Manipulation of the Nanometer Size Aerosol Particles Using the Atomic Force Microscope.

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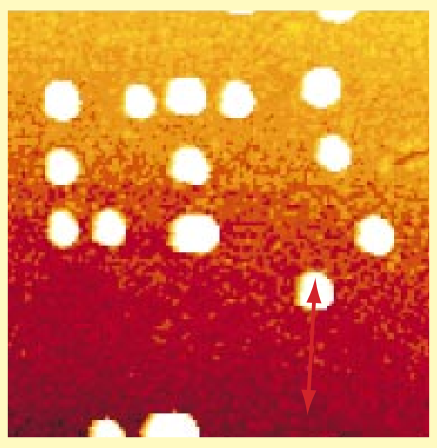
Abstract:

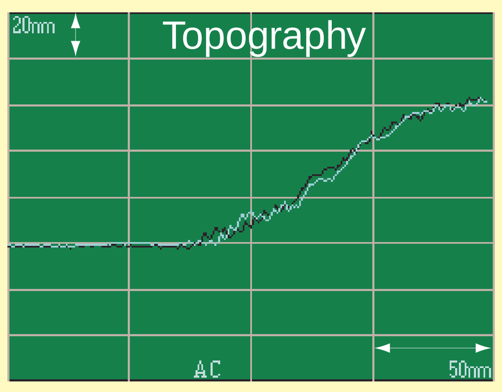
We have developed a novel scheme to manipulate metallic aerosol particles on silicon dioxide surface using an atomic force microscope. The method utilizes the non-contact mode both for locating and moving nanoparticles of size 10 - 100 nm. The main advantage of our technique is the possibility to "see" the moving particle in real time. Our method avoids well the sticking problems that typically hamper the manipulation in the contact mode.

Moving Algorithm

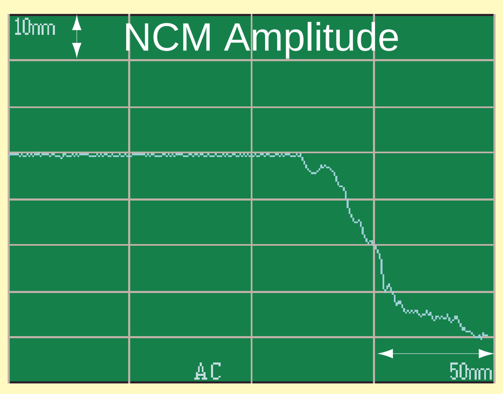


1) Topography image of the sample surface is taken in NCM to locate the particles.

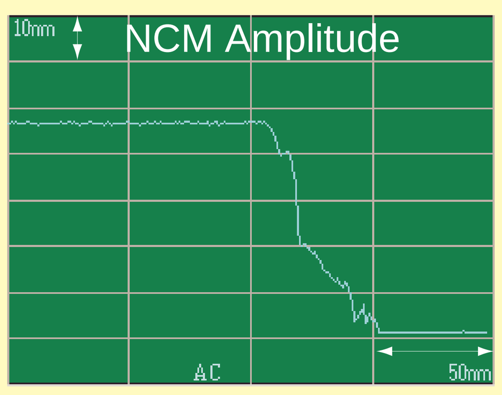
2) Line scan position (↗) is selected with the help of the NCM image.



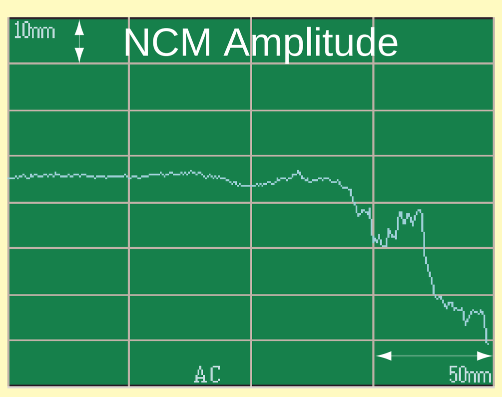
3) The exact position of the particle is found by looking the **topography** of the line scan and by varying the line scan position slightly.



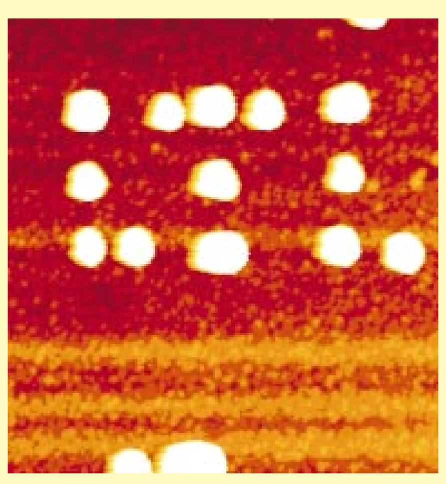
4) Feedback-loop is turned off and **NCM amplitude** is acquired from the scanned line. The particle is visible in the data.



5) The tip is lowered until plateau start to be visible at the position of the particle in the **NCM amplitude** data.

