Electric Field Induced Patterning in Computational Lithography

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To make nanoscale structures, top-down and bottom-up lithography techniques have been continuously studied and developed over decades. Searching for ways to create nanoscale patterns in both organic and inorganic materials at reduced operation time and cost is one of the challenges in nanotechