will be invited to participate in the x-ray characterization of his/her samples in the upcoming beamtime at CHESS.

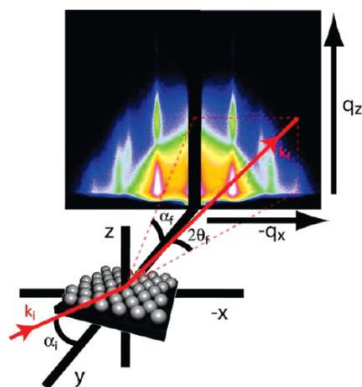


Figure 3. GISAXS image of a well ordered monolayer of PtFe nanocrystals [Heitsch].

## References

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