Capillary symmetrization of a thin freestanding film

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Abstract

Theoretical descriptions of thin films dynamics typically use the scale separations of the Stokes equations to derive evolution equations of film. This means that the vertical flows are neglected with respect to horizontal ones. For a supported film, this procedure is called the lubrication approximation. For a free standing film, one needs to make the additional approximation that the two interfaces are symmetric with respect to the mid plane in order to perform the scale separation.

Here, we investigate the capillary leveling of a hole in a polystyrene free standing film, a situation where the symmetry assumption is not valid. By scanning the two interfaces with a Atomic Force Microscope, we observe the symmetrization of the hole at short times. In order to understand this dynamics, we derive an hydrodynamic model that goes beyond scale separation. Our model can be exactly solved in the limit of a small hole. In this case, we identify two modes that evolve independently. The first one is the symmetric mode that follows a diffusive- like process leaded by lateral flows. The second one is due to the asymmetry of the interfaces which induces a vertical pressure gradient that drives a vertical flow. We show that asymmetric mode relaxes much faster than the symmetric one which explains the symmetrization observed.

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