KELVIN FORCE MICROSCOPY WITH SIMULTANEOUS NON-CONTACT TOPOGRAPHY IMAGING - INTERACTION BETWEEN THE TWO INVOLVED CANTILEVER RESONANCES

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Kelvin force microscopy (KFM)[1] consists in eliminating the contact potential difference (CPD) between an AFM tip and the sample surface and mapping the surface potential of the sample. It can reveal potential drops on circuits under operation, detect charge storage and perform dopant profiling at a nanometer scale.

KFM imaging is performed in an Omicron ultrahigh vacuum scanning probe microscope by electrostatically exciting the cantilever at its second resonance, simultaneously with non-contact topography imaging using frequency detection on the fundamental mode, in a setup comparable with the one proposed by Sommerhalter et al. [2]. This setup has a good surface potential sensitivity, allows simultaneous topography and surface potential imaging, and fast acquisition speed. In a first approach, it should be expected that the simultaneous operation makes the topography and surface potential imaging benefit from each other, since the non-contact topography feedback loop maintains the resonance frequencies constant while the KFM loop eliminates any contact potential difference between tip and sample, assuring pure Van der Waals type interaction and thus preventing surface potential variations from causing topography artifacts.

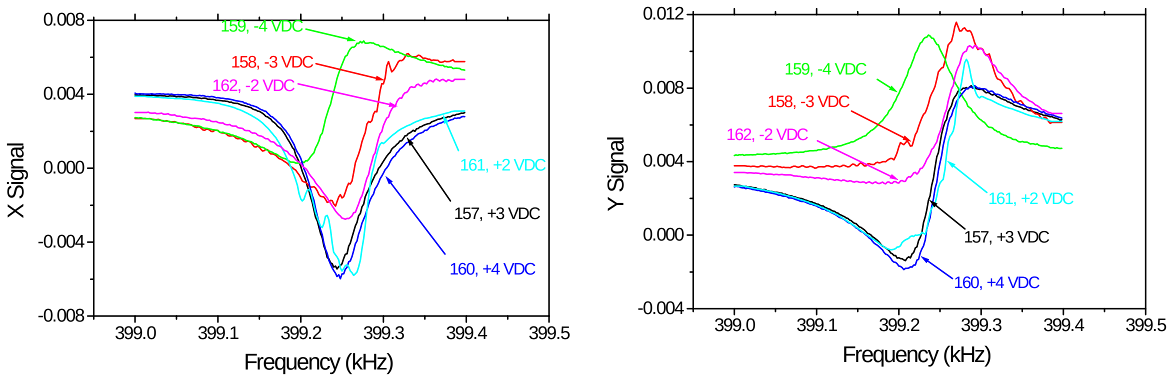

Fig. 1: Electrostatic excitation resonance curves of a non-fundamental cantilever frequency, at different contact potential difference DC components. Mechanical tip excitation at the fundamental frequency and non-contact distance regulation loop were active during the acquisition. An apparent rotation of the drive phase is observed as the DC component is modified, showing that parasitic capacitive coupling of the electrostatic excitation signal into the force feedback circuit introduces an excitation at a drive phase different from the direct electrostatic force applied to the tip.

On the other hand, since the cantilever is part of a self-oscillating force feedback loop as the pendulum of a clock, any excitation (even at higher order resonance) applied to it concerns the loop as a whole. In particular, we show that parasitic coupling between the electrostatic kfm excitation signal and any other part of the loop has to be considered as an excitation source by itself and cannot be corrected by simply subtracting a constant offset beyond the loop. Moreover, the direct electrostatic force acting on the tip and the one due to parasitic coupling have different drive phases, making the overall drive phase rotate as the electrostatic contribution varies (fig.1). We propose an active compensation of parasitic excitation within the foce feedback loop.

Another phenomena often encountered is a fluctuation between the ratio of the two resonance frequencies: if the KFM feedback is switched off and a CPD is applied, the fundamental mode frequency is kept constant by the topography feedback while the higher order frequency drifts away, leaving a typical Lorentzian signature in the amplitude vs. CPD curve.

References:

[1] M. Nonnenmacher, M. P. O'Boyle, and H. K. Wickramasinghe, Appl. Phys. Lett. **58** (1991) 2921

[2] Ch. Sommerhalter,a) Th. W. Matthes, Th. Glatzel, A. Jager-Waldau,, Appl. Phys. Lett. **75** (1999) 286