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Deformation and dewetting of thin liquid films induced by moving air-jets

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Application: immersion lithography

A resolution of <45nm is reached by introducing water between wafer and lens. At high scan speeds, a thin water film is left on the substrate, which ruptures, dewets and breaks into droplets.

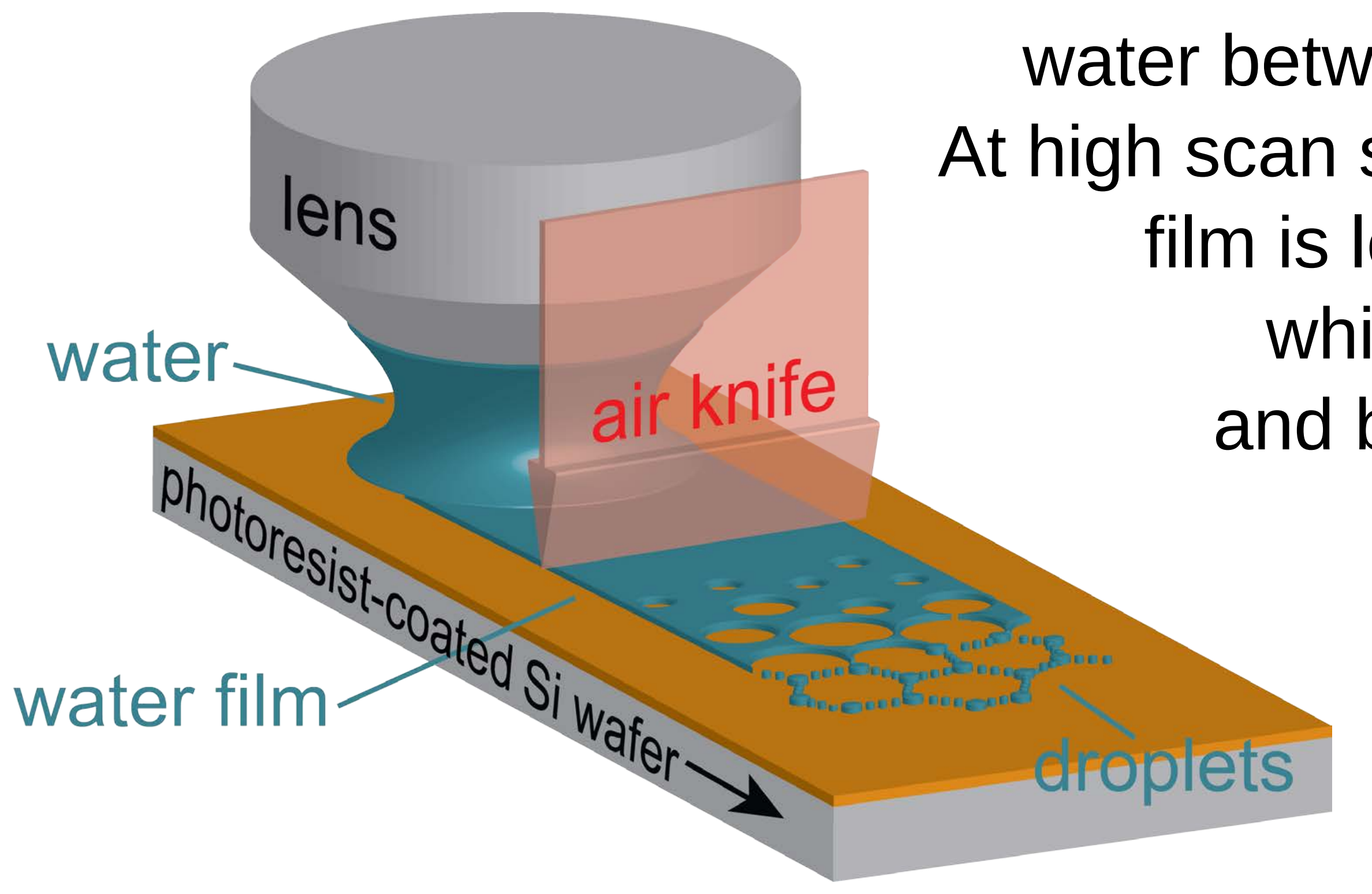

Figure 1: *Schematic representation of the immersion system at high scan speed.*

Objective: controlling film rupture

We want to understand the rupture of thin liquid films disturbed by an impinging air-jet. The ultimate goal is to control the droplet patterns.

