Supplementary material for "Coating thickness prediction for a viscous film on a rough plate"

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1. Material characterization

The liquid in our dip coating experiments is silicone oil (Bluestar Silicones 2011). Density ρ was measured by recording the weight of different volumes between 2–10 mL (figure 1). Surface tension γ was measured from images of 35 pendant drops using an ImageJ plugin (Daerr & Monge 2016) (figure 2). Dynamic viscosity η was measured using an Anton Paar MCR 302 parallel plate rheometer: 10 samples were tested from the same batch of silicone oil as was used for the experiments, and a best fit line was found to relate shear stress to shear strain (figure 3). Raw data are provided in the data repository for this work (Molefe *et al.* 2024).

2. Interferometry measurement

To faciliate reproduction of our experiments, we provide an expanded description of our optical path and procedure (see main text, figure 4). A red laser (Arima ADL-63054TL) with wavelength $\lambda_0 = 635$ nm passes through a beam expander and is directed toward the thin film by a 50:50 beamsplitter (CCM1-BS013/M, ThorLabs). The beam is focused onto the sample by an objective (M Plan APO 5× objective, 0.14 NA, Mitutoyo) where it partially reflects from the front of the film and partially transmits through the film to subsequently reflect from the surface of the silicon wafer. The output beams interfere with each other so that the total intensity observed at the camera (Nikon D850) depends on the film thickness. Each pair of successive dark fringes indicates a change in film thickness by a distance $\Delta h = \lambda_0/(2n_{oil})$ that depends on the light wavelength λ_0 and the refractive index of silicone oil ($n_{oil} = 1.4$) (Bluestar Silicones 2011; Schödel 2018). As described in the main text, we count the fringes until the contact line, where either the free film meets the silicon surface (for a smooth surface) or where the free film meets the trapped film (for a rough surface). **Supplementary Movie 1** is an example of an experiment with a smooth plate, whereas **Supplementary Movie 2** is an example with a rough plate having pillar spacing $\ell = 12$ µm.

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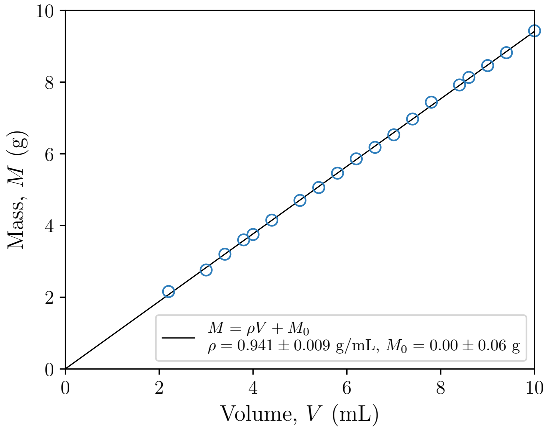

FIGURE 1. The density of silicone oil is $\rho = 0.941 \pm 0.009$ g/mL.

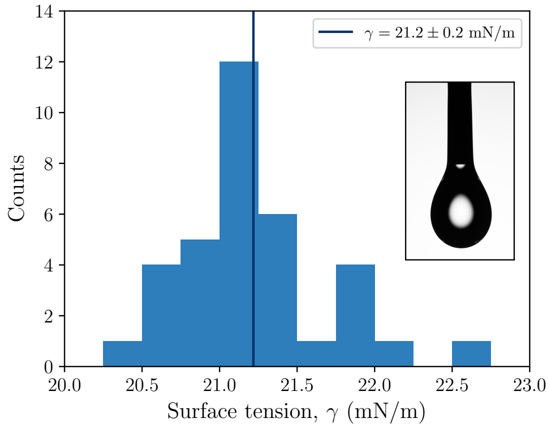

FIGURE 2. The surface tension of silicone oil is $\gamma = 21.2 \pm 0.2$ mN/m. The inset is an image of pendant drop; the syringe tip has a width of 0.71 ± 0.02 mm.

