

Simultaneous AFM and QCM measurements of biological and electrochemical processes.

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We focus on a better understanding of the interaction of the quartz crystal microbalance (QCM) resonator with fluid media while a biological layer is being adsorbed on the grounded sensing electrode. With this purpose in mind, we combined an atomic force microscope (AFM from Molecular Imaging, USA) working in liquid medium and a QCM based on the electronics provided by Q-Sense AB (Göteborg, Sweden). The advantage of this latter instrumentation is the ability to measure the evolution of the frequency of several overtones (first, third and fifth in our experiments) as well as the damping.

The requirement of working with overtones in the AFM/QCM combination is mandatory since the fundamental mode (4.7 MHz to 5 MHz in our setup) is so much disturbed by its fluctuating environment (liquid flow, cantilever holder motion) because of its wider energy distribution on the sensing electrode. We have identified the standing wave pattern of acoustic waves between the resonator and the cantilever holder to be a major source of QCM frequency fluctuations [1]. These QCM frequency shifts are greatly reduced when monitoring the third and fifth overtones and, while increasing the frequency noise level, do not prevent meaningful measurements during adsorption processes.

First, we display the ability of our instrument to monitor simultaneously at different scales (square cm for the QCM, nanometer scale for the AFM) the adsorption process of biological species (fibrinogen, collagen, antigens/antibodies).

Secondly, we studied the physics of the QCM interaction with the layer and the surrounding liquid by using the experimentally simpler chemical process of electrodeposition of copper and silver on gold [2]. The electrodeposition of these two metals on the sensing electrode display different layer shapes (roughnesses) which provide an easy calibration tool for the various types of interactions (viscous or rigid layer leading to different behaviors of the overtones). In the case of rigid layers, the frequency variations of the overtone number n evolve as $\Delta f_n/n$, while in the case of viscous interactions in which the thickness of the liquid interacting with the resonator is a function of the oscillation frequency, the frequency variations of the overtone number n evolve as $\Delta f_n/\sqrt{n}$. These two behaviors are indeed observed in electrochemical processes and are coherent with damping informations.

The second type of behavior – viscous layer – is most often observed in biological adsorbed layer, leading to the conclusion that the mass shift observed for thick layers is mostly due to trapped liquid.

References

- [1] J.-M.Friedt, K.H.Choi, L.Francis and A.Campitelli: *Simultaneous Atomic Force Microscope and Quartz Crystal Microbalance Measurements: Interactions and Displacement Field of a Quartz Crystal Microbalance* Jpn. J. Appl. Phys. **41** (2002)
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