Announcing the Final Examination of Abhishek Saha for the degree of Doctor of Philosophy

Time & Location: May 31, 2012 at 9:00 AM in ENG1 288
Title: Evaporation, Precipitation Dynamics and Instability of Acoustically Levitated Functional Droplets

Evaporation of pure and binary liquid droplets is of interest in thermal sprays and spray drying of food, ceramics and pharmaceutical products. Understanding the rate of heat and mass transfer in any drying process is important not only to enhance evaporation rate or vapor-gas mixing, but also to predict and control the final morphology and microstructure of the precipitates. Acoustic levitation is an alternative method to study micron-sized droplets without wall effects, which eliminates chemical and thermal contamination with surfaces. This work uses an ultrasonic levitation technique to investigate the vaporization dynamics under radiative heating, with focus on evaporation characteristics, precipitation kinetics, particle agglomeration, structure formation and droplet stability. Timescale and temperature scales are developed to compare convective heating in actual sprays and radiative heating in the current experiments. These relationships show that simple experiments can be conducted in a levitator to extrapolate information in realistic convective environments in spray drying.

The effect of acoustic streaming, droplet size and liquid properties on internal flow is important to understand as the heat and mass transfer and particle motion within the droplet is significantly controlled by internal motion. Therefore, the droplet internal flow is characterized by Particle Image Velocimetry for different drop size and viscosity. Nanosuspension droplets suspended under levitation show preferential accumulation and agglomeration kinetics. Under certain conditions, they form bowl shaped structures upon complete evaporation. At higher concentrations, this initial bowl shaped structure morphs into a ring structure. Nanoparticle migration due to internal recirculation forms a density stratification, the location of which depends on initial particle concentration. The time scale of density stratification is similar to that of perikinetic-driven agglomeration of particle flocculation. The density stratification ultimately leads to force imbalance leading to a unique bowl-shaped structure.

Chemically active precursor droplet under acoustic levitation shows events such as vaporization, precipitation and chemical reaction leading to nanoceria formation with a porous morphology. The cerium nitrate droplet undergoes phase and shape changes throughout the vaporization process followed by formation of precipitate. Ex-situ analyses using TEM and SEM reveal highly porous morphology with trapped gas pockets and nanoceria crystalline structures at 70 deg C. Inhomogeneity in acoustic pressure around the heated droplet can induce thermal instability. Short wavelength (Kelvin-Helmholtz) instability for diesel and bio-diesel droplets triggers this secondary atomization, which occurs due to relative velocity between liquid and gas phase at the droplet equator. On the other hand, liquids such as Kerosene and FC43 show uncontrollable stretching followed by a catastrophic break-up due to reduction in surface tension and viscosity coupled with inhomogeneity of pressure around the droplet.

Finally, a scaling analysis has been established between vaporizing droplets in a convective and radiative environment. The transient temperature normalized by the respective scales exhibits a unified profile for both modes of heating. The analysis allows for the prediction of required laser flux in the levitator experiments to show its equivalence in a corresponding heated gas stream. The theoretical equivalence shows good agreement with experiments for a range of droplet sizes.

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Approved for distribution by Dr Ranganathan Kumar, Committee Chair, on May 14, 2012.

The public is welcome to attend.