Supporting Information

Rapid spreading of a droplet on a thin soap film

M. Motaghian[1], R. Shirsavar[2], M. Erfanifam[2], M. Sabouhi[2], E. van der Linden[1], H. A. Stone[3], D. Bonn[4], Mehdi Habibi[1]

1) Physics and Physical Chemistry of Foods, Wageningen University, Wageningen, The Netherlands

2) Department of Physics, Faculty of Science, University of Zanjan, Zanjan, Iran

3) Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ 08544, USA

4) Institute of Physics, van der Waals-Zeeman Institute, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

Table of contents

S1.Dynamic Surface tension measurements

In order to measure surface tension of the samples we used the bubble pressure method to be able to capture the surface tension of the samples on short time scales. In this method a capillary with a known diameter is submerged in the liquid sample. Air is blown into the liquid through the capillary at a constant rate, making an air bubble in the liquid, while a pressure transducer measures the pressure inside the capillary. The pressure inside the bubble continues to grow and reaches to its maximum when the bubble is hemispherical with a radius equal to the radius of the capillary. At this point surface tension can be determined using the Young-Laplace equation. This process can be repeated with different rate of blowing air into the bubble, therefore the generated air-liquid interfaces will have different surface ages before the bubbles reach to their maximum pressure. In the other words interfaces with different surface ages, ranging from 5 ms to a few seconds are produced and the surface tension of the air-liquid interface is measured.

S2. Determination of soap film thickness

When a droplet of ALS solution is deposited on a soap film of SDS solution, the coalescence of the droplet and soap film initially triggers a very fast mechanical wave. This propagating wave is different and much faster than the spreading front studied in detail in the main body of the paper. The latter one is a front of a stretching droplet while the first one is a propagating wave moving on the initial soap film. A sequence of images in Fig. S1 shows the mechanical wave propagating over the original soap film. The radius of the wave (R_W) was measured in time for four different experiments. Results are shown in Fig. S2. The average speed of the mechanical waves can be determined from the slopes of linear fits in Fig. S2.

The characteristic speed v of a mechanical wave on an elastic sheet under tension is defined by $v = \sqrt{\frac{\sigma}{\lambda}}$ where σ is the surface tension of the film and λ is the mass per unit area of the sheet, which can be defined as $\lambda=\rho h$, where ρ is the density and h is the thickness of the sheet. In our experiments, we have a fluid sheet (made of SDS 0.005 M) with a surface tension of $\sigma \sim 47$ mN/m and density of $\rho=1000$ kg/m^3 (i.e., the density of water). Substituting these parameters and the average speeds of the mechanical waves into the above equation results in a value of the thickness of the soap film for each experiment. The results for 4 different experiments are summarized in Table S1. The average thickness of the soap film is about 3.5 μm.

To check the accuracy of the soap film thickness measurements using the above method, we have also measured the thickness of the soap film using Taylor-Culick equation [1]. Taylor-Culick model is based on measuring the retraction speed of the soap film after bursting. When a suspended liquid film, bursts, based on its retraction speed, inertia dominated or viscous dominated regimes can explain the dynamics of the retracting film[2-4]. For liquids with low viscosity like the SDS solution used in our experiments, the inertial regime applies. In this regime after rupture, the liquid film retracts with a constant speed obtained by balancing the capillary and inertial terms and called Taylor-Culick speed ($U_T = \sqrt{\frac{2\sigma}{\rho h}}$) where σ, ρ and h are the surface tension, density and the thickness of the soap film respectively. Although this equation is very similar to the previous one but the mechanisms are different. Sequence of photos in Fig. S3 shows a soap film of 0.005 M SDS, 1, 2 and 3 ms after bursting. A retraction speed of 6.4 m/s was obtained by tracking the position of the edge using a high-speed imaging with 7000 frame per second. Taylor-Culick formula predicts a thickness of 2.5 μm, for this soap film in a good agreement with results of the previous method.