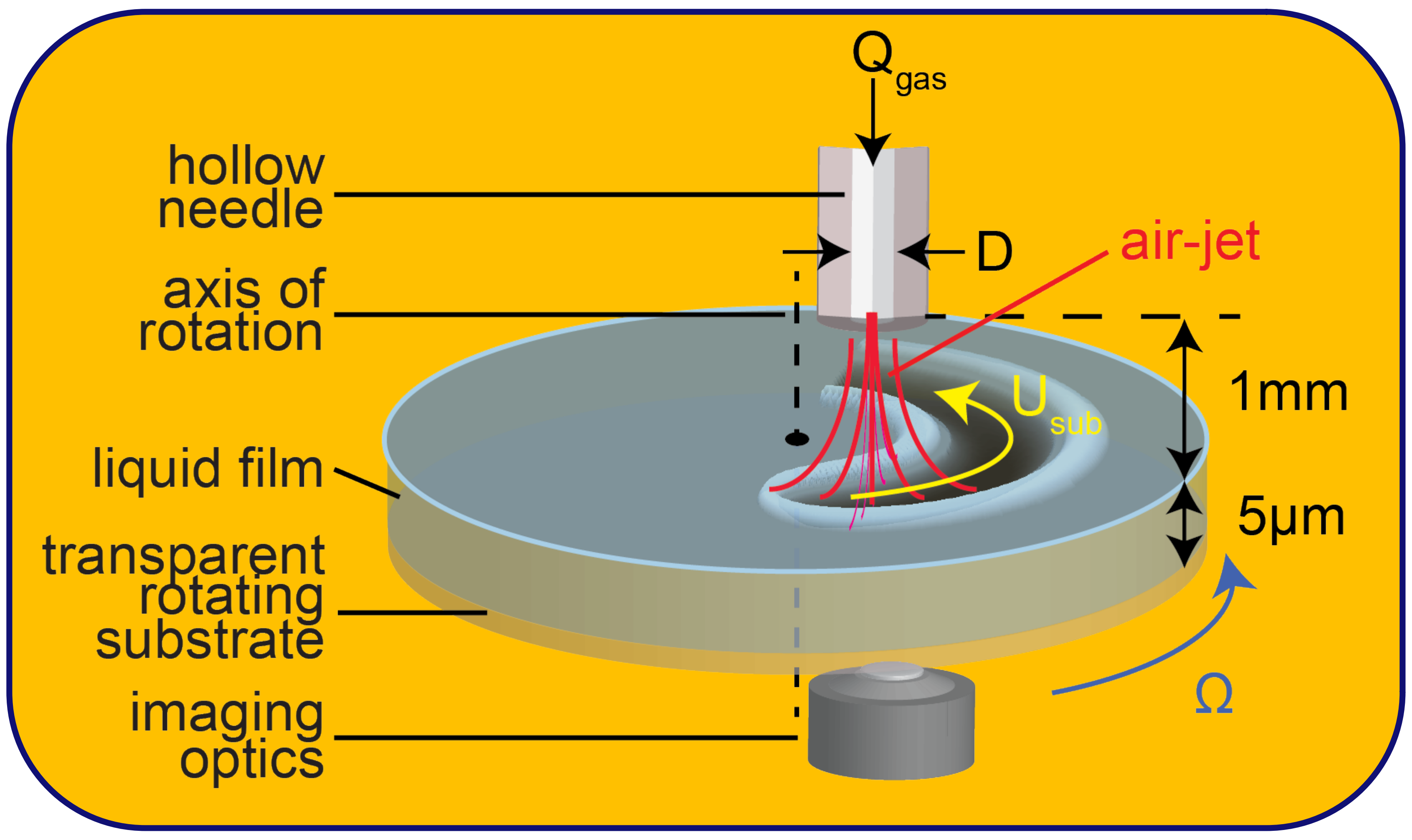

Figure 2: *A thin liquid film of triethylene glycol on polycarbonate is rotated with respect to a laminar air-jet. The film deformation and dewetting is recorded using interference microscopy with two alternating wavelengths of light. (Figure not to scale)*

