Buckling Substrates Caused by Drying Polymer Droplets

Kyle Anthony Baldwin, David Willmer, David John Fairhurst

Nottingham Trent University, Clifton Lane, Nottingham, NG11 8NS

The evaporation of a liquid droplet is complex problem due to the simultaneous influence of many effects. For example, the evaporation rate is not uniform across a droplet's surface and depends on the contact angle between the liquid and the substrate. For angles less than 90 degrees, enhanced evaporation occurs at the contact line, leading to convective flow. Deegan et.al. [1] demonstrated that when the droplet contains suspended particles this convective flow causes the particles to build up at the contact line, forming a ring stain, just as is seen when spilt coffee dries. If the droplet contains polymers, further complications arise. Alain and Pauchard [2] reported that as dextran solutions dry, a glassy skin forms which is incompressible, flexible yet permeable so does not impede further evaporation. As drying continues the skin buckles with various morphologies to accommodate the reduction in volume.

Here we present experimental work on the drying of dextran droplets placed on thin glass coverslips. In addition to the buckling morphologies seen by Alain and Pauchard, we observe the glass coverslips to bend significantly and in some cases to break during the drying process. We attribute this behaviour to drying stresses caused by contraction of the glassy polymer skin due to water loss. We use surface profilometry, laser interferometry, and optical coherence tomography to dynamically monitor this bending. By placing the droplets on a substrate covered with micro-pillars we visualise the stresses that develop within the droplet during. The bending of the coverslip is shown to be related to droplet surface tension and is compared with mathematical and experimental results for crumpled sheets and developable cones [3].

References:

[1] R.D. Deegan, O. Bakajin, T.F. Dupont, G. Huber, S.R. Nagel and T.A. Witten, *Nature*, **1997**, 389, 6653.
[2] L Pauchard and C Allain, *Europhysics Letters*, **2003**, 62, 6.
[3] S. Chaïeb, F. Melo, J.-C. Géminard, *Physical Review Letters*, **1998**, 80, 2354. and E. Cerda and L. Mahadevan, *Physical Review Letters*, **1998**, 80, 2358.