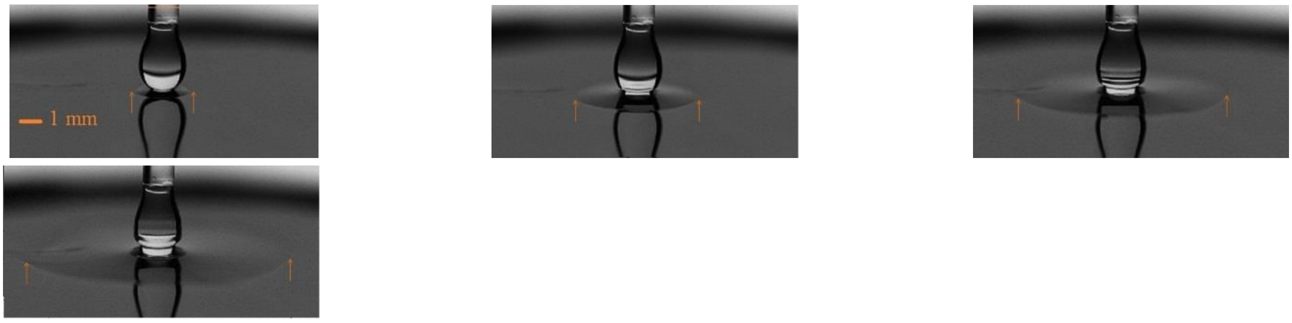

Figure S1. Immediately after coalescence of the droplet with the soap film a fast mechanical wave travels over the initial soap film. Images from left to right are captured at 1, 1.5, 2 and 2.5 ms after droplet touches the soap film.

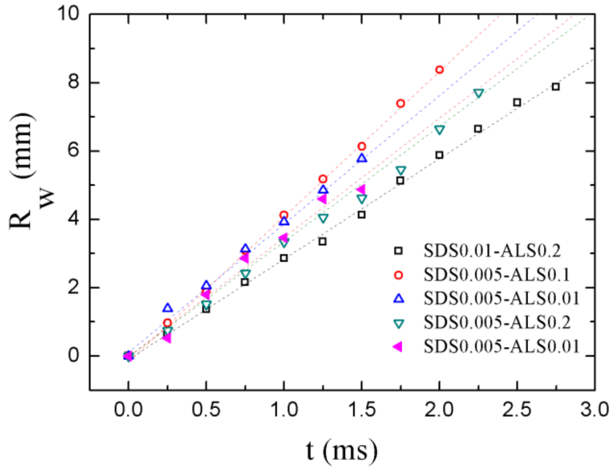

Figure S2. Radius of the mechanical wave as a function of time for experiments with droplets of ALS solution with different concentrations on a soap film of SDS 0.005 M.

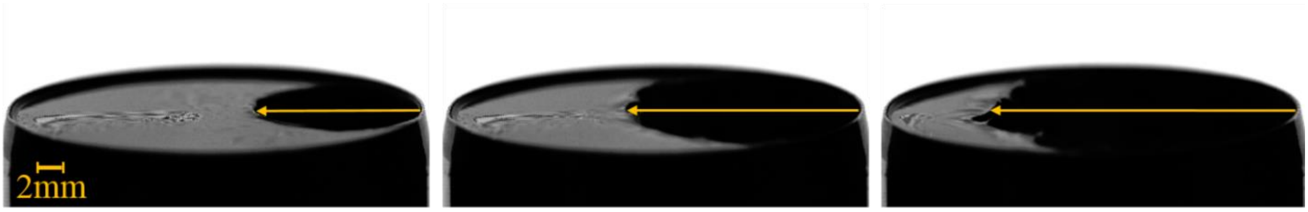

Figure S3. Bursting of a soap film of 0.005 M SDS. From left to right the images are captured 1, 2 and 3 ms after bursting.

Table S1. Average velocity of the mechanical wave calculated by fitting lines to the data in Fig. S2, and thickness of the initial soap film for different experiments with ALS droplet of different concentrations.

ALS concentration (M)	Speed of the mechanical wave (m/s)	Thickness of the soap film (µm)
0.01	*3.73*	*3.4*
0.1	*4.23*	*2.6*

0.2	*3.34*	*4.2*
0.3	*3.49*	*3.9*

References

1. Taylor, G. I., The dynamics of thin sheets of fluid. III. Disintegration of fluid sheets. *Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences* **1959,** *253* (1274), 313-321.
2. Murano, M.; Okumura, K., Bursting dynamics of viscous film without circular symmetry: The effect of confinement. *Phys. Rev. Fluids* **2018,** *3* (3), 031601.
3. Müller, F.; Kornek, U.; Stannarius, R., Experimental study of the bursting of inviscid bubbles. *Phys. Rev. E* **2007,** *75* (6), 065302.
4. Savva, N.; Bush, J. W. M., Viscous sheet retraction. *Journal of Fluid Mechanics* **2009,** *626*, 211-240.