DC electrostatic manipulation of gold nanoparticles with Atomic Force Microscopy

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There exist tools such as Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), and Scanning Electron Microspy (SEM) [1]-[2] that enable to manipulate particles of nanometric sizes. In the present contribution we extend existing techniques by report on the electrostatic manipulation of gold nanoparticles with AFM

Initial attempts at manipulation of nanoparticles with the AFM were based on pushing the nanoparticle with the AFM tip [2-5]. However, the pushing process does not enable building 3D structures nor provides feedback on how the nanomaniplation process is proceeding. We have shown that the electrostatic manipulation overcomes these limitations.

Electrostatic nanomanipulation uses electrostatic forces to detach the particle form the substrate and Van der Waals forces [6] to attach back the particle to the substrate (or viceversa). The election of one procedure or another depends on the relative value of the Van der Waals forces of the particle-susbtrate and particle-tip systems. In both cases, during the translation process, the nanoparticle remains adhered to the tip.

To perform the electrostatic manipulation [7] the tip must be situated at a fixed distance on top of the nanoparticle and then a potential difference has to be applied between the AFM tip and the substrate high enough to overcome the Van der Waals force and hence to detach the nanoparticle from the substrate.

In order to perform such an experiment one has to estimate the value of the force necessary to detach the nanoparticle. This value determines the applied bias necessary. Once the applied bias is known one has to determine the initial distance between tip and nanoparticle. This distance has to be chosen such as not to be too far from the nanoparticle (the transfer does not occur) nor too close to the particle such as the application of the DC bias makes the tip to collapse onto the nanoparticle [8] [9]. In order to assist in this tip positioning we have developed a theoretical model able to predict for a given probe geometry and for every initial distance to the nanoparticle, the maximum applied potential at which the tip will collapse onto the nanoparticle (Vc) (or conversely the distance at which collapse will start (Dc)) (Fig. 1). This modeling has enabled us to choose the correct probe (e.g. elastic constant) and the parameters (initial distance) to perform the experiments.

In Fig. 2a and 2b successful transport of a 50 nm gold nanoparticle from position A to position B performed electrostatically with the AFM is shown.

A graph of the deflection signal as a function of time during the nanomanipulation experiment is shown in Fig. 3. From this type of signal one can monitor the nanomanipulation experiment by detecting, in particular, the instant at which the detachment of the nanoparticle from the substrate takes place (big spike in the deflection signal in Fig. 3) or any eventual loss of the nanoparticle during the transport (not shown in Fig. 3).

To create 3D structures we need to transport one particle over other particles and deposit it with precision, otherwise, we can destroy the structure. The images in figure 4 show the possibility of positioning a nanoparticle on top of other nanoparticles by means of electrostatic manipulation with AFM.

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Figures:

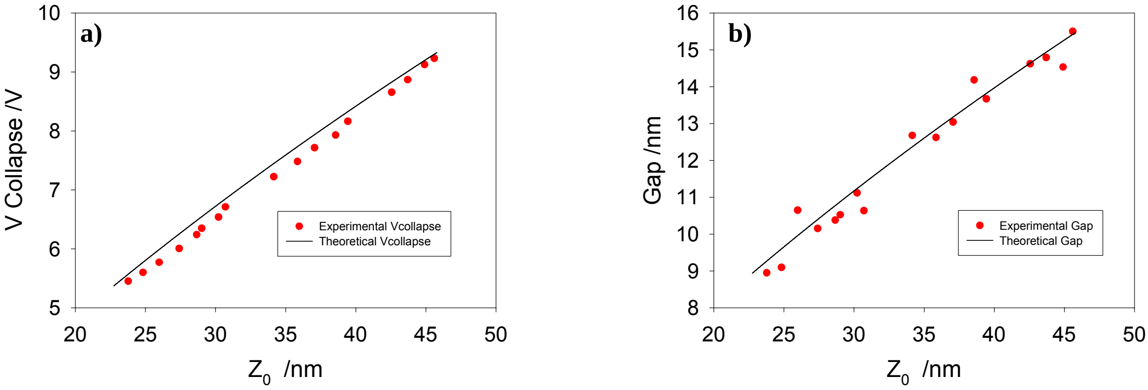
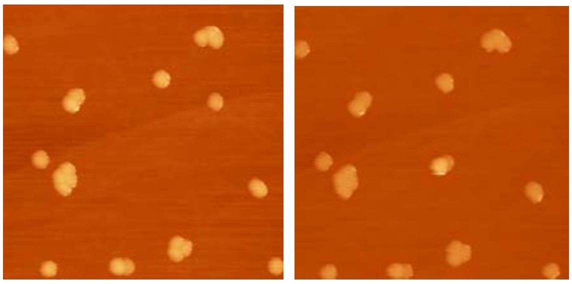


Figure 1: a) Collapse potential vs initial distance for a probe with elastic constant k=1.5 N/m AFM tip. b) Collapse distance vs initial distance for the same probe (solid line theoreticla model, red circles experimental results).



2a) 2b)

Figure 2: 2a and 2b we show the transport of a gold nanoparticle from position A to position B performed electrostatically.

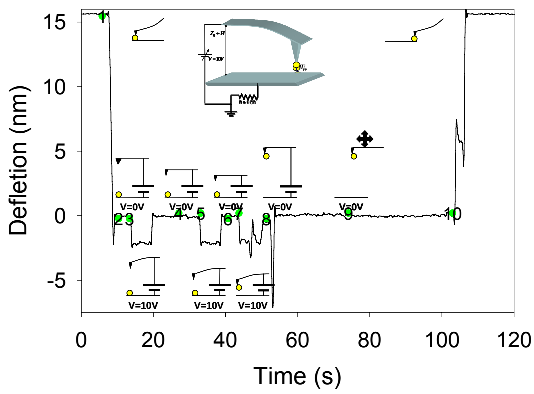
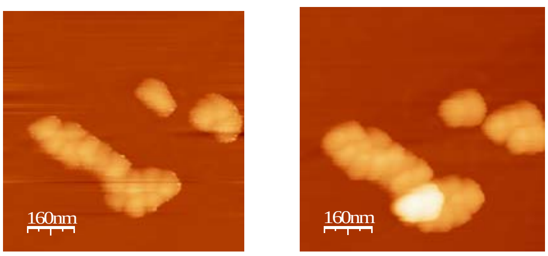


Figure3: Deflection signal as a function of time during the nanomanipulation experiment.



4a) 4b)

Figure 4: (a) and (b) 2D AFM images before and after the deposition of a nanoparticle on top of an aggregation of nanopartícles.