UW Chemical Engineering

Spring 2013 Seminar Series

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Place: PAA A110

The Odd Behavior of Oppositely Charged Drops

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Abstract

Electrically induced droplet motion manifests itself in processes as diverse as storm cloud formation, commercial ink-jet printing, petroleum and vegetable oil dehydration, electrospray ionization for use in mass spectrometry, electrowetting, and lab-on-a-chip manipulations. An important issue in practical applications is the tendency for adjacent drops to coalesce, and oppositely charged drops have long been assumed to experience an attractive force that favors their coalescence. In this talk, I will describe two counterintuitive phenomena recently observed with oppositely charged droplets. (1) We present evidence for a critical field strength above which oppositely charged drops simply do not coalesce. Appropriately positioned and oppositely charged drops migrate towards one another in an applied electric field; but whereas the drops coalesce as expected at low field strengths, they are repelled from one another after contact at higher field strengths. Qualitatively, the drops appear to 'bounce' off one another. We directly image the transient formation of a meniscus bridge between the bouncing drops, and propose that this temporary bridge is unstable with respect to capillary pressure when it forms in an electric field exceeding a critical strength. (2) We describe the existence of a critical ionic conductivity below which oppositely charged drops only partially coalesce. The extent of coalescence between dissimilarly sized water drops in oil can be tuned from complete coalescence at low electric field strengths to complete non-coalescence at high field strengths, thus providing external control over the daughter droplet size. Strikingly, the size and charge of the daughter droplet are both independent of the ionic conductivity. We present evidence suggesting the charge transfer is instead strongly influenced by convection associated with the capillary-driven penetration of a vortex into the larger drop, and we demonstrate that the size of the daughter droplet is consistent with a scaling model based on a balance between capillary-driven inertia and electrostatic repulsion.

(1) Ristenpart et al, "Non-coalescence of oppositely charged drops," *Nature*, 2009.
(2) Hamlin, Creasey, & Ristenpart, "Electrically tunable partial coalescence of oppositely charged drops," *Physical Review Letters*, 2012.