Ultrasonic Force Microscopy at Sb nanoparticles: elastic internal structure and ultrasound-controlled tip-induced particle motion

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We have performed Ultrasonic Force Microscopy (UFM) [1] at Sb nanoparticles grown on highly oriented pyrolytic graphite (HOPG) and molybdenum disulfide (MoS_2) [2]. Sb_4 clusters evaporated on clean HOPG or MoS_2 surfaces form first spherical Sb nanoparticles up to a radius of about 60 nm, and then fingerlike-shaped particles for higher coverages. The morphological transition of the nanoparticles has been related to an Sb thickness-dependent amorphous to crystalline phase transition. Transmission Electron Microscopy (TEM) studies evidence the presence of bending contours in the fingerlike-shaped particle contrast, which are indicative of the coexistance of various crystalline areas of varying relative orientation and enhanced stress [3]. UFM images at those such particles clearly reveal internal elastic contrast. Fig. 1 shows contact mode topographic (a) and UFM (b) images simultaneously recorded on a Sb nanoparticle on MoS_2; (c) corresponds to UFM contrast recorded at a finger of the particle in (b) with higher resolution. Straight brighter bands apparent in the UFM image contrast can be attributed to stiffer regions within the nanoparticle. At the poster, the relationship between TEM data and UFM images will be discussed in detail.

Recent results in the literature demonstrate that Sb nanoparticles can be controllably displaced on HOPG and MoS_2 surfaces using the tip of an AFM cantilever by means of the so-called dynamic surface modification (DSM) mode [4]. In DSM, switching between gentle imaging and particle manipulation is achived by increasing / decreasing the AFM cantilever excitation amplitude. It has been suggested that the occurrance of multielastic inestabilities at the fingerliked-shaped particles may play an important role to account for the energy dissipated during the DSM-mode induced particle motion [4]. Displacement of relatively big islands using the tip of an AFM cantilever can also be achieved in contact mode [4, 5]. Nevertheless, in general, in this latter case the election of the cantilever is not trivial [4]: it should be sufficiently compliant to image without pushing the nanoparticles at low loading forces, and at the same time sufficiently stiff to exert enough pressure at the bigger particles at high loading forces. Here, we experimentally demonstrate that it is feasible to manipulate Sb particles with the tip of a compliant AFM cantilever in the presence of vertical ultrasonic vibration at the tip-sample gap, operating the AFM in the UFM mode. Fig. 2 shows UFM images recorded at different stages of the manipulation process. Fig. 2(a) and (c)were recorded using the same AFM and ultrasonic "non-manipulating" parameters; the particles in (b) were moved by increasing the ultrasonic amplitude relative to that used in (a), keeping the other parameters constant. Previous experimental results in the literature demonstrate that ultrasonic vibration of sufficiently high amplitude reduces and even eliminates friction at the tip-surface contact [6]. In the poster, we will discuss the possible mechanisms of nanoparticle manipulation in the presence of ultrasound and the opportunities to control a tip-induced particle motion by means of ultrasound excitation because of the modification of the frictional properties at the nanoparticle/surface interface.

References:

[1] The UFM technique is described in O. Kolosov and K. Yamanaka, Jpn. J. Appl. Phys. 32 L 1095 (1993); M. T. Cuberes et al. J. Phys. D.: Appl. Phys. 33 (2000) 2347; M. T. Cuberes et al. Nanotechnology 12 (2001) 53, and ref. therein.
[1] The samples were provided by C. Ritter, Humbold Universität zu Berlin.
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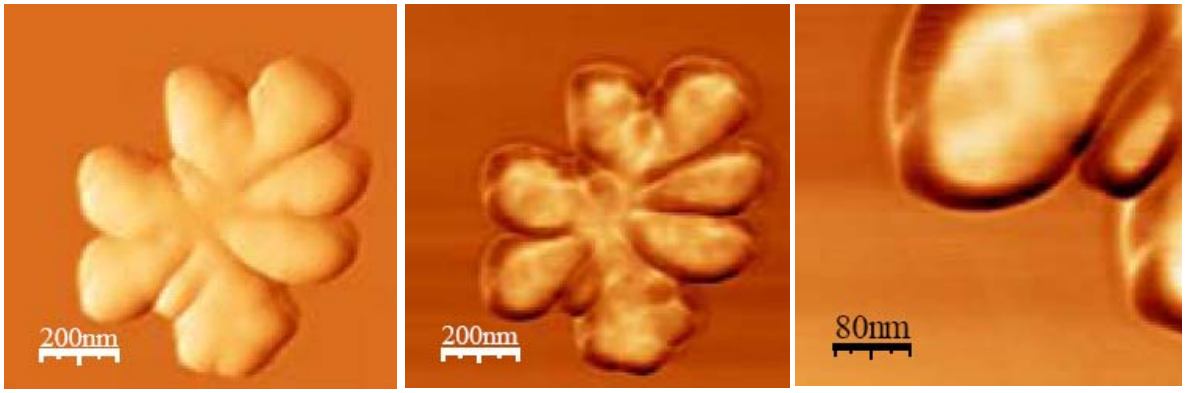
[3] C. Ritter et al. Phys. Rev. B 71 e085405.
[4] R. Lüthi et al. Science 266 (1994) 1979.
[5] F. Dinelli et al. Appl. Phys. Lett. 71 (1997) 1177 ; G. Behme and T. Hesjedal, Appl. Phys. A 70 (2000) 361

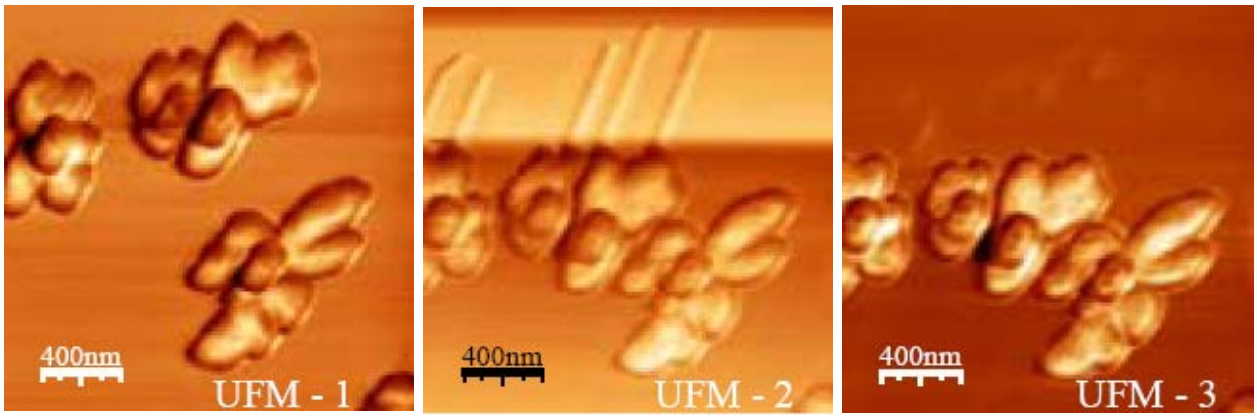
Figures:

Figure 1



(a) (b) (c)

Figure 2



(a) (b) (c)