Experiments:

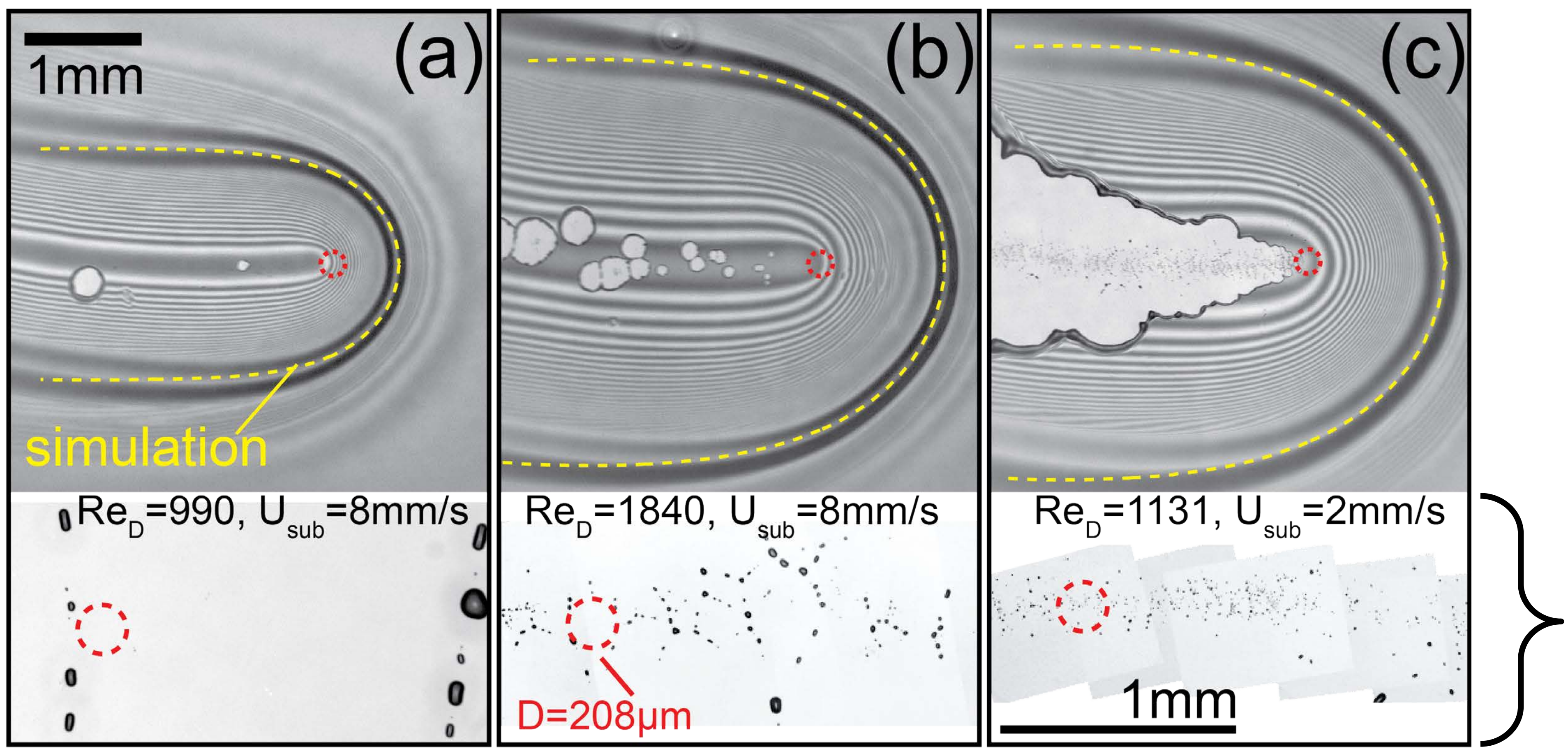

Figure 3: *Experimental film deformation (top) and residual droplet distributions (bottom). The dashed yellow lines represent numerical simulations.* ***(a)*** *h_{min}=126±2nm,* ***(b)*** *h_{min}=42±10nm and* ***(c)*** *h_{min}=25±6nm.*

