New high electromechanical coupling LiNbO3 fully shielded tuning fork sensor for multi-environment non-contact AFM

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Non-contact atomic force microscopy (NC-AFM) is a well-established tool renowned for atomic resolution imaging in the UHV environment. Its success relies on the self-sensing piezoelectric probes derived from standard quartz tuning forks (TF) with extreme sensitivity to the contact forces. The noise of such TF sensors is directly linked with (and hence, unfortunately, is limited by) piezoelectric coefficient of quartz [1]. Even more importantly, the sensor surface electrodes are shorted by immersion in the water and biological solutions, precluding the highly sought after use of NC-AFM in the biomedical research [2]. In the NC-AFM - scanning tunnelling microscopy (STM) experiments, the crosstalk between surface TF and STM electrodes is also unfavourable.

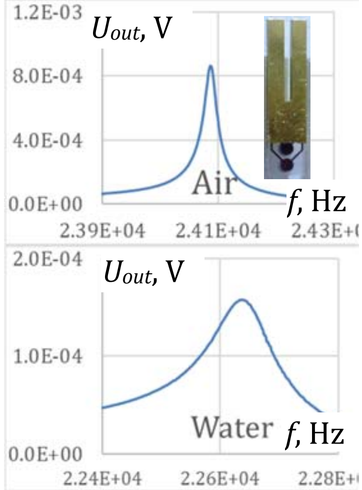

Fig 1: Frequency response of LiNbO3 TF in air and water (1V drive, 50 Ohm load). The water is only ~10 db below air, no electrical shorting is evident.

Fortunately, there are other materials such as Lithium Niobate (LiNbO3), with up to ten fold higher piezoelectric coefficients. Here we are introducing a new paradigm of the LiNbO3 based NC-AFM TF sensor with entire electrodes embedded in the piezoelectric material, and surface fully coated with the Au layer (inset in Fig.1). The design of the TF, described in details elsewhere [3], consists of two separate internal electrodes that can be used independently to drive the TF (between the first electrode and a ground) and to detect displacement (via the potential of the second electrode with respect to the ground), with high effective decoupling the electrodes. The new sensor is then becomes a three terminal electromechanical device, compared to two-terminal quartz TF.

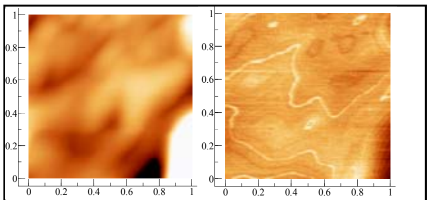

Fig 2: LiNbO3 TF response in contact with AFM tip. Left – AFM topography map, right –TF amplitude at resonance.

The extremely high piezoelectric constant of such "super-TF" is demonstrated in the Fig. 1 where the 1V electrical drive results in the low noise output of the TF loaded directly on 50 Ohm (!) load (no amplification) with Q~1000. More essentially, submersing the TF in water produces only moderate ~10 db drop of the signal (with an expected frequency shift due to mass loading). We tested the response of the TF to the nanoscale contact by approaching it with AFM tip (Fig.2), observing clear spatial correlation of AFM topography and TF response. The high sensitivity and insulation of the such "super-TF" from the environment, makes it a highly beneficial platform for both vacuum and liquid environment NC-AFM applications.

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