Dewetting of thin polymer films on Heterogeneous substrates

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The chemical and topological heterogeneities encountered on solid surfaces raise important issues when studying the interaction of surfaces with liquids. Those heterogeneities are indeed a major source of perturbation of the contact line and deviations from Newton's law, and therefore may modify the local equilibrium state of the liquid volume as compared to what is expected considering average surface properties. One of the most specific feature of a liquid contact line is its characteristic response dominated by a special elasticity due to the presence of a meniscus [1]. More recently, surface chemical heterogeneities have been shown to have striking effects on equilibrium morphology of liquid domains adsorbed onto it [2]. The control of liquid manipulation by surface structuring opens new perspectives for microfluidics devices, which nevertheless require a precise control of the dynamics of the system [3]. Driven by the potential of polymer thin films to provide systems easily transformed to three dimensional architectures, the use of substrate chemical patterning has been recently developed to control morphology of thin films [4]. Here, we suggest a new possibility to pattern thin films by controlling dewetting dynamics.

We consider Newtonian films of thickness $e \sim 1\mu m$. Since $b \sim e$ (where b is the slip length), the dewetting dynamics are controlled by the friction at the polymer-substrate interface and the dewetting velocity V is given by $V = |S|/\xi W$ where S is the spreading parameter, $\xi = \eta/b$ is the friction coefficient (η is the viscosity) and W is the width of the rim [5]. Volume conservation leads to a time dependence $W \sim t^{1/3}$ and therefore $V \sim t^{-1/3}$. Contrarily to the viscoelastic case, this expression is valid for the two different geometries of dewetting, i.e., holes and fronts. A specific feature of Newtonian slipping films is the occurrence of a rim instability, with the formation of "polymer tears" at of the rear of the receding contact line [6].

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152   We achieved the surface patterning by a standard microcontact printing process, and used bare or piranha treated gold substrates to produce various wettability contrasts. Our results show that dewetting of thin films on such heterogeneous substrates is dependant on the correlations between the geometry of dewetting, the thickness of the film, and size of the pattern.

Because of the confinement due to surface structure, the rim is distorted as compared to the usual cases on homogeneous surfaces. Then, pressure gradients in distorted rims lead to either weakly or strongly confined dewetting, which in turn produces major variations of dewetting velocities of holes. In the case of dewetting fronts, the flow of liquid from the rim to the chemical stripes of lowest contact angle, and contact line distortion are at the origin of a subtle effect which forces the rim instability to appear, as opposed to what is expected for such "thick" films.

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