The evaporation of droplet containing insoluble particles has grown into an active area of research due to the needs for nanofluids for applications in heat transfer, combustion, and manufacturing desired micro/nano particles in the pharmaceutical industry. The evaporation of droplets containing particles involves complex physical phenomena of multiphase heat and mass transport. The evaporation process is usually divided into two stages: the first stage consists of evaporation until a shell of particle forms or when the solid to liquid ratio is sufficiently large and the second stage, where the droplet size is commonly assumed to be unchanged. The dissertation investigates the evaporation kinetics in the first stage.

An experimental setup based on electrodynamic balance (EDB) is built to allow the observation of evaporation of a free standing micro size droplet. Besides experimental design, a novel theoretical model is developed to first describe the morphological evolution process in the absence of internal convection. The model accounts for the effect of particles at the droplet surface on the diffusion of liquid vapor. The gradually increasing particle number at the droplet surface reduces the area for evaporation, leading to reduction in evaporation rate in the first drying stage, contrary to previous assumptions. The evaporation in the first stage is controlled by Peclet number (defined as the ratio of droplet evaporation rate to the particle diffusion rate) and particle properties such as wettability. For large values of Pe, the particles concentration is high near the droplet surface, leading to the change of evaporation rate. For small values of Pe, the effect of particles on the evaporation rate of droplet in the first drying stage is small because particles are allowed sufficient time to redistribute within the droplet.

The model analysis also reveals that particle wettability is an important factor affecting the first drying stage. For hydrophilic particles, the contact angle of the particles at the droplet surface is small, leading to small change of evaporation in the first stage. For the hydrophobic particles that have large contact angles, the change of evaporation rate in the first drying stage is significant.

In the model that accounts for the internal convection, the evaporation behavior during the first stage is controlled by the particle mobility, initial particle concentration, and droplet recession/evaporation rate. For particles with high mobility, the particle distribution within the droplet tends to be smooth. The effect of convection flow on the particles distribution becomes stronger as particle mobility decreases. Once the particles mobility is decreased to a limit at which the surface particle density is only controlled by the internal flow and the evaporation process is independent of the particles mobility. For a given internal flow field and a specific particles mobility, the duration of the first stage and the final dry particle size are both controlled by the initial particles concentration. A smaller/larger initial particle concentration results in a longer/shorter first stage and smaller/larger dry particle.
The public is welcome to attend.