POLYMER PROGRAM SEMINARS

POLYMER PROGRAM SEMINAR

Friday, April 19th, 2019
11:10 AM, IMS 20

"Instability and Explosion of Electrified Drops: EHD Tip and Equatorial Streaming"

Osman Basaran

Gedge Professor of Chemical Engineering and
Academic Director, Purdue Process Safety and Assurance Center (P2SAC)
School of Chemical Engineering, Purdue University

In this seminar, we will discuss two fascinating and celebrated problems of historic significance in science in general and electrohydrodynamics (EHD) in particular. First, we will examine the behavior of electrified drops that are surrounded by an insulating fluid, e.g. air. When subjected to an electric field of sufficiently high strength, such drops emit thin fluid jets from conical structures—Taylor cones—that form at their surfaces. Such behavior has practical, e.g. electrospray mass spectrometry, printing or coating, crop spraying, and particle/capsule formation, as well as fundamental, e.g. raindrops in thunderclouds and the liquid drop model of the nucleus, implications. Theoretical analysis of the temporal development of such EHD tip-streaming phenomena is challenging given the large disparity in length scales between the macroscopic drops and the microscopic jets, i.e. the multi-scale nature of the underlying physics. Furthermore, there exist conflicting theories and measurements on the size and charge of these small electrospray droplets. We use theory and ultra-high-resolution simulations to show that conductivity can be tuned to yield three scaling regimes for droplet radius and charge, a finding missed by previous studies. The amount of charge Q that electrospray droplets carry determines whether they are Coulombically stable and charged below the Rayleigh limit of stability Q_R or are unstable and hence prone to further explosions once formed. Previous experiments reported droplet charge values ranging from 1/10th to in excess of Q_R. Simulations unequivocally show that electrospray droplets are Coulombically stable at the instant they are created and that there exists a universal scaling law for droplet charge, $Q=0.44\ Q_R$. In the second part of the talk, we will consider what happens when the drop is surrounded by an ambient fluid (the continuous phase) whose conductivity is comparable to that of the drop fluid (the dispersed phase). When subjected to an electric field, such drops can deform in the direction of or in the direction perpendicular to that of the applied field. The response of such drops obtained through simulations will be highlighted. The talk will conclude with a quick overview of some new ways in which electrified drops can be used as valves, particle transporters, and liquid lenses.