Particle-laden droplet evaporation - Simulations and Experiments beyond the Coffee Ring Effect

Evaporation of solutions and suspensions plays a central role in many phenomena in nature and industrial processes, for example in ink deposition or diagnostic devices, or to evaluate whether the attachment of suspended virus particles on a complex surface can lead to fomite transmission.

Experimentally, nanoparticles are excellent model systems to investigate such processes, because their tuneable properties can be used to visualize them under very different conditions. However, the drying process is influenced by a multitude of factors, that can not be easily separated to study them individually. Therefore, we aim to provide a simulation to study evaporation of a single droplet with suspended particles. We use a two-phase flow model governed by the Navier-Stokes-Cahn-Hilliard equations. The simulation can account for complex surface topologies as found in nature and many industrial applications. The model handles the evaporation of the solution and tracks the concentration of particles in the solution as well as the attachment of suspended particles on the surface. We show that the numerical simulations can reproduce the coffee ring effect and characterize the influence of several parameters. Finally, the numerical results are validated using the experimental setup based on nanoparticles from different materials such as gold or fluorescently labelled latex.

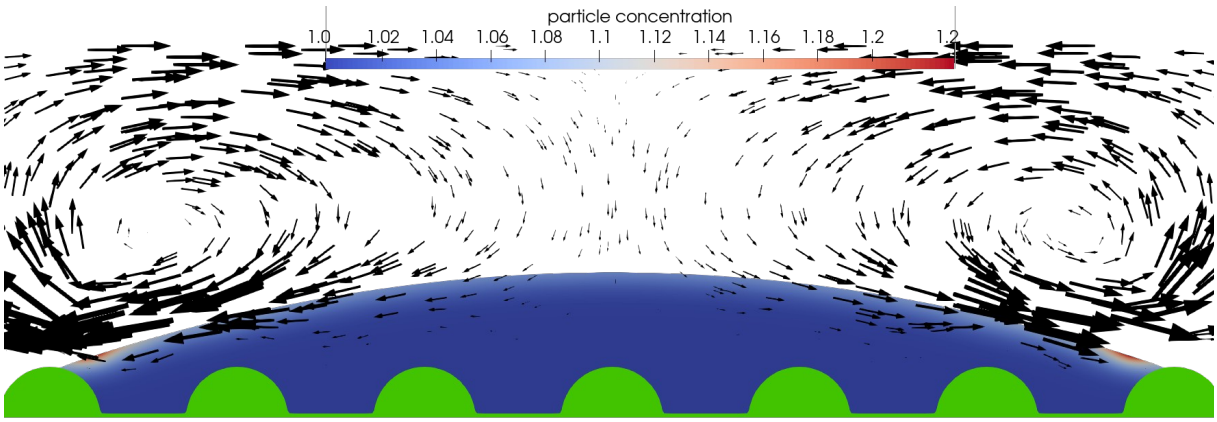

Figure 1: Snapshot of the simulation showing the concentration of the particles inside the droplet on a structured surface