Order-to-disorder transition in coffee stains

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July 22, 2011

Abstract

If a droplet with suspended particles evaporates while its contact line is pinned, liquid and particles are dragged towards the contact line and form the well-known coffee-stain ring. This mechanism is frequently used to create ordered arrays of colloidal particles, however, the conditions for crystallization have remained unclear. Our experiments with water drops containing monodisperse colloidal particles show a structural transition in the remaining stain, from crystalline to disordered particle packing. We explain this order-to-disorder transition from the hydrodynamics within the drop. A temporal divergence of the velocity field inside the evaporating drop, which simply follows from mass conservation, causes the particle velocity to increase dramatically in last moments of the droplet's life time. Particles that arrive at the contact line at an early time, when the deposition speed is still low, have time to arrange by Brownian motion and form an ordered stain. Particles that arrive when the deposition speed is high, are quenched into a disordered phase.