Simulations: lubrication approximation

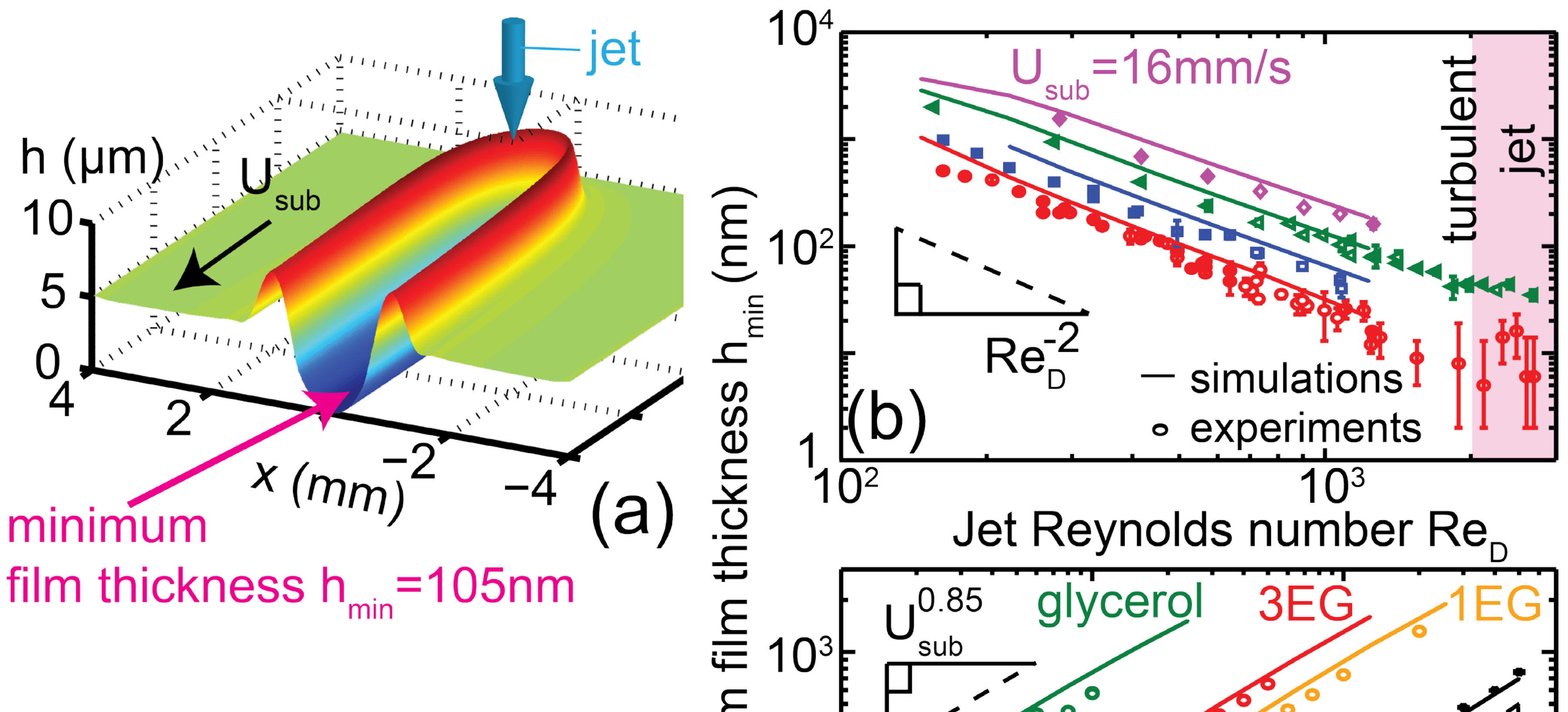

Figure 4: ***(a)*** *Example of a numerical simulation for Re_D=500 and U_{sub}=2mm/s.* ***(b,c)*** *Experimental and numerical results for h_{min} versus* ***(b)*** *jet Reynolds number, Re_D and* ***(c)*** *substrate speed, U_{sub}.*

