Dynamic modeling of Electrohydrodynamic Patterning by Moving Mesh Method

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Electrohydrodynamic (EHD) patterning[1] is an intriguing technique to fabricate micro/nano structures on thin polymer film with a representative configuration shown in Figure 1. A numerical simulation on it however is still a great challenge owing to its computational complexity. In this paper, a fully nonlinear numerical model is presented to investigate the dynamic process of this technique. As a multi-physics coupling problem, the solution of electric field requires the knowledge of the geometric deformation of the polymer/air interface and the interface shape is in turns affected by the electrical force originating from the nonuniformity of electrical permittivity across the polymer/air interface. Since the free surface requires a special treatment during calculation, a moving mesh method is proposed to enable the solution. In this numerical model, the Navier-Stokes equation for the fluid flow and Laplace equation for electric field are solved simultaneously, and the grid gains its remeshing via the moving mesh method. Surface tension and Maxwell stress tensor are imposed to the fluid flow as external forces imposing on the free surface together with appropriate boundary conditions on it. After discretized, all the governing equations are solved by Finite Element Method,[2] thus fully nonlinear analysis can be carried out of polymer dynamic evolution associated with the fluid flow and the electric field. Extensive numerical simulations are subsequently conducted to investigate the effect of parameters. It is found that a critical voltage exists, below which the polymer film gradually evolves into structure with a small height, the electrical force is delicately balanced by the surface tension. On the other hand, if the applied voltage is above that value, polymer would be accelerated growing until gets geometrically ceased by the template. These conducted results provide guideline for experiments and its further industrial applications of EHD patterning.

[1] Wu N., Russel, W. B., 2009. Micro- and nano- patterns created via electrohydrodynamic instabilities. Nano Today 4, 180–192.
[2] Reddy J. N., 1993. An Introduction to The Finite Element Method (McGraw-Hill, New York).

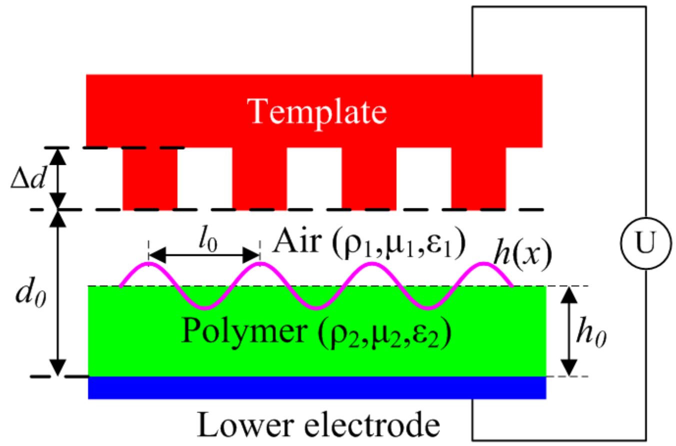

Figure 1. Configuration of Electrohydrodynamic pattering: A thin polymer/air film is sandwiched between a substrate (lower electrode) and a template (upper electrode). An external electric field is imposed between the electrode pair.

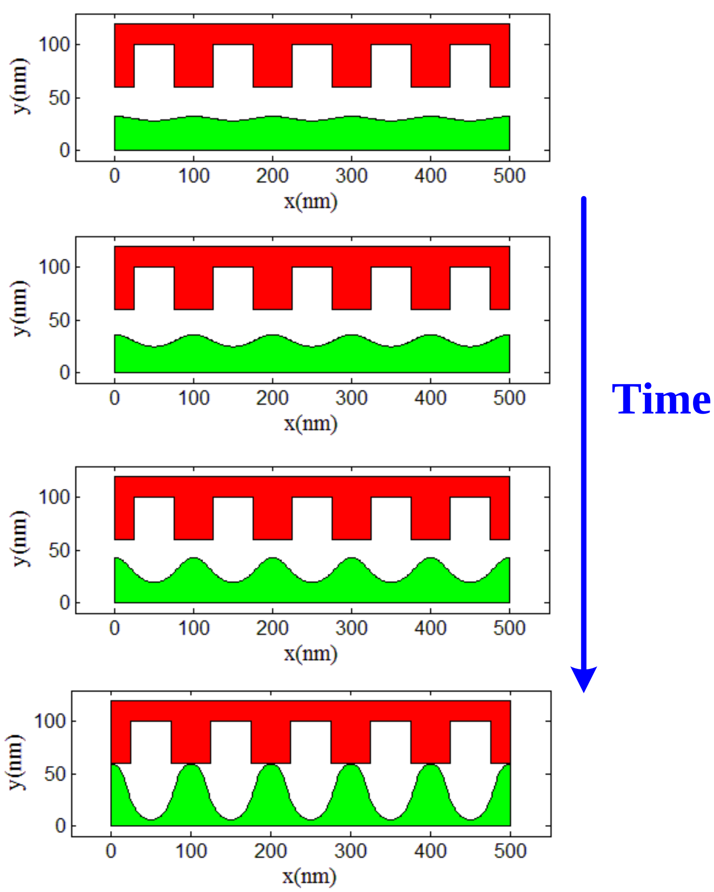

Figure 2. Dynamic process of Electrohydrodynamic pattering: A voltage of 60V is applied to the system, and the corresponding dimensionless time is t^*=1, 2, 3, 4 from top to bottom.