EVAPORATION OF COLLOIDAL DROPS AND FORMATION OF COFFEE RINGS ON POROUS SUBSTRATES

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It is widely known that evaporation of colloidal drops on flat solid substrates may result in the deposition of colloidal particles in the vicinity of the three-phase contact line. This phenomenon is commonly referred to as the coffee ring effect [1]. A similar phenomenon is observed on porous substrates, where the colloidal fluid is initially imbibed into the porous substrate to form a wetted region, and thereafter evaporates. At the end of evaporation process the colloids are preferentially deposited near the periphery of the wetted region [2]. Whereas the mechanism governing the formation of coffee rings on flat substrates is well understood [1], the corresponding effect on porous substrates is still not sufficiently elucidated. A profound understanding of this phenomenon is important for controlling the formation of coffee rings in numerous applications, including inkjet printing, dried spot sampling of biological liquids, and spray coating of paper substrates.

In this work, evaporation of colloidal drops and the formation of coffee rings on porous substrates has been studied experimentally. A dispersion of cationic lipid vesicles was used as a model colloidal liquid. Cellulose fiber filter papers were used as porous substrates. The drops of different sizes were placed on the porous substrate within a glove box chamber with low humidity. A combination of two measurement techniques has been used to obtain insights into the mechanism underlying the coffee ring formation. Evaporation process was observed from the top with a high resolution color camera. The rate of evaporation was simultaneously monitored using an analytical balance. It has been found that the evaporation process took place in two phases: (i) the constant wetted area phase which occurs initially and is accompanied by the formation of coffee rings, and (ii) the phase of fast decrease of the wetted area, which occurs towards the end of evaporation process and is accompanied by a uniform deposition of colloidal particles. The effect of different parameters, such as drop size, colloidal concentration, and substrate porosity, on the size of the coffee rings has been investigated. It has been found that the coffee ring width increases with droplet size for small initial drop volumes and reaches saturation.

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