Supplementary Material to "Influence of Slip on the Rayleigh-Plateau Rim Instability in Dewetting Viscous Films"

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SUBSTRATE (SURFACE AND SUB-SURFACE) PARAMETERS AND THE RECONSTRUCTED EFFECTIVE INTERFACE POTENTIAL

The simulations of the thin-film equations were adapted to the experimental system via the reconstructed effective interface potential given by [1],

$$\phi(h) = \frac{C_c}{h^8} - \frac{1}{12\pi}\left[\frac{A_c}{h^2} - \frac{A_c - A_{SiO_2}}{(h+d_c)^2} - \frac{A_{SiO_2} - A_{Si}}{(h+d_c+d_{SiO_2})^2}\right], \tag{1}$$

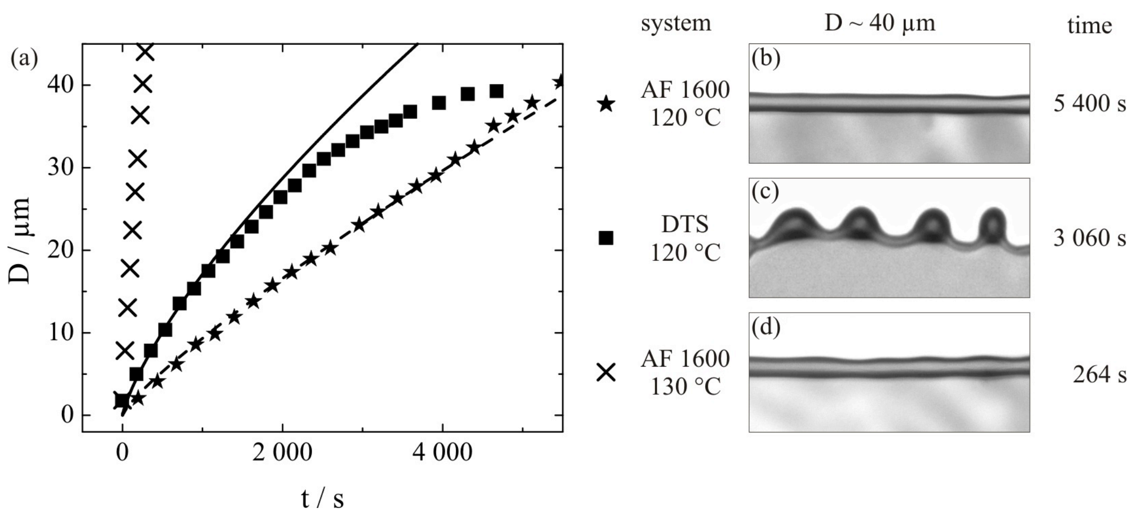
consisting of long-range attractive van der Waals-contributions with Hamaker constants A_i ($i = c$, SiO_2, Si) and a short-range Born-repulsion term of amplitude C_c that penalizes the thinning of the film of initial height H below a minimum of value h^*. The effective potential arises from the contributions of a silicon wafer coated with a native SiO_2 layer of thickness d_{SiO_2} coated by the hydrophobic layer ($c =$ AF1600, DTS) of thickness d_c [2].

	Units	DTS	AF1600
C_c	J/m^6	10^{-81}	$7{\cdot}10^{-81}$
A_c	J	$1.9(3){\cdot}10^{-20}$	$4.3(2){\cdot}10^{-20}$
A_{SiO_2}	J	$2.2(4){\cdot}10^{-20}$	$2.2(4){\cdot}10^{-20}$
A_{Si}	J	$-1.3(6){\cdot}10^{-19}$	$-1.3(6){\cdot}10^{-19}$
d_c	nm	1.5(2)	20(2)
d_{SiO_2}	nm	1.7	1.7
θ_Y	$^\circ$	67(3)	88(2)
rms	nm	0.13(2)	0.30(1)