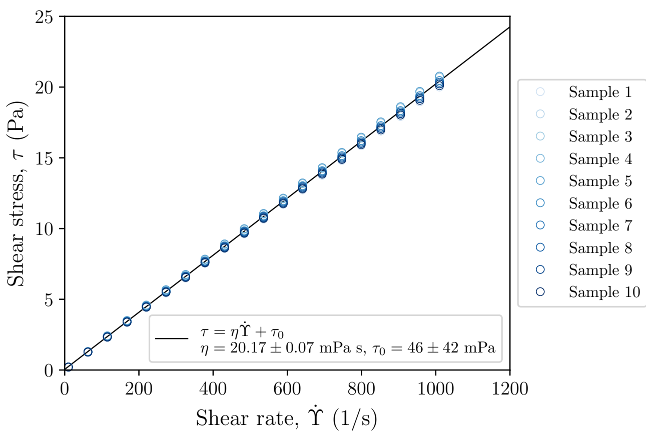

FIGURE 3. Dynamic viscosity of silicone oil is $\eta = 20.17 \pm 0.07$ mPa s. Viscosity was measured for ten samples of silicone oil using an Anton Paar MCR 302 rheometer.

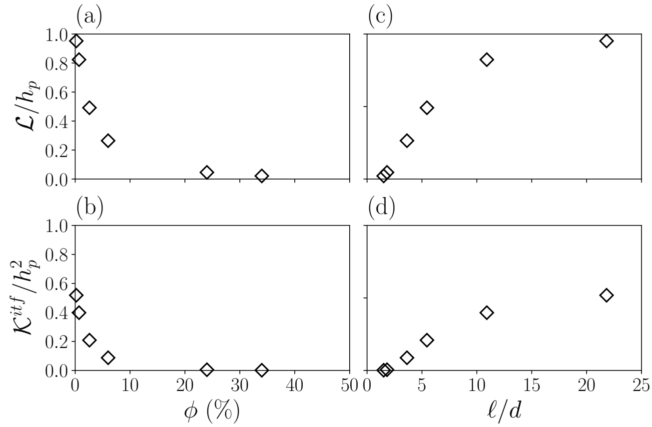

FIGURE 4. Slip and interface permeability nondimensionalized by pillar height h_p, as a function of ϕ (a, b) or pillar spacing ℓ/d (c, d). At large spacings ℓ, one may estimate the slip $\mathcal{L}$ as $\mathcal{L} \sim h_p$.

3. Relation of effective parameters $\mathcal{L}$ and $\mathcal{K}^{itf}$ to pillar height h_p

Because micropillars are frequently used as surface textures – for instance, in designs for microfluidic devices – we here provide plots of $\mathcal{L}/h_p$ and $\mathcal{K}^{itf}/h_p^2$ for all the pillars listed in table 1 of the main text as a function of ϕ (figure 4a, b) and as a function of spacing normalized by the pillar diameter ℓ/d (figure 4c, d). Both $\mathcal{L}$ and $\mathcal{K}^{itf}$ decrease as ϕ increases, until they are nearly zero at $\phi \approx 30\%$. Both $\mathcal{L}/h_p$ and $\mathcal{K}^{itf}/h_p^2$ increase with increasing normalized spacing ℓ/d. The slip length $\mathcal{L}$ appears to approach the pillar height h_p ($\mathcal{L}/h_p \to 1$) at large ℓ/d. Physically, this indicates that as ℓ/d becomes large, the interface at $\mathbb{ES}$ appears to be almost completely a liquid area with only a small solid fraction, and the predicted slip length appears to reflect a velocity profile over a liquid region with a no-slip condition at $x = -h_p$. The asymptotic values of slip and permeability are reached after ℓ is greater than approximately 10–20 pillar diameters ($\ell/d \gtrsim 10$).

4. Code

Python code to solve the macroscopic model is provided in the JFM Notebook coating_thickness_prediction.ipynb. COMSOL files slip_solver.mph and permeability_solver.mph for solving the microscopic problem are provided in the associated repository (Molefe *et al.* 2024). All code and data for producing the manuscript figures are also found in the data repository associated with this publication (Molefe *et al.* 2024).

REFERENCES

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