Poster

QPLUS AFM WITH SMALL OSCILLATION AMPLITUDES AND HIGH FREQUENCIES AT 5 K

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The creation and investigation of nano-structures, molecules or atomic structures on insulating surfaces is a key approach for electronic decoupling from the substrate. It pushes AFM as an complementary imaging and spectroscopy technique to STM. Ideally, the used AFM probe should simultaneously or alternatively work in STM/STS modes without performance compromises on the latter. Based on a proven low temperature (5K) LT STM platform, we have integrated a QPlus sensor [1], which employs a quartz tuning fork for force detection in non-contact AFM. For combined STM operation, this sensor has key advantages over conventional cantilevers: (i) a solid metal tip for optimal STM/STS and (ii) high stiffness and high stability, i.e. low vibrational noise due to small self-resonance amplitudes.

For quantitative force spectroscopy on insulating thin films or semiconductors, decoupling of tunneling current and piezo-electrically induced AFM signal is important. By measurements on Si(111) and Au(111) we prove that a dedicated pre-amplification technique avoids cross-talk. In addition, extremely low signals require the first amplification stage to be very close to the sensor, i.e. to be compatible with low temperatures. STS measurements using a Niobium tunneling tip reveal the superconducting gap with a FWHM of approx. 2.5 meV and prove a probe temperature of approx. 5K.

The high stiffness (1800 N/m) of the sensor allows for operation with extremely small amplitudes to (i) more precisely keep the sensor with a certain force interaction regime, (ii) increase sensitivity especially for short range forces and (iii) allow for force measurements during atom manipulation experiments without disturbing the manipulation event as such [2].

As benchmark measurements, we present (1) atomic resolution imaging on single crystal NaCl with oscillation amplitudes down 72pm (peak-to-peak) in constant df imaging feedback (fig. 1) and, (2) operation at higher flexural modes in constant df imaging feedback with frequencies above 300 kHz (fig. 2). We also present atomic resolution measurements on MgO(100), Au(111), and first evaluation measurements of the QPlus sensor in Kelvin Probe (KPM) mode operation on Si(111) 7x7.

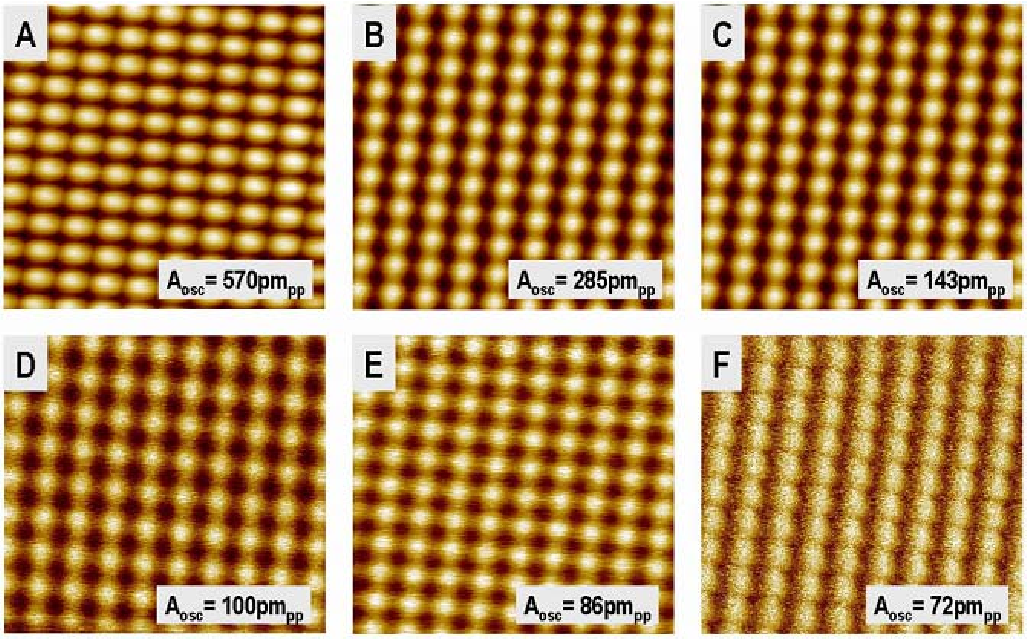

Fig.1: QPlus AFM on single crystal NaCl(100) in df feedback at low oscillation amplitudes down to 72 pm$_{pp}$. Raw data, line-by-line background correction, no filtering. 4 nm x 4 nm, T = 5 K, f_0 = 47874 Hz, Q = 90000, U_{gap} = +500 mV (a to c) and U_{gap} = -400 mV (d to f), df = -10.8 Hz, -16.5 Hz, -22.3 Hz, -17.5 Hz, -19.3 Hz, -40.75 Hz (a to f).

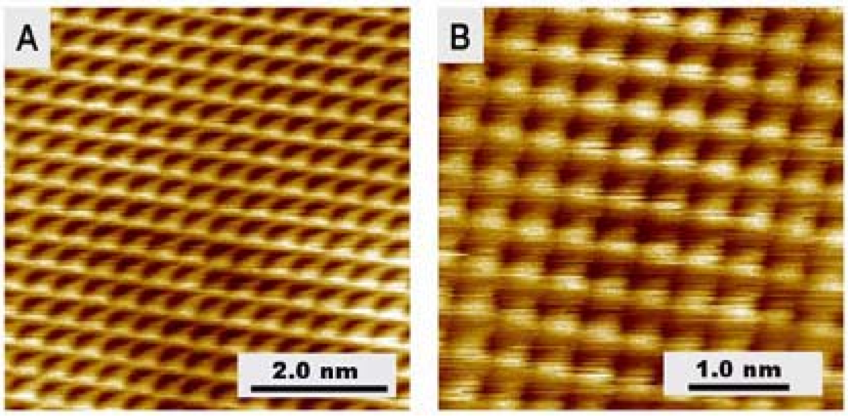

Fig. 2: QPlus AFM on NaCl(100) using a flexural mode at T = 5 K. Sensor operated at a frequency of f_0 = 318534 Hz for df feedback. Base frequency is 47 kHz. U_{gap}= 450 mV, Q = 9300. (a) df= -2.37 Hz, A_{OSC} = 1.5 nm$_{pp}$. (b) df= -4.45 Hz, A_{OSC} = 0.5 nm$_{pp}$ Raw data, line-by-line background correction, no filtering.

[1] F. J. Giessibl, et al., Appl. Phys. Lett. 73, 3956 (1998)
[2] M. Ternes, et al., Science 319, 1066 (2008)