Studying Particulate Adsorption by Drying Droplets on a Microfabricated Electro-Acoustic Resonator

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When a droplet or film of liquid containing dispersed particles evaporates, it often leaves behind a residue in the form of a ring stain consisting of a dense congregation of particles within the thin ring relative to the total droplet contact area – a phenomenon commonly known as “the coffee-ring effect”[1]. Understanding this phenomenon is of interest, for example, in applications where highly ordered ring/shell configurations of self-assembled particles need to be generated[2] or, in other instances, to suppress the staining effect[3] where particulates need to be uniformly adsorbed onto a surface. In the case of mechanical biosensors, the attachment of analyte on the functionalized sensor surface is often read after drying the surface where the spatial distribution of the residue can impact the accuracy of the measurement.

In this study, we utilize two electrically addressed microfabricated silicon resonators operating in the square-extensional mode at ~3.14 MHz to study particulate adsorption, as a result of drying droplets, by monitoring the resonant frequency and quality factor. High-purity water droplets with homogenously dispersed polystyrene particles (300 nm diameter) were sequentially dispensed onto the surface of a *sensor* resonator and an identical resonator was used as a *reference* on which identical volumes of high-purity water droplets (without particles) were dispensed. It was seen (Figs. 1(a)-(b)) that the residue created by droplet drying on the sensor resonator is consistent with the “coffee-ring effect”. Subsequent droplets produced negative frequency shifts in both resonators (Fig. 1(c)) where the shift for the sensor resonator was much larger (several fold higher than expected) as compared to the reference resonator where the shift remained relatively linear with a slope of -52.89 Hz/drop. The extended paper will elaborate on these observations providing further insight into the interaction of droplet drying and subsequent particle re-distribution/adsorption on the measured frequency response and the formation of the ring stain.

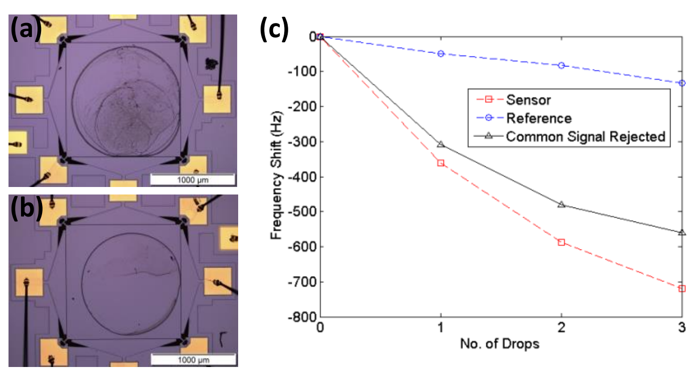

Fig. 1: (a), (b) Images of the sensor and the reference resonators, respectively, showing ring stain formation and particle adsorption on the surfaces. (c) Frequency shift plots for the reference resonator and the sensor resonator presented together with the measured differential frequency shift.

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