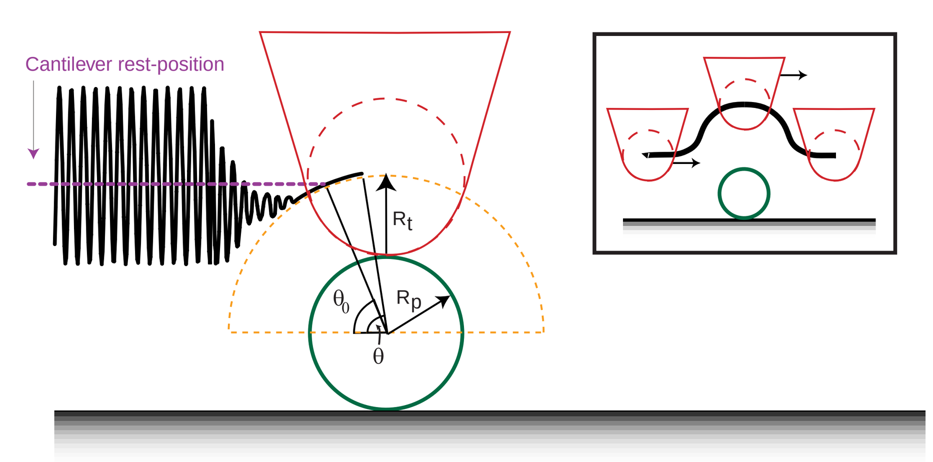


6) After lowering the tip some nanometers more, the particle has moved as is obvious in the **NCM amplitude** data.



7) Steps 2-6 or 1-6 may be iterated to arrange the particles at the desired positions.

a)



b)

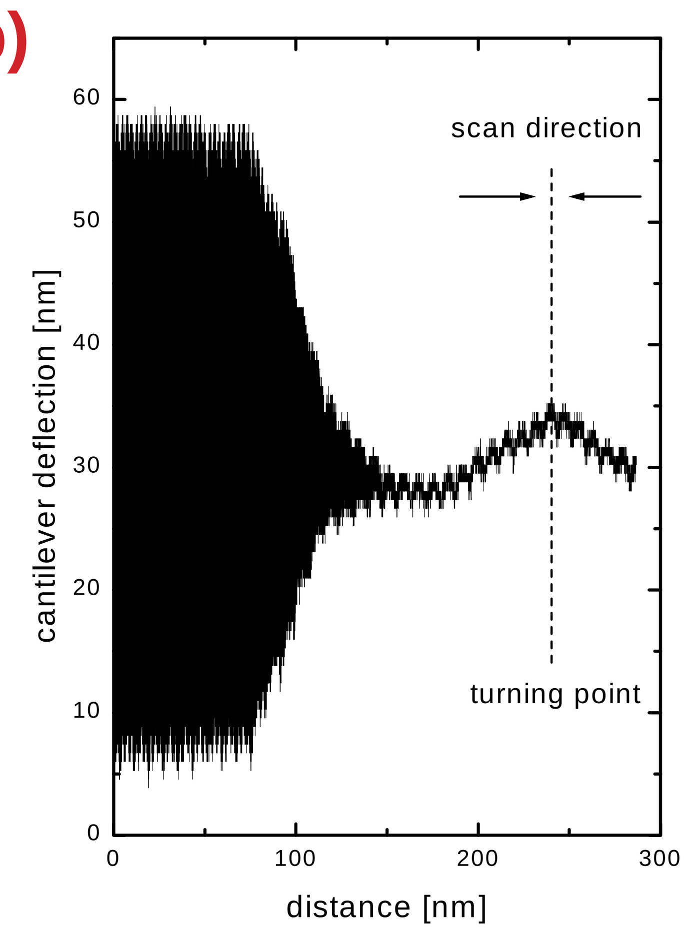


Figure 1: *a) Schematic illustration of the vibrating tip's trajectory in the vicinity of the spherical particle without the regulating loop. The inset shows corresponding DC trajectory in NCM with regulating loop. b) Measured cantilever deflection as illustrated in a).*

It has been demonstrated recently that AFM can be used to arrange and manipulate aerosol particles /1/. We have developed a novel method to move aerosol particles with the AFM (PSI Autoprobe CP) in non-contact mode (NCM). The AFM was operated in ambient air using Ultralevers with resonance frequency 104 kHz. The spring constant of these triangular cantilevers is 2 N/m. The tip radius was measured with the SEM in the worst case to be 37 nm. The algorithm we developed is described in the Moving Algorithm box on the left-hand side.

