Electrostatic manipulation of gold nanoparticles using an atomic force microscope.

Jordi Toset, Gabriel Gomila, Josep Samitier.
Departament d’Electrònica, Universitat de Barcelona,
Laboratori de Nanobioenginyeria-CREBEC, Parc Científic de Barcelona
C/Josep Samitier 1-5, 08028, Barcelona, Spain
jtoset@pcb.ub.es

There exist tools such as Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), and Scanning Electron Microscopy (SEM) [1]-[2] that enable to manipulate elements of nanometer sizes. In the present case, we investigate the electrostatic nanomanipulation with AFM.

Initial attempts at manipulation of nanoparticles with the AFM were based on pushing the nanoparticle with the AFM tip [2] [3] [4] [5]. Unfortunately, the pushing process does not enable building 3D structures. We will show that the electrostatic manipulation overcome these difficulties.

Electrostatic nanomanipulation uses electrostatic forces to detach the particle from 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-substrate and particle-tip systems. In both cases, during the translation process, the nanoparticle remains adhered on the tip.

To perform the electrostatic manipulation [7] the tip must be situated at a fixed distance on the nanoparticle. When a potential difference is applied between the AFM tip and the substrate, the generated electrostatic field exercises a force on the nanoparticle enabling to detach the particle from the substrate.

The manipulation method requires a precise control of the tip. If the tip is too far from the nanoparticle the transfer does not occur. On the other hand, if the tip is too near to the particle, the tip collapses onto the nanoparticle on the substrate surface [8] [9]. It is necessary to take into account the deflection of the cantilever when the potential is applied. Simulations estimate this deflection to be about 3 nm for 10 V applied. With this potential the maximum tip-nanoparticle distance is 20 nm (see fig. 1). In this case the tip-particle distance before applying the potential must be approximately 23 nm.

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

A graph of the deflection signal as a function of time during the nanomanipulation experiment is shown in Fig. 3. The protocol is (1) push the tip onto the nanoparticle (2) raise the piezo 50 nm (3) apply 10V during 6 seconds. Nothing is happening, so (4) approach the piezo 5 nm to the nanoparticle (5) apply 10V during 6 seconds. Nothing is happening, so (6) approach the piezo 5 nm to the nanoparticle (7) apply 10V during 6 seconds. There are a change in AFM deflection so (8) raise the piezo 100 nm (9) move the piezo horizontally (10) switch on the feedback.

To create 3D structures accurately 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 others by means of electrostatic manipulation.

References:

Figures:

Figure 1: Force on the nanoparticle versus tip-nanoparticle distance for different applied potentials. The discontinuous black line is the Van der Waals force between the particle and the substrate. At 10V the transfer of the particle occurs at approximately 20 nm tip-particle distance.

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

Figure 3: Deflection signal as a function of time during the nanomanipulation.

Figure 4: (a) and (b) 2D AFM images before and after the deposition of a nanoparticle on an aggregation of nanoparticles. (c) and (d) the corresponding 3D images before and after the deposition.