The table displays the experimental substrate parameters as a basis for the reconstruction of the effective interface potential $\phi(h)$ used in the 2D (unperturbed) simulations: Hamaker constants A_i for Si, SiO_2, DTS and AF1600 were taken from Refs. [1, 2]. The repulsion coefficients C_c for DTS and AF1600 were calculated to match the experimentally determined Young's contact angle θ_Y of PS on DTS or AF1600, respectively. The surface tension of PS is 31 $mJ.m^{-2}$ [3]. Layer thicknesses d_i were obtained from nulling ellipsometry measurements (EP^3, Accurion); values for the Young's contact angle were determined from AFM images of PS droplets on the respective substrates in the final stage of dewetting. The root-mean-square roughness rms of the substrate surface, as a characterization of the smoothness and quality of the substrates, was obtained from AFM scans, using a typical scan area of 1 μm x 1 μm and 512 x 512 pixels.

Computationally expensive 3D (perturbed) simulations shown in Fig. 1e,f were run with a set of parameters typical for a liquid on a non-wettable surface for (intermediate) slip (Fig. 1e) and no-slip (Fig. 1f) conditions [4].

EVALUATION OF THE DEWETTING DYNAMICS AND RIM MORPHOLOGY OF DIFFERENT DEWETTING VELOCITIES



The figure (a) quantifies the evolution of the dewetted distance $D(t)$ for both cases, DTS (rectangles) and AF1600 (stars), shown in the morphological comparison of Fig. 1a,b. On DTS it approaches the asymptotic behaviour $D(t) \sim t^{2/3}$, as expected for the slip-dominated situation [5], before breakdown of the rim into bulges (around 2000 s). In this figure, we also show results from simulations of an unperturbed rim with the strong-slip thin-film equation (straight line) which agree with the experimental data for DTS until the bulging regime is reached. The approach to this growth law strongly depends on the numerical value of b. As we start out with simulations of the strong-slip equation and the obtained growth law corresponds to the intermediate-slip behaviour, we can conclude that in case of slip the asymptotic behaviour of $D(t)$ is universally governed by the behaviour predicted for the intermediate-slip case. By contrast, for AF1600, $D(t)$ is just slightly sublinear, as expected for the no-slip case [5]. Numerical simulations (dashed line) of an unperturbed rim are in excellent agreement with the experimental data.

At the same temperature and for the same film thickness, the temporal evolution of D on AF1600 (stars) is slow as compared to DTS (rectangles). Increasing the temperature (i.e. decrease the viscosity of the liquid, respectively) for the film on AF1600, a much faster dewetting dynamics can be achieved (crosses, 130 °C, 10.3 kg.mol^{-1}, $H = 115(5)$ nm). The significant difference in the morphological evolution (b,c,d) of the rim at the same dewetted distance, however, persists and is clearly determined by slippage.

EXTENSION OF THE MODEL BY BROCHARD-WYART AND REDON (BWR)

In the no-slip case, BWR [6] showed in an approximate calculation that the rise-time τ_q of the undulatory instability, defined by $\dot{u}_q = (-1/\tau_q)u_q$ where u_q is the undulation mode with wavevector q, is given by an expression

$$\frac{1}{\tau_q} = \frac{v^* \theta_Y^3}{3\ell} \frac{1}{1 + \frac{4}{q^2 W^2}} F(q) \tag{2}$$

where

$$F(q) = q \left[-\frac{2}{qW} + \tanh\left(\frac{qW}{2}\right) \right] \tag{3}$$

is the wavevector-dependence of the energy per unit length of a varicose mode of a rim due to Laplace pressure [7]; here, v^* is a characteristic speed and θ_Y the contact angle. Modes with wavevectors q for which the bracket in Eq.(3) is negative will grow, while those for which the bracket is positive will decay exponentially, hence a critical value q_c exists, as is common for a Rayleigh-Plateau instability, and likewise a wavevector of maximal growth, q_m, which determines $\lambda = 2\pi/q_m$. Slip can enter into this theory via the logarithmic prefactor $\ell \equiv \ln(W/b)$ [8] in Eq.(2) for $b \neq 0$.

Consequently, a larger slip length imposes a shorter rise-time τ_q, including a shorter rise-time of the dominant mode.

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