Fundamental Studies on Liquid Transfer Between Surfaces

Professors: Paul Kenis, Mark Shannon
Graduate Students: Chaitanya Gupta

Goals

• Understanding effect of electric field on solid-liquid interface properties.
• Development of printing techniques that are tuned by applied potentials.
  • Field dependent Liquid Printing (FLP)

Mapping to Center’s Objectives

• Interaction between solid and liquid determines amount of liquid transferred.
• Engineering tunable solid-liquid interactions onto the toolbit is an ongoing effort.

Fundamental Questions/Challenges

• How does applied electric field modify solid-liquid interfacial properties?
• Can electric field-induced modifications in solid-liquid interfacial properties be utilized to print “small”?
• Design of toolbit surface and substrates to enable robust and “controlled” transfer of material.

Research Plan

• Develop a robust model for double layer structure of solid-liquid interface under the influence of applied potential.
  • Modify solid surface by a self-assembled monolayer — create surface with uniform hydrophobicity/hydrophilicity and uniform electronic properties.
  • Utilize small signal frequency spectroscopy to characterize current-potential characteristics of metal-monolayer-electrolyte systems.
  • Predict surface charge density as function of applied potential, electrolyte pH, concentration, anion and cation type, etc.
  • Utilize potential dependent properties of solid-liquid interface to minimize transfer from printing stamp.

Constitutive equations used in analysis

\[
J(x) = \mu \rho(x) E(x) - D \frac{d\rho(x)}{dx} + \nabla \cdot (\kappa \nabla \phi)
\]

\[
\sigma_{\text{interfacial}} = \sigma - \rho \left[ \frac{kT}{\kappa D_{\text{liq}} c_{\text{liq}}} \right] \left(1 - \frac{kT}{c_{\text{liq}}} \nabla \phi_{\text{liq}} \right)
\]

Surface charge density as function of applied potential difference.

Broader Impact

• Improves state-of-art understanding of double layer at solid-liquid interface. Lays foundation for electrolytic sensor.
• Published as “Mechanisms of charge transport through monolayer modified polycrystalline gold electrodes in the absence of redox active moieties” and as “Electronic properties of a monolayer-electrolyte interface obtained as mechanistic impedance analysis” in Journal of Physical Chemistry C.

Interaction with Other Projects

• Interdisciplinary team to build molecular based toolbit (Shannon, Ferriera, Kenis, Bohn, Adesida groups).

Future Efforts

• Characterize interface properties at PZF for printing inks (organic polymers, biomolecules etc.).
• Manipulate properties at PZF to print “small”.
• Integrate double layer engineering within toolbit.