Mechanics of Drying Suspensions: How Colloidal Fluids Buckle and Crack

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Minute concentrations of suspended particles can dramatically alter the behavior of a drying fluid. Most strikingly, drying suspensions can crack and buckle like elastic solids. These instabilities occur far from equilibrium as the rapid evaporation of fluid compacts particles into a jammed solid just inside the fluid/vapor interface while an inner core of the sample remains a dilute fluid. We study the mechanics of drying suspensions using model systems of nanometer- to micron-sized monodisperse particles suspended in water, with initial volume fractions from 0.01 to 10%. We observe the buckling of freely suspended droplets and the fracture of thin films. We find that capillary forces drive the flow of fluid and compaction of particles as well as fracture and buckling. We show that microscopic particle interactions can play a critical role in determining the onset of macroscopic elastic instabilities. Furthermore, we find that classical elasticity describes the mechanics over long time scales, while coupling between the elastic deformation of the particle network and the flow of interstitial fluid plays a critical role at shorter time scales.

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