Measuring low magnetic signals with magnetic force microscopy: absence of ferromagnetism in graphite grain boundaries

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The most outstanding feature of the Scanning Force Microscopy (SFM) is the capability to detect different short and long range interactions. In particular, Magnetic Force Microscopy (MFM) is used to characterize the domain configuration in ferromagnetic materials like thin films grown by physical techniques or ferromagnetic nanostructures. It is a usual procedure to separate the topography and the magnetic signal by scanning at a lift distance of 25-50nm so the long range tip –sample interactions dominate. The MFM is nowadays proposed as valuable technique to characterize more complex system such as organic nanomagnets, magnetic oxide nanoislands and carbon based materials [1]. In those cases, the magnetic nanoelements and its substrate present quite different electronic behavior i.e. they exhibit large surface potential differences which causes heterogeneous electrostatic interaction between tip and sample [2] that could be interpreted as magnetic interaction. To distinguish clearly the origin of the tip-sample forces we propose two different methods: (i) by applying *in situ* magnetic field during the MFM operation to detect the variation in the image contrast corresponding to the modification of the magnetic state of the tip or sample [3], (ii) by performing a combination of Kelvin Probe Force Microscopy (KPFM) and MFM to compensate the electrostatic contribution in the frequency shift signal The useful of the KPFM-MFM combination is illustrated by studying Co nanostripes grown by Focused Electron Beam [4] (Figure 1). As another example of this technique we investigate possible ferromagnetic order on the graphite surface [5]. The results show that the tip-sample interaction along the steps is independent of an external magnetic field. By combining KPFM and MFM, we are able to separate the electrostatic and magnetic interactions along the steps obtaining an upper bound for the magnetic force gradient of 16 µN/m (Figure 2). Our experiments suggest the absence of ferromagnetic signal in graphite at room temperature in strong contradiction with [1].

References

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Figures

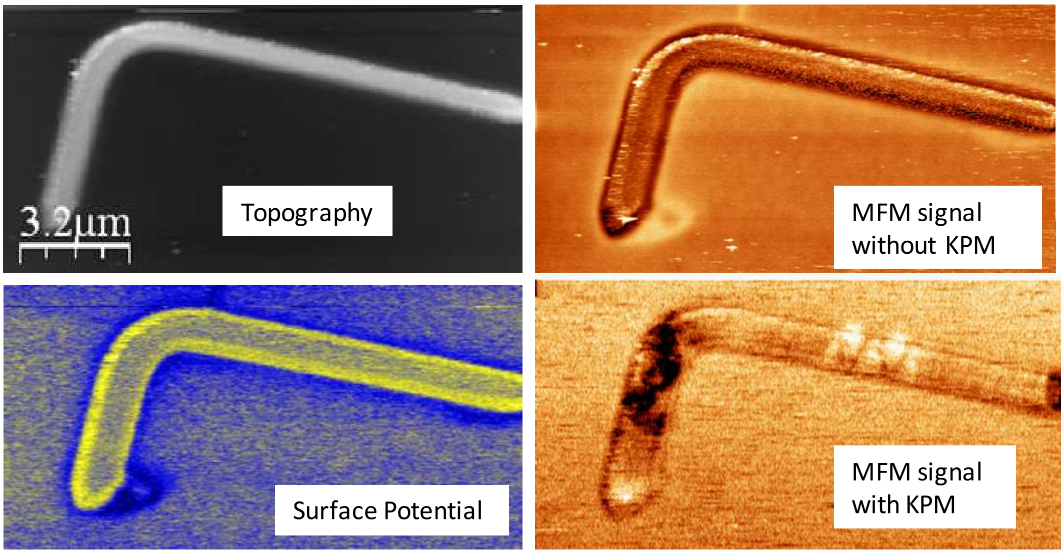

Figure 1: *(a) Topography and (b) MFM signal (frequency shift) of a cobalt nanostripe without electrostatic compensation. The contrast drastically changes when KPM is used simultaneously: (c) Surface potential image and (d) MFM signal with KPFM.*

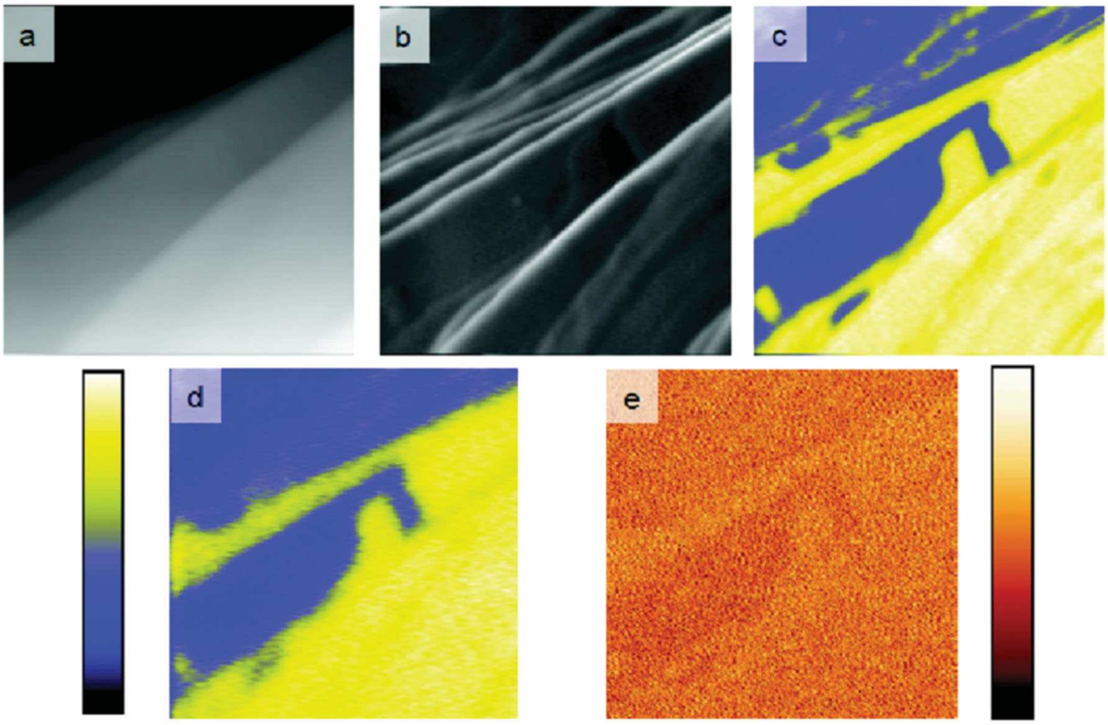

Figure 2*. 3 µm x 3 µm AFM, KPFM, and MFM images taken in high vacuum with a cobalt-coated probe on ZYH-HOPG. (a) Topography. (b) Edge enhanced image of (a) showing the surface steps. (c) KPFM image simultaneously taken with (a), showing electrostatic domains and steps on the sample surface (the potential difference between bright and dark areas is 200 mV). (d) KPFM image taken in retrace at 50 nm lift distance. (e) Frequency shift image taken simultaneously with (d). The total frequency shift variation in figure (e) is 0.4 Hz.*