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Successive Coulombic fissions of evaporating charged water and nanofluid droplets

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ABSTRACT:

Charged droplets suspended in an electrodynamic balance (EDB) experience a form of instability known as Coulombic fission when electric forces (resulting from the electrical charges on the droplet surface) surpass surface tension forces. For a pure-fluid droplet with a given diameter, a charge limit (known as Rayleigh limit, q_R) exists at which Coulombic Fission occurs. In an evaporating droplet with a certain initial amount of charge (q), the Rayleigh limit is reached when the droplet decreases to a certain smaller diameter due to evaporation. During Coulombic fission, the droplet releases some of the charges and returns to a stable state. Further evaporation will lead to the next Rayleigh limit. As a result, several successive Coulombic fissions may occur during the evaporative lifetime of a droplet. In this study, charged, sub-millimeter droplets of deionized water were suspended using an electrodynamic balance and left to evaporate into their surroundings. As many as 15 Coulombic fissions were observed during the evaporation of a single droplet. The time of evaporation and droplet diameter at Coulombic fissions were recorded using high-speed imagery and digital image processing. The amount of charge at the time of each fission was calculated based on droplet size and Rayleigh limit. It was found that during each fission, the droplet releases about 14% of its charge. Results indicated that droplets with similar initial relative charge (q/q_R) sustained Coulombic fissions at similar normalized diameters independently of initial droplet size and evaporation rate. As a consequence of this, and in accordance with the d^2-law of pure-fluid droplet evaporation, the times at which Coulombic fissions occur during the droplet's lifetime can be predicted for a given initial droplet size and evaporation rate. The results exhibit a self-similar behavior. Preliminary results of charged nanofluid droplet fission will be discussed if time permits.

BIOGRAPHY:

Ruey-Hung Chen received his Ph.D. in aerospace engineering from the University of Michigan (1988) and his BS degree in aeronautical engineering from National Cheng Kung University, Taiwan (1981). Before joining University of Central Florida in 1992, he conducted research at the University of Michigan and Princeton University. He became the Robert Meyer Professor and Head of Department of Mechanical and Aerospace Engineering at New Mexico State University in 2016 before moving to University of Maryland Baltimore County in 2018, where he is the chair of Department of Mechanical Engineering. Between 2012 – 2015, he served as a program director of NSF's Combustion and Fire Program and Thermal Transport Processes Program (the latter in the acting role for one year). His research interests include reacting flow, supersonic jet mixing and noise, and heat and mass transfer, with recent emphasis on evaporation of droplets with and without nano-sized particles..