Latex skater at the nanoscale: QCM study of analyte induced sliding in complex loadings with polymer beads

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Introduction.

Nanostructured latex beads layers are of significant interest as sensitive layers for gas sensors applications [1].

Surface properties of quartz crystal resonator (quartz crystal microbalance, QCM) strongly depend on the elasticity and viscosity of the sensing material, which can vary greatly during adsorption and desorption. Thus, back in 1993, Hauptmann [2] noted that while most polymer films responded to polar and nonpolar molecules in the usual way (reduced frequency), the polymer triethanolamine-tribenzoate gave positive responses, i.e. increased the frequency of adsorption of chloroform.

Methods.

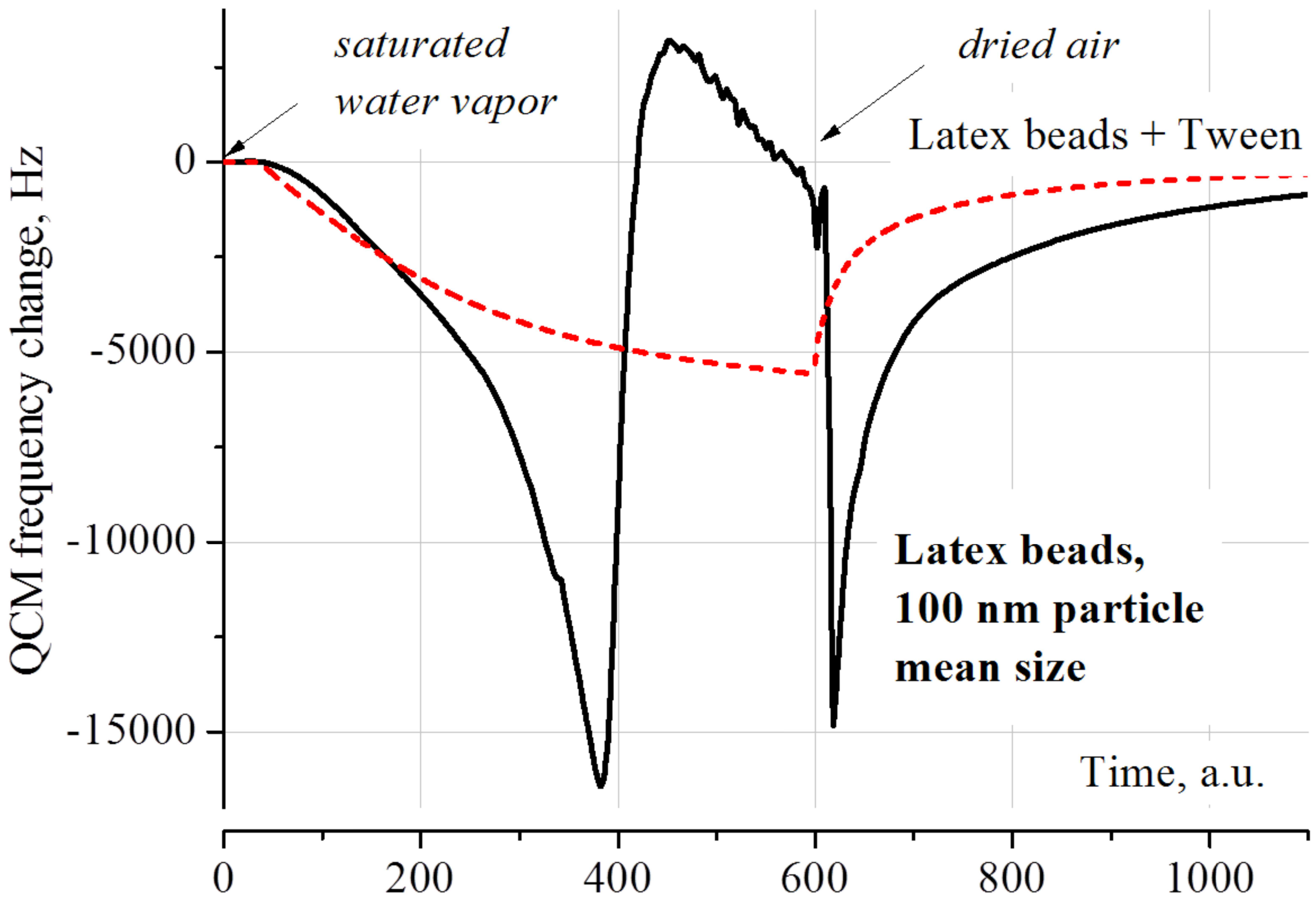
10 MHz quartz crystal resonators of AT-cut were used as sensors for the investigation. Sensors were placed in the flow-type measurement chamber. Liquid analyte was in the flask. The flow of molecules from the analyte`s surface was captured by the carrier gas at a constant flow-rate at a constant room temperature, forming a gas sample. Argon was used as the carrier gas.

10 μl of latex beads suspension (LB1, 100 nm, Sigma-Aldrich) was deposited on the surfaces of QCMs from both sides, followed by deposition of the solution LB1 in 0,2% Tween with following drying under room temperature. The solution of Tweens and latex nanoparticles was made by mixing of LB1 solutions prepared from Sigma-Aldrich preparations in double-distilled water.

Results.

The generally accepted way of describing quartz crystal microbalance (QCM) response is based on the phenomenological Sauerbrey model, where coating characteristics are expressed by some effective values reflecting the inert nature of the loaded mass. More recently, it was recognized that resonance frequency shift could assume a variety of values which appear in more complex systems.

The analysis of the adsorption measurements specific for films of latex nanoparticles LB1 (Sigma- Aldrich) with saturated water vapor (Figure) unambiguously indicates the manifestation of new nanoscale effects in the analytical QCM methods. When the fixation of LB1 nanoparticles on the surface was carried out using



Tween compounds, a classic Sauerbry-type dependence is observed. At the same time, when particles can form large aggregates on the surface, “oscillatory” behavior of QCM response has been recorded. It was demonstrated that “transformation” of Sauerbrey into anti-Sauerbrey behavior of QCM sensors can be related to the formation of a mechanical nonlinear contact accompanied by the change in friction or surface across contact area which is induced by its interaction with the analyte. So, “massive” interfacial ensembles of LB1 with weak interfacial adhesion capable of slippage on the surface under exposure in water vapor: a loosely-coupled mechanical assembly able to move its center of mass freely across the surface disturbing the conditions of the phenomenological Sauerbrey model. Finally, it becomes clear that a volatile compound is able to change not only the mass loading, but also induce the transition from static friction to sliding in the areas when the friction coefficient locally changes owing to the adsorption.

Conclusion.

The response of a quartz crystal microbalance with a sensitive layer to the adsorption of volatile molecules in certain situations is determined not so much by the actual increase in mass as by a change in the mechanical properties of the sensitive material. Analysis of adsorption measurements specific for LB1 (Sigma-Aldrich) latex nanoparticle films with saturated water vapor indicates the occurance of new effects.

References

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2: Hauptmann P., Lucklum R., Hartmann J., Auge J., Using the quartz microbalance principle for sensing mass changes and damping properties. Sensors and Actuators A 37-38 1993 P.309-316