Acoustic levitation permits the study of droplet dynamics without the effects of surface interactions present in other techniques such as pendant droplet methods. Despite the complexities of the interactions of the acoustic field with the suspended droplet, acoustic levitation provides distinct advantages of controlling morphology of droplets with nanosuspensions post precipitation. Droplet morphology is controlled by vaporization, deformation and agglomeration of nanoparticles, and therefore their respective timescales are important to control the final shape. The balance of forces acting on the droplet, such as the acoustic pressure and surface tension, determine the geometry of the levitated droplet. Thus, the morphology of the resultant structure can be controlled by manipulating the amplitude of the levitator and the fluid properties of the precursor nanosuspensions. The interface area in colloidal nanosuspensions is very large even at low particle concentrations. The effects of the presence of this interface have large influence in the properties of the solution even at low concentrations.

This thesis focuses on the dynamics of particle agglomeration in acoustically levitated evaporating nanofluid droplets leading to shell structure formation. These experiments were performed by suspending 500um droplets in a pressure node of a standing acoustic wave in a levitator and heating them using a carbon dioxide laser. These radiatively heated functional droplets exhibit three distinct stages, namely, pure evaporation, agglomeration and structure formation. The temporal history of the droplet surface temperature shows two inflection points. Morphology and final precipitation structures of levitated droplets are due to competing mechanisms of particle agglomeration, evaporation and shape deformation. This thesis provides a detailed analysis for each process and proposes two important timescales for evaporation and agglomeration that determine the final diameter of the structure formed. It is seen that both agglomeration and evaporation timescales are similar functions of acoustic amplitude (sound pressure level), droplet size, viscosity and density. However it is shown that while the agglomeration timescale decreases with initial particle concentration, the evaporation timescale shows the opposite trend. The final normalized diameter hence can be shown to be dependent solely on the ratio of agglomeration to evaporation timescales for all concentrations and acoustic amplitudes. The experiments were conducted with 10nm silica, 20nm silica, 20nm alumina and 50nm alumina solutions. The structures exhibit various aspect ratios (bowls, rings, spheroids) which depend on the ratio of the deformation timescale (tdef) and the agglomeration timescale (tg). For tdef<tg a sharp peak in aspect ratio is seen at low concentrations of nanosilica which separates high aspect ratio structures like rings from the low aspect ratio structures like bowls and spheroids. The time duration of pure evaporation, agglomeration and structure formation are presented in phase diagrams where these stages are represented by regions in the time-particle concentration domain. A comparison of phase diagrams for different particle solutions is made illustrating the influence of liquid properties on the duration of the structure formation phases and the transition to different morphology when concentration is increased.

Major: Aerospace Engineering

Educational Career:
Bachelor's of Mechanical Engineering, BS, 2008, Universidad del Valle de Guatemala

Committee in Charge:
Dr. Ranganathan Kumar, Chair, MMAE
Dr. Saptarshi Basu, MMAE and IISc, India
Dr. Louis Chow, MMAE
Dr. Weiwei Deng, MMAE

Approved for distribution by Dr. Ranganathan Kumar, Committee Chair, on October 15, 2012.
The public is welcome to attend.