Evaporative Drying of Droplets and the Formation of Structured and Functional Microparticles

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A greater understanding of the evaporation of aerosol droplets under different conditions is of fundamental importance to a range of industries, particularly spray-drying. Using a comparative-kinetics electrodynamic balance (CK-EDB), a single aerosol droplet several tens of microns in radius can be levitated whilst it dries under different temperatures and relative humidities (RH). The radius of the trapped droplet can be recorded using the elastically scattered radiation produced from a 532 nm green laser passing through the droplet.

To date, droplets of a range of formulations have been observed evaporating in the CK-EDB. Simple aqueous solutions, such as NaCl, Na_2SO_4, $NaNO_3$ and KNO_3 have been studied. Also, more complex solutions have been investigated, such as those containing mixtures of organic and inorganic components, like glycerol with $NaNO_3$; or those containing multiple volatile components, such as ethanol and water. This is to study the mass and heat transfer during evaporation under different conditions, so that ultimately, the final particle size and morphology of a product could be predicted and controlled.

Droplets containing inorganic salts tend to crystallise below a certain RH. A numerical model is being developed to predict the time of crystallisation by modelling the competition between the receding droplet surface and the Fickian diffusion of the components in the droplet. In comparison, droplets of sucrose solutions do not crystallise in dry air; they slowly continue to lose water until an amorphous sucrose particle is formed.

The evaporation of droplets of multiple components, such as ethanol-water droplets, has also been studied in the CK-EDB. Mixed ethanol-water droplets evaporate in two regimes of evaporation: initial fast evaporation of ethanol, followed by slower evaporation of water. The rate of the latter depends upon the RH (see Fig.1). An important and interesting result was that even a pure ethanol droplet evaporating into humid air showed a second regime of water evaporation, which was not present in the evaporation of ethanol in dry air (see Fig.2). This suggests that the ethanol droplet had undergone a large amount of evaporative cooling, and in the moisture-rich air this had induced water condensation onto the droplet. Further work will be to examine this interesting effect of evaporative cooling, and to develop a model that can track the changing composition with time.

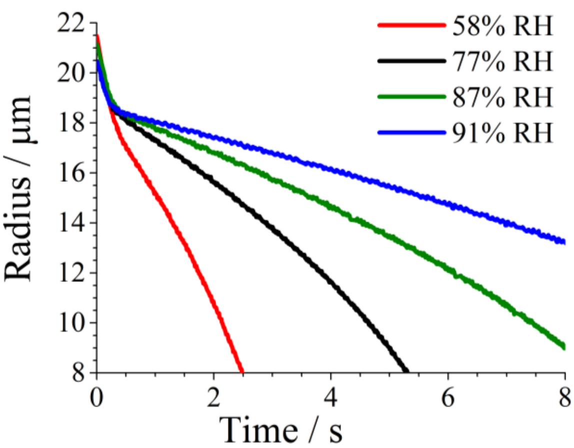

Figure 1: The evaporation of a droplet containing 50% ethanol and 50% water (by weight) into air of varying moisture content, show a rapid region of ethanol loss, followed by slower water evaporation.

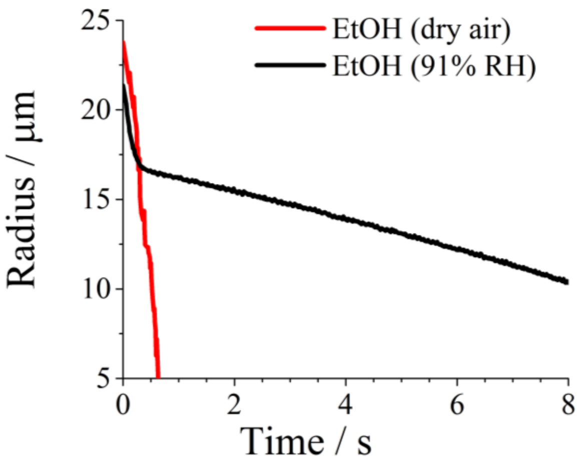

Figure 2: The evaporation of a pure ethanol droplet within dry air (red) and within air of 91% RH (black). In humidified air the evaporative cooling from the EtOH evaporation causes water condensation from the gas-phase.