Quartz Sensor for Atomic Force Microscopy in Liquid Environment

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Atomic force microscopy (AFM) provides a promising approach to in situ microscopic characterization of biosystems or solid-liquid interface. However, conventional imaging techniques based on cantilever often suffer from low resonance quality factor or instability of the sensor due to its rather low stiffness. In addition, detection schemes based on optical method has limitation due to characteristic noises of laser optics and detection electronics, and can hardly attain thermally-limited theoretical sensitivity unless the above noises are elaborately suppressed. As an alternative approach, we have attempted to develop a non-optical sensing scheme based on quartz oscillator. With piezoelectricity of quartz, a self-detective force sensing system can be implemented in this approach. In addition, excellent resonance characteristics of quartz serve as an ideal frequency filter and therefore a stable and spurious-free operation of dynamic force microscopy is expected. A schematic view of the sensor is shown in Fig. 1. A custom-made 550 kHz length-extensional oscillator was used. A 10 µm thick tungsten wire was attached to one end of the quartz and its apex was shaped with focused ion beam (FIB) technique. Instead of immersing the entire sensor into the liquid as in the previous report[1)], it was accommodated into a diving bell[2)] that keeps the quartz from wetting while 300 µm long portion of the tip is immersed into the liquid. The typical measured Q value was ca. 6000 in ambient air, while it still remained ca. 4000 in distilled water. This fact implies that increase in force noise as the sensor is introduced into water from ambient air is of a factor of ca. 1.2. Oscillation of quartz is detected via induced current with a current-voltage converter with a conversion constant of 10 MΩ. From the dimension of the quartz and its piezoelectric constant, its sensitivity to the oscillation amplitude is calculated to be 1.4×10^9 (V/m), which is in good agreement with a value of 1.8×10^9 (V/m) estimated from a measured thermal peak voltage. These facts imply that the typical signal amplitude of 1 V corresponds to tip amplitude of about 0.5-0.7 nm. This value is more than one order of magnitude smaller than that of a typical cantilever used in dynamic or tapping mode. The force-distance curves and preliminary results of imaging will be presented.

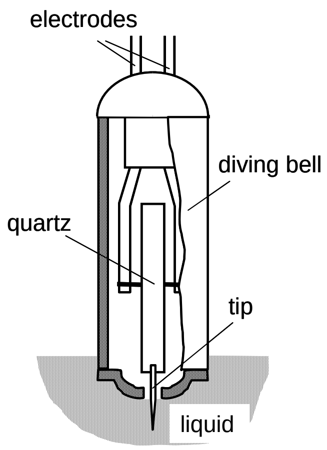

Fig. 1 Schematic view of sensor made with quartz oscillator.

[1] M. Kageshima et al., Appl. Surf. Sci. **188** (2002) 440.
[2] M. Koopman et al., Appl. Phys. Lett. **83** (2003) 5083.