Measurements and theory of ion relaxation times near electrified surfaces using frequency-modulated surface acoustic waves

Sudeepthi Aremanda [a], Yifan Li [a], Jian Su [a], Ofer Manor [a]

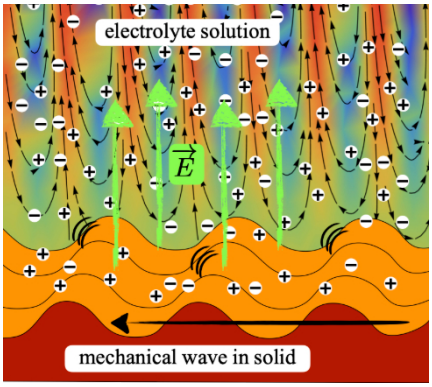
[a] Technion - Israel Institute of Technology, Haifa, Israel

manoro@technion.ac.il

We show recent theory and measurements of the dynamical behaviour of an electrified glass surface in electrolyte. We use MHz-level frequency-modulated surface acoustic waves (SAWs) to study the dynamics of an array of ions and ion mixtures in the electrical double layer (EDL) that appears at the electrified glass/solution interface . The SAW travels in the flat solid, and the EDL exists in the electrolyte solution; both phenomena are entangled through a field effect, a mechanical evanescent wave, which is invoked in the solution by the SAW [1] and vibrates ions in the EDL [2, 3]. The excited EDL leaks a measurable electrical field to the bulk of the electrolyte solution. This is a new MHz-level spectroscopy for studying ion relaxation times near isolated electrified surfaces.

Electrical double layers (EDLs) are nanometer-thick clouds of ions that appear at the charged interface between a substrate and an electrolyte solution and determine its electrical properties. Ions diffuse and migrate through the thickness of an EDL within micro- to nano-seconds: These are ion-specific limiting-times for charging and discharging the EDL and are known as the EDL relaxation-times. They are a product of the EDL structure and the ion size and charge. An ion relaxation-time similar to the SAW periodic time results in an ion electro-mechanical resonance, which maximises ion vibration and the leakage of the electrical field, introducing a peak in the measured voltage spectrum. The spectrum of the electrical field leakage identifies the interaction between the SAW and different ions, elucidate ion relaxation times in the EDL and hence the intrinsic rate of the EDL charge and discharge by specific ions, and gives a glimpse into the dynamical behaviour of EDLs.

Keywords:
electrical double layer, relaxation times, spectroscopy, surface acoustic waves



An illustration of a surface acoustic wave destabilising ions near an electrified surface to result in the emission of an electrical field into the bulk of electrolyte solution

References:

[1] O. Manor, L. Y. Yeo, J. R. Friend, J. Fluid Mech. 707, 482–495 (2012)
[2] O. Dubrovski and O. Manor. Langmuir 2021, 37, 14679–14687 (2021)
[3] S. Aremanda and O. Manor. J. Phys. Chem. C, 127, 20911–20918 (2023)