Electric Field Induced Patterning in Thin Films

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Abstract

Interfacial structures/pattern, especially with small-scale dimensions, are important to the chemistry of materials in determining the optical, electrical, mechanical, or other physical properties of novel materials [1,2]. Polymers are often used for surface patterning. The diversity, the relatively low cost, the convenient mechanical properties and the compatibility with most patterning techniques render polymers attractive candidates for patterning processes. The objective is to demonstrate through Finite Element Analysis, the utility of the Electro-hydrodynamic Induced Patterning (EHDIP) for patterning nano scale morphology (Figure 1).
By numerical simulation using COMSOL Multiphysics® software, finite element analysis software, a model is developed showing that the presence of an electric field close to a liquid polymer surface can be used to induce instabilities of the polymer-air interface and thereby controlling the morphology of the surface (Figure 2). An extensive study has been done on the limiting parameters for electric field induced patterning. Variation of morphology with respect to period limit of mask, applied voltage, surface tension, viscosity and other parameters is the focus of this study. For results validation a computational model has been verified [3](Figure 3).
We have done an extensive study on the parameters that are under the control of an experimentalist in the described system. Line width, Electrode width, thickness of the film, film fluid and the bounding fluid are the parameters we can vary for obtaining different patterns. Here we try to quantify the types of patterns formation. So to study the behaviour of system we divide our study in two sections, a) geometric parameters (line width, electrode width, film thickness) and b) fluid properties (viscosity, surface tension). As result, minimum period limit of mask is reported for the formation of stable morphologies with respect mask as a variation of geometric properties. Effect of surface tension and viscosity is studied for the formation these polymeric pillars. Comparison of different morphologies one the basis of their width and shape has been done for qualitative analysis of the same (Figure 4).

Reference

1) Influence of Electrostatic and Chemical Heterogeneity on theElectric-Field-Induced Destabilization of Thin Liquid Films”, A. Atta, D. Crawford, Langmuir 2011, 27, 12472–12485
2) Electrohydrodynamic instabilities in polymer films, E. Schaffer, T. Thurn-Albrecht, Europhys. Lett., 53 (4), pp. 518–524 (2001)
3) Simulation and modelling of sub-30 nm polymeric channels fabricated by electrostatic induced lithography, H. Li, W. Yu, L. Zhang, Z. Liu, K. E. Brown, E. Abraham, S. Cargill, C. Tonry, M. K. Patel, C. Baileyd and M. P. Y. Desmulliez, RSC Adv., 2013,3, 11839-11845.

Figures used in the abstract

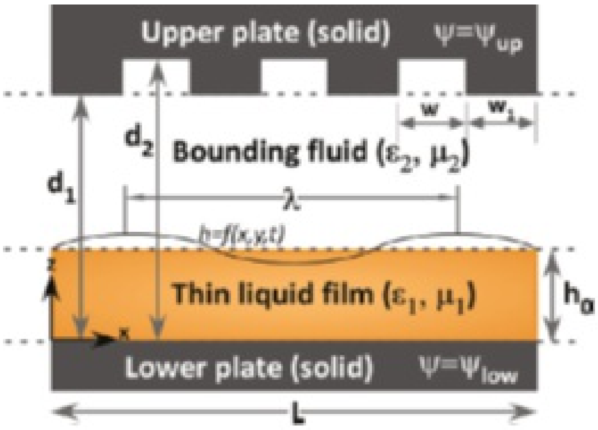

Figure 1: Schematic of fluid instability induced by heterogeneous electric field due to patterned mask.

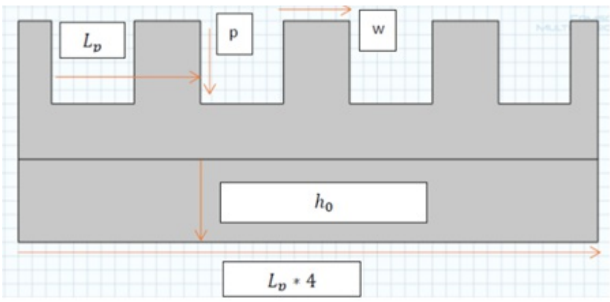

Figure 2: Computational model geometry with geometric parameters.

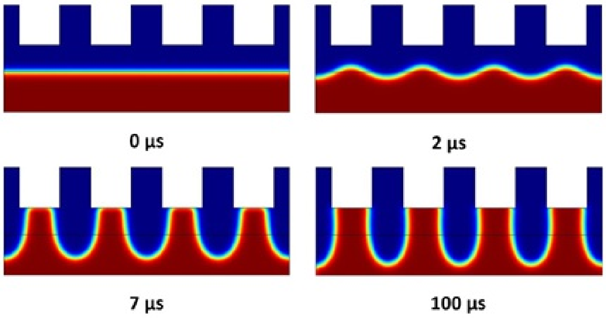

Figure 3: Temporal evolution of 30 nm thick polymeric film on application of 50 V potential difference with top electrode having 30 nm X 30 nm protrudes with a periodicity of 53 nm.

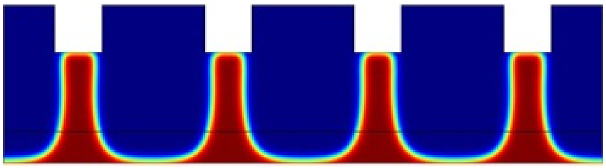

Figure 4: Steady state pattern formation on application of 70 volt on a film thickness of 20 nm through a patterned mask of 30 nm X 30 nm protrusion and periodicity of 95 nm.