Results: droplet distributions

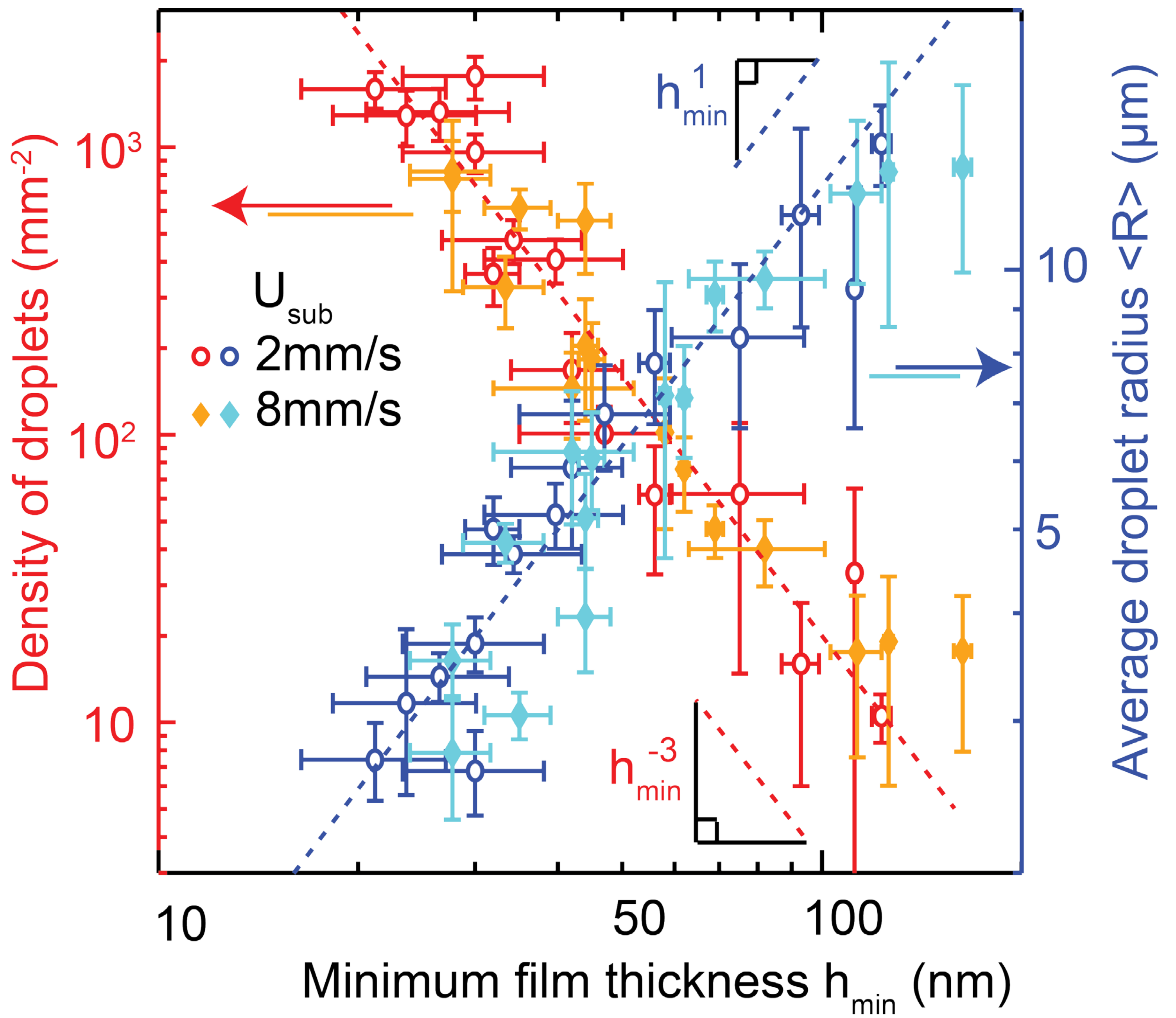

Figure 5: *Density of residual droplets and average droplet diameter as a function of mimum film thickness h_{min} obtained at different jet Reynolds numbers Re_D and substrate speed U_{sub}.*

Conclusions:

- Shape and depth of deformations reproduced well by numerical simulations
- Densities of dry-spots and droplets vs. minimum film thickness follow reproducible scaling laws
- Shear stress and pressure gradients of the air-jet do not directly influence rupture behavior

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