Air-jet induced deformation, rupture and dewetting of liquid coatings on partially wetting substrates

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In many industrial applications, such as discrete area coating [1], immersion lithography [2] and galvanisation of steel [3], air-jets are employed to influence the flow of liquids over solid substrates.

Thin liquid films on partially wetting substrates (receding contact angle θ>0°) can be destabilized by impinging air-jets. This will lead to the appearance of dry-spots in the deformed liquid film that dewet the substrate and lead to residual droplet patterns [4].

We have studied the deformation and rupture [5] of thin liquid films on wetting and partially wetting substrates subjected to air-jets in experiments and numerical simulations. Our simulations combine an axisymmetric model for the impinging jet combined with a thin film model, based on the lubrication approximation [6].

For our experiments we designed a pin-coater with an optically accessible axis of rotation. This enables us to apply a thin liquid film, subject it to impinging air-jets while the sample is rotating [Fig. 1(a)] and dynamically measure the height profile of the liquid film by high-speed, dual-wavelength interference microscopy.

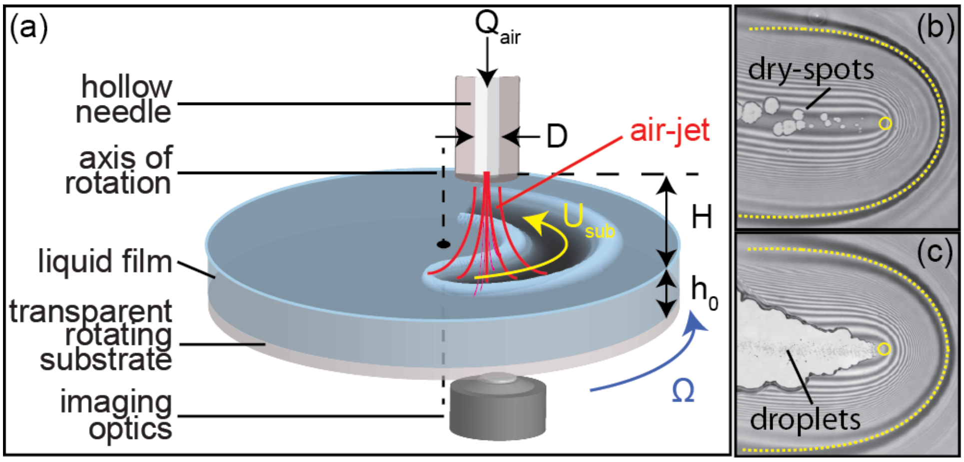

Fig. 1: (a) A schematic of the experimental setup. (b,c) Interference micrographs and numerical simulations (dashed lines) of a thin liquid film deformed and ruptured due to a moving air-jet for different experimental conditions.

We systematically investigated the areal density of dry-spots appearing in the deformed film [Fig. 1(b,c)] as well as the areal density and average radius of residual droplets, remaining on the substrate after the dewetting process. We studied the effects of substrate velocity and jet Reynolds number for two different nozzle geometries: a round jet and a slot jet (or “air-knife”) and find robust scaling laws describing the film rupture and droplet statistics over a large range of minimum film thicknesses.

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