Experimental investigation of the motion and deformation of droplets on surfaces with a linear wettability gradient.

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Abstract

The phenomenon of droplets moving along solid substrates with a wettability gradient was first noted by Greenspan [1] in 1978. An approximation of the velocity of the moving drop was later proposed by Brochard 1989 [2], and the first experimental demonstration was made by Chaudhury and Whitesides [3] in 1992, when they made a water drop move up an inclined gradient surface against gravity.

Our work is mainly focused on two aspects of droplet motion. First, we are interested in the velocity of droplets during motion for varying droplet size, liquid and steepness of the gradient. Literature reports in general only data relating to a "quasi static" velocity for a droplet of specified size and certain liquid on a gradient of certain steepness. Besides one work [4] no results regarding the velocity course have been published as known to us. Our experiments (see Fig. 1 for an example) do not show such "quasi static" motion. Instead, one can distinguish three different domains. When placed on the hydrophobic end of the (linear) gradient surface the droplet first accelerates to a maximum velocity, then slows down and accelerates again at the hydrophobic end. Whether this behaviour is due to the special preparation method of the gradient surfaces or generally characteristic for the motion is still under investigation.

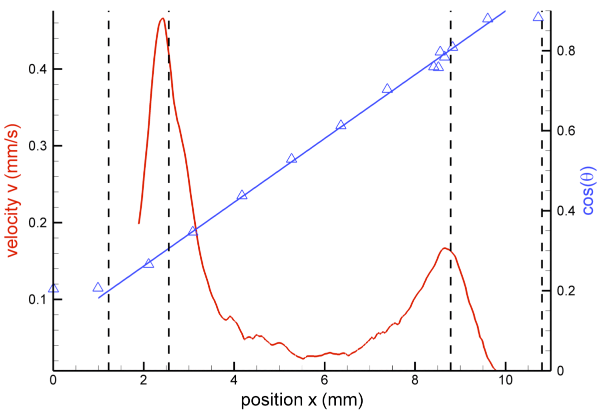

Fig. 1: velocity course of moving droplet and static contact angle profile of linear gradient of wettability; liquid: 3-pyridylmethanol; Motion from left to right; vertical dashed lines represent droplet extension at the beginning and end of motion

The effect of droplet size and gradient steepness on the velocity is shown in Fig. 2. Using pyridazine instead of 3-pyridylmethanol, the first acceleration phase could not be observed. As expected, velocity increases with increasing steepness of the gradient and droplet volume.

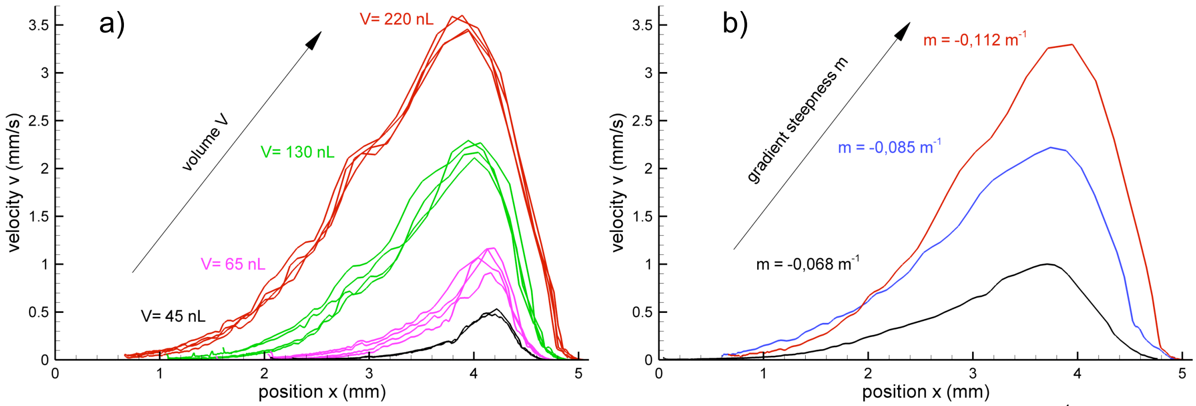

Fig. 2: velocity courses for a) different droplet sizes, gradient steepness m = -0,0112 m^{-1}; b) varying gradient steepness, V = 220 nL; liquid: pyridazine

Besides the velocity course we are investigating the evolution of the droplet planform during motion. Almost all theoretical analyses regarding driving force and drag are mainly based on the assumption of a spherical droplet shape since gravity is usually neglected. As our results clearly show this is not true in general. In the last part of droplet motion we observe (see Fig. 3) elongation of droplets, length exceeding width up to 12%.

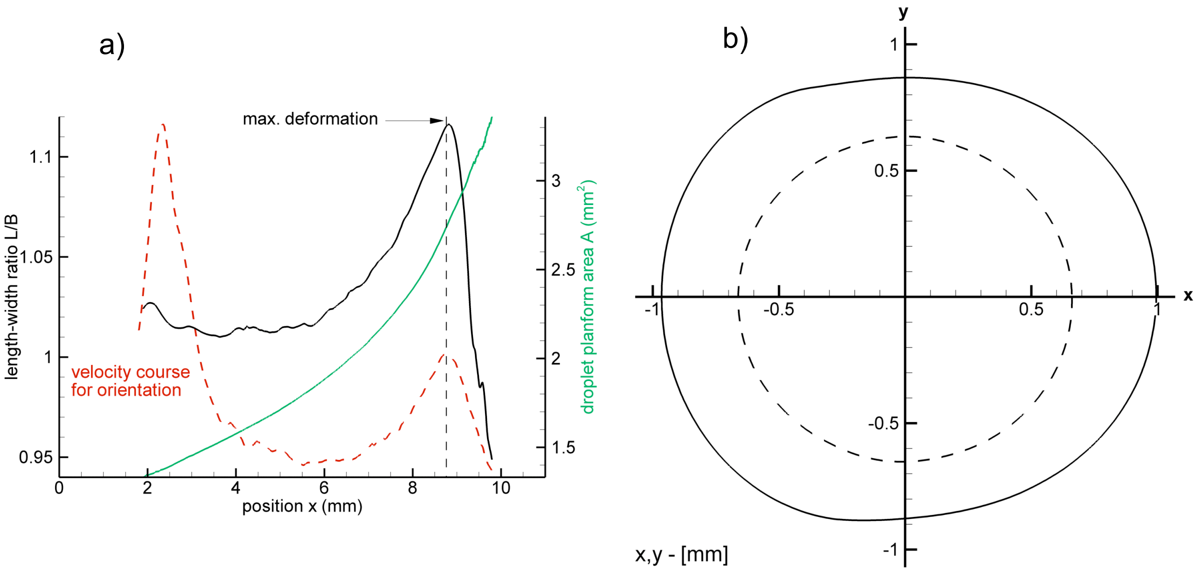

Fig. 3: a) deformation of droplet during motion; b) solid line: droplet shape at maximal deformation, dashed line: droplet shape at beginning of motion; liquid: 3-pyridylmethanol

References

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