The tip-particle interaction during the movement, as seen by the difference A-B of the photodetector, is illustrated in figure 1. Three different regimes can be resolved in the trace of the oscillation amplitude. First, far away from the particle and substrate, the vibration amplitude is determined solely by the drive and response of the cantilever. In the second regime, where the tip starts to feel the Van der Waals force, the resonance frequency shifts and the oscillation amplitude is reduced strongly. In the third regime the tip is trapped by the surface and the vibration amplitude becomes zero. The tip traces the particle and the pushing starts supposedly when the cantilever deflection has become positive (at angle θ0 .) This would suggest that the pushing occurs close to the top of the particle. This explains why there is no sticking problems, while it is geometrically obvious that the particles stick easier to the size of the tip than to the vertex.

We have demonstrated the method by moving 45 nm spherical silver aerosol particles on silicon dioxide surface. The aerosol particles are produced by a technique called spray pyrolysis /2/ by VTT Chemical Technology. It took around one working day to move 13 aerosol particles to form the letters "LTL" as is illustrated in the figure 2. The method is demonstrated to work at least down to 10 nm particles.

The future work will concentrate on building a single electron transistor using aerosol particles.

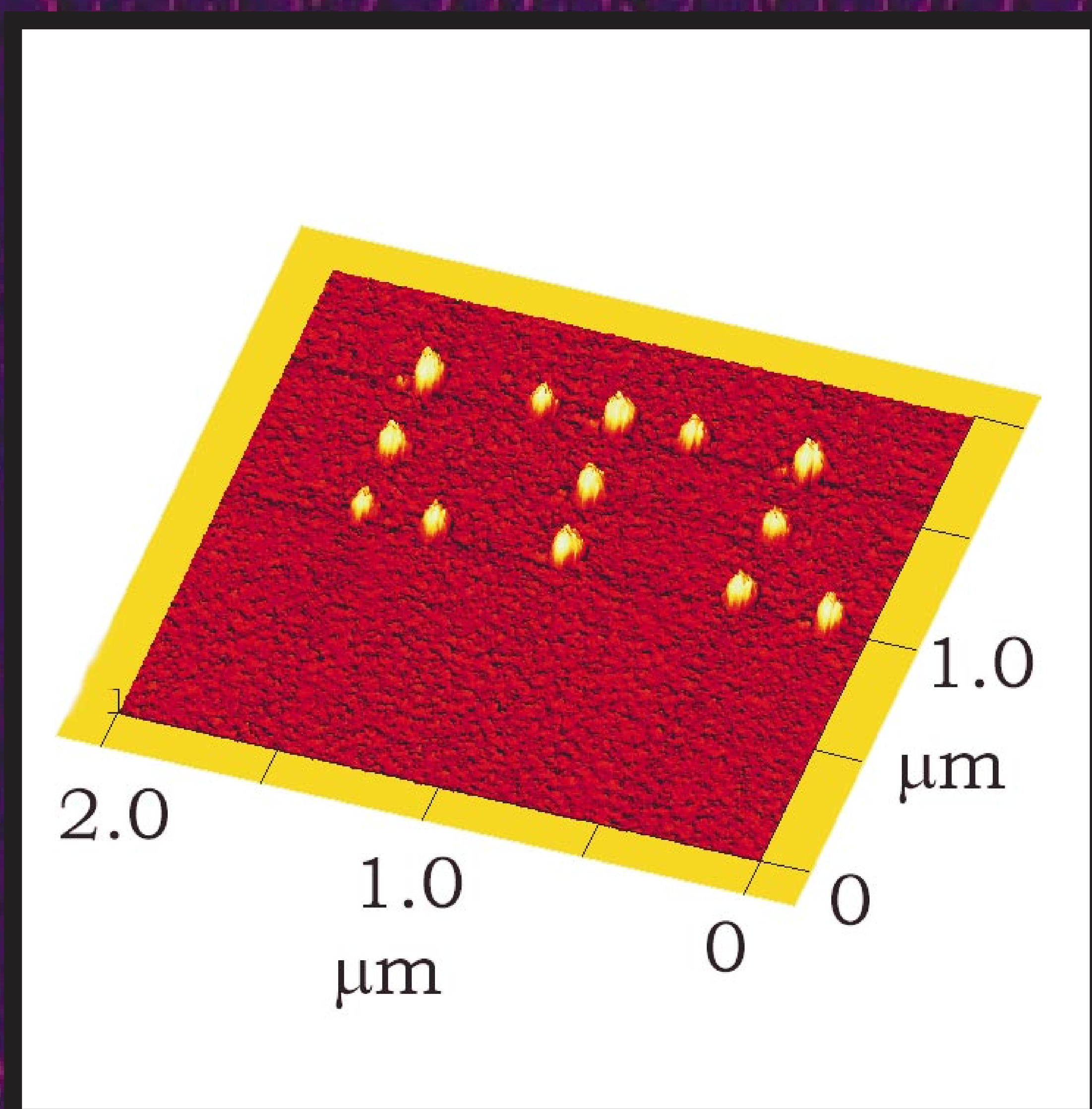


Figure 2: *"LTL" (Low Temperature Laboratory) written in block letters using 45 nm silver particles.*

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References:
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/2/ J. Joutsensaari and E. I. Kauppinen, Mat. Res. Soc. Symp. 457 (1997).