# Gravimetric and Viscoelastic Dynamics of Water Drop Evaporation

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## Introduction

Controlling liquid evaporation on a single-droplet scale is crucial to assure formation of thin layers of defect-free flexible organic electronics. Our team works on developing an instrument which would allow measurements of mass (gravimetric) and viscoelastic changes during liquid evaporation using a Quartz Crystal Microbalance with Dissipation (QCM-D). The QCM-D is a high-sensitivity AT-cut quartz crystal acoustic resonator, resonating at 5MHz and odd harmonics thereof (up to the 17th at 85MHz).

Our goal was to demonstrate that we can find correlations between these 9 frequencies during solvent evaporation.

## Methods

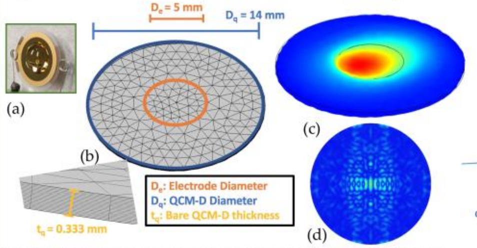
We recorded the nine frequencies of QCM-D during liquid evaporation. We used a Butterworth Van-Dyke (BVD) circuit model to extract resonant peak position and FWHM.

Peak position changes correlate both with changes in mass of the droplet (gravimetric, Sauerbrey equation) and with changes in viscoelastic properties of the liquid at the interface.

We used a Finite Element Model (FEM) with COMSOL software to visualize the displacement of a bare QCM-D surface at fundamental resonance.

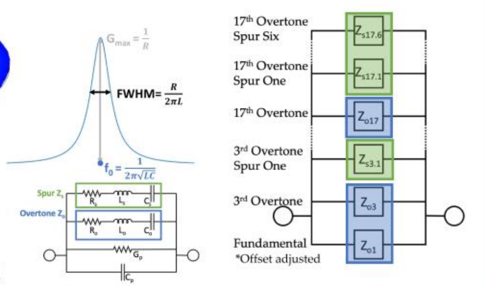
## Results

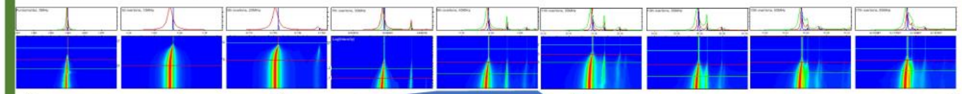
QCM-D surface displacement FEM analysis

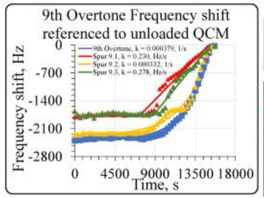


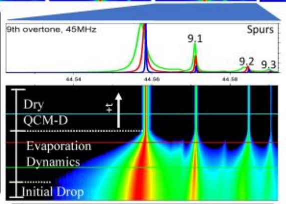

(a) Real QCM-D with viscoelastic layer (b) FEM mesh; (c) QCM-D displacement amplitude at 5MHz with viscoelastic layer; (d) Unloaded

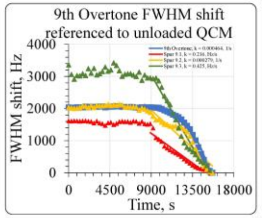
Extended BVD circuit for all resonances

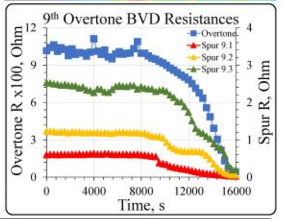


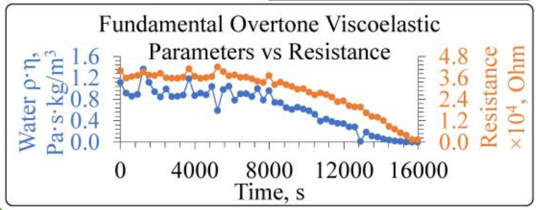



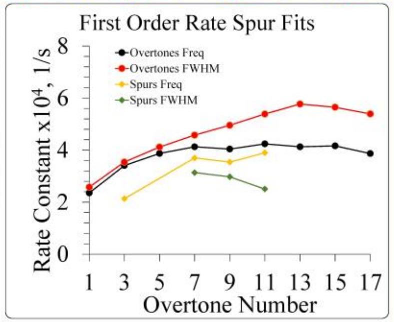


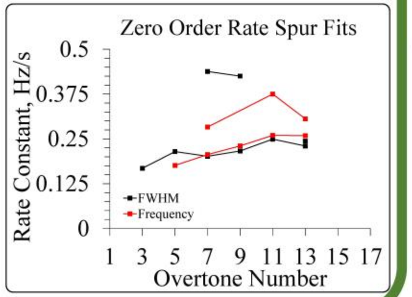




## Conclusions & Future Work

We showed that QCM-D fundamental, overtones, and spurious peaks exhibit correlated dynamic behavior during water evaporation, suggesting that they can be used to monitor solvent evaporation. The first order rate constants for dynamic changes of overtone peaks (gravimetric changes) are slightly smaller compared to FWHM rates (viscoelastic changes) except for overtones 1,3, and 5 which show similar behavior for both. Dynamic changes in spurious peaks can be fit to zero-order rate laws, and in general all lowest order "spurs" had lower rates than overtones. We applied the BVD equivalent circuit model to all overtones and extracted all corresponding RCL constants.

We demonstrated a workflow allowing characterization of gravimetric and viscoelastic properties of liquid dynamic evaporation process.

## Acknowledgements

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