Toward the True Shape of Supramolecular Structures by Contactless Drying

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Understanding the intrinsic structure of supramolecular aggregates during drying remains challenging, as conventional approaches often introduce external constraints that distort the final morphology. Sessile droplets are affected by substrate interactions such as contact line pinning and capillary flows, while pendant droplets, although substrate-free, still experience asymmetric boundary conditions and gravity-induced distortions. As a result, the observed structures frequently reflect method-specific artifacts rather than the true aggregate morphology. To overcome these limitations, acoustic levitation provides a contactless drying environment, minimizing substrate-induced effects and enabling a more symmetric evaporation process. However, strong acoustic streaming and enhanced convective transport can significantly alter evaporation kinetics, potentially influencing structure formation. A critical assessment of these competing effects is therefore required.

We compare sessile, pendant, and acoustically levitated droplets using aqueous silica nanoparticle suspensions (Aerosil 90 and Aerosil 300, differing in specific surface area and resulting aggregate morphology) as model systems. Evaporation kinetics were evaluated within a Maxwell-type framework. This approach assumes the steady evaporation of a droplet as the evaporation rate is governed solely by vapor diffusion in the surrounding gas.

While the initial evaporation phase can be described by this approach for the three methods during the late phase of drying, clear, method-dependent differences in the aggregation of the particles were observed. Sessile droplets exhibit pronounced substrate-induced inhomogeneities and often characteristic ring-like deposits, whereas pendant droplets, although substrate-free, remain influenced by gravity and the presence of a supporting capillary, leading to deviations from spherical symmetry. In contrast, acoustic levitation enables drying in a contactless and geometrically unconstrained environment, allowing for a more intrinsic evolution of aggregate structures.

Furthermore, particle-specific morphologies are resolved under levitated conditions. Aerosil 90 forms collapsed, shell-like structures, whereas Aerosil 300 yields more compact and spherical aggregates. This indicates that, in the absence of substrate interactions, the final morphology is governed primarily by particle properties rather than external constraints.

Overall, these results indicate that acoustic levitation provides improved access to the intrinsic shape of supramolecular aggregates. At the same time, it offers a controlled environment in which transport-induced effects can be assessed without the superposition of substrate induced effects inherent to sessile or pendant geometries.

Keywords:

Drying, Droplets, acoustic levitation, silica particle