Kelvin Probe Controller Module

NANONIS SPMCS-KC-1

The SPMCS-KC-1 is an add-on module to the Nanonis SPM Control System that enables Kelvin Probe Force Microscopy (KPFM), i.e. the tracking of contact potential difference (cpd) and charge distribution on the sample. This application can only be performed in non-contact operation, thus in combination with the Nanonis Oscillation Controller Module (OCM-2).

Generally, a change in the bias voltage results in a change of the force gradient between the tip and the sample due to electrostatic interactions (measured through the frequency shift in ncAFM). In a very good approximation this change is parabolic. The bias voltage at the maximum of the parabola, i.e. the point at which a change in bias does not influence the frequency shift, lies at the relative work function between tip and sample material. To measure this work function (also known as contact potential) is the scope of Kelvin Probe Microscopy.

In a Kelvin Probe experiment the bias voltage applied between tip and sample is modulated at a frequency that is higher than the cut-off frequency of the z-feedback controller, i.e. an AC-component of a few kHz is added to the DC-offset of the bias. The response of the modulation on the frequency shift is measured with a built-in fully digital lock-in detector. A separate PI-controller regulates the DC-offset such that the response of the frequency shift is zero, i.e. it is at the maximum of the parabola. Now the DC-offset is a direct measure of the work function/contact potential.

FM-Mode: In the FM mode the bias is modulated at a frequency that is higher than the bandwidth of the z-feedback, but not commensurate with the oscillatory motion of the cantilever. This mode is directly supported by the Nanonis Kelvin Probe Module.

AM-Mode: In the AM mode the bias is modulated at a frequency that is commensurate with the oscillatory motion of the cantilever, usually at a higher resonance of the cantilever. This mode is supported by the Nanonis Kelvin Probe Module but needs an extra second Oscillation Control Box (OCB-2) or an external lock-in detector capable of operating at the desired frequencies.

The Kelvin Controller Module is tightly integrated with the control system, especially the scan control, spectroscopy and z-feedback module. The KPFM data can therefore be acquired, displayed and analysed in exactly the same way as all other data channels.

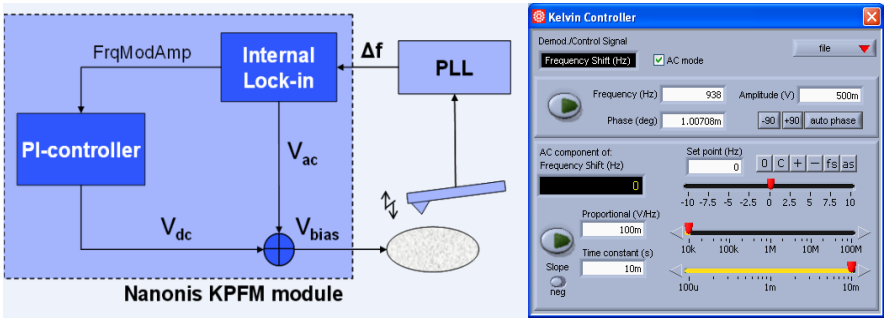

Fig. 1: Block diagram of the KPFM mode (left) and screen shot of the user interface (right). Typically, Bias and Z signal are recorded simultaneously in order to get information both on the contact potential difference and the corresponding sample topography.

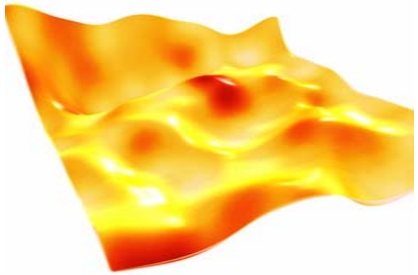

Fig. 2: Example application: KPFM (color code) and topography (height) shown on the same image. Acquired on a CeO2 sample. Courtesy of S. Gritschneder, S. Torbrügge, M. Reichling, University Osnabrück.

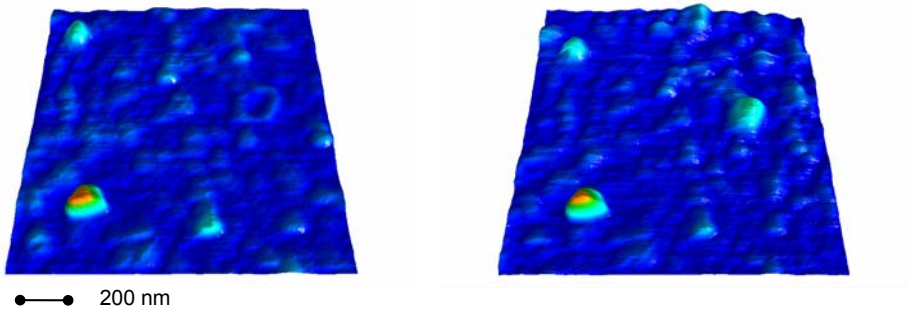

Fig. 3: True height determination. Left image: topography with constant bias voltage. Right image: topography of the same area with KPFM control loop on in FM-mode. Notice the artifact topography indicated with the arrow. Sample: Si quantum dots on SiO_2. Image Courtesy of Th. Mélin and H. Diesinger at IEMN in Lille acquired on an Omicron VT-AFM with the Nanonis control system.

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