ULTRASOUND-INDUCED FEATURES AT ATOMIC FORCE MICROSCOPY / LATERAL FORCE MICROSCOPY IMAGES OF HIGHLY ORIENTED PYROLYTIC GRAPHITE

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In this contribution, we discuss experimental results on Highly Oriented Pyrolytic Graphite (HOPG) that evidence effects due to the presence of ultrasonic vibration at the tip-sample contact (i) on nanoscale friction and (ii) on the Atomic Force Microscopy (AFM) / Lateral Force Microscopy (LFM) image contrast.

Recently, a new family of SPM techniques based on the use of AFM with ultrasound excitation have been proposed [1-4]. It has been demonstrated that these procedures provide a valuable means for the characterization of dynamic elastic, viscoelastic and adhesive material properties, and permit to obtain subsurface information. In addition, it has been shown that ultrasound at the tip-sample gap acts as a lubricant, reducing and even eliminating friction at a nanometer scale [5].

We have implemented the possibility to excite ultrasonic vibration at the tip-sample contact on a commercial AFM (NANOTEC). A PZT ceramic piezo is attached to the sample holder and the sample is bonded to the piezo using a thin layer of crystalline salol (phenyl salicilate). The electrodes of the transducer are connected with soft wires to a BNC connector. A Function Generator (HP3302) is used to excite a 2 MHz ultrasonic signal. Using this set-up, we have recorded conventional AFM and LFM images at the surface of a HOPG sample (provided by MikroMasch, ZYA Quality, Nominal Thickness 2 mm) (i) in the absence of ultrasound and (ii) in the presence of ultrasonic vibration of sufficiently high amplitude.

Fig. 1(a) shows a 700 nm x 700 nm topographic image of the HOPG surface measured in contact-mode AFM (without ultrasound excitation). Fig. 1(b) is the derivative of Fig.1(a). Fig. 2 (a,b) correspond to LFM images (Fig. 2a forwards, Fig. 2b backwards) at a 700 nm x 650 nm scan area of the same surface region (without ultrasound excitation). In agreement with previous reports, [6] the HOPG surface exhibits smooth surfaces with a small fraction of line-shaped and disordered regions, in which the coefficient of friction is considerably larger. A variation of the friction coefficient at the line-shape region indicated by the arrow at Fig. 1 (top left) is apparent at Fig. 2(a,b). Fig. 2 (c,d) correspond to LFM images (Fig. 2c forwards, Fig. 2d backwards) of the same surface region, with a 2 MHz vibration excited at the transducer located at the back of the sample. In spite of drift effects, equivalent topographic features can be easily identified in Fig. 2 (c, d) and Fig. 2 (a,b), Fig. 1. Consistently with the expected ultrasound-induced lubricant effects (reduction/elimination of friction) [5], contrast in Fig.2 (c,d) is independent of the scan direction; no different friction-coefficient regions can be distinguished at the surface from those images. Moreover, Fig. 2(c,d) show novel features (see arrow at middle right) probably related to subsurface features. Previously, [7] subsurface dislocations have been observed at HOPG by Ultrasonic Force Microscopy (UFM). As will be discussed, with ultrasound excitation LFM can also provide this kind of information.

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Figures:

Figure 1

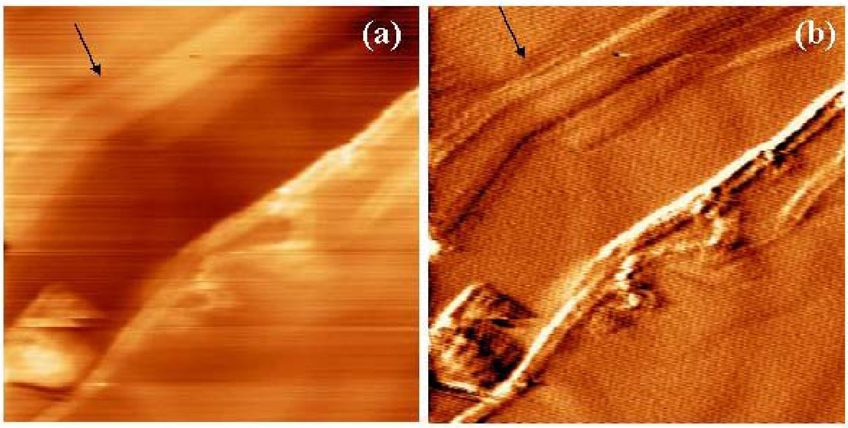

Figure 2