Formation of Topographical Patterns on Liquid Film Coatings using Electric Fields

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When DC electric fields are applied normal to a liquid-air interface, the interface may become unstable. Through this process, a regular array of pillars, lines, or holes may be systematically created on the surface of a thin liquid film, as illustrated in figure 1. These structures can then be solidified, thereby providing a mechanism for producing topographically patterned coatings. Creating sub-100 nanometer topographical features is of great interest for many important technologies such as printed electronics, biomaterials, and optical/adhesive coatings. Electric-field-driven instabilities are of particular interest because they have the potential to create these features in a self-assembled manner, which would allow cheaper fabrication of products currently created with conventional lithography.

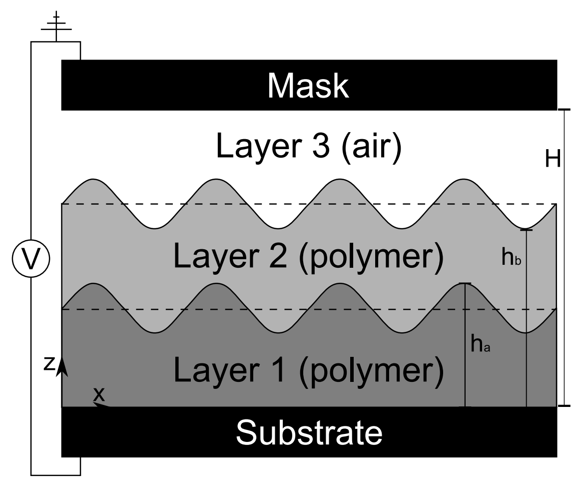

Figure 1: Schematic of the electrohydrodynamic patterning process.

We examine the possibility of using AC electric fields to exert further control over the size and shape of the regular arrays formed through electric-field-driven instabilities. Linear stability analysis and nonlinear simulations are applied to lubrication-theory-based models for perfect (no free charge) and leaky dielectric (free charge present only at fluid-fluid interfaces) thin liquid films. For perfect dielectric films, linear stability analysis shows that the effect of an AC field can be understood by considering an effective DC field. For leaky dielectric films, Floquet theory is applied to carry out the linear stability analysis and it reveals that the frequency may be used to control the accumulation of interfacial free charge, and thus the dominant growth rates and wavenumbers. Nonlinear simulations confirm the results of the linear stability analysis while also uncovering additional mechanisms for tuning overall pillar height and width through adjustment of the magnitude and frequency of the AC field. The results presented here may be of interest for the controlled creation of surface topographical features in applications such as patterned coatings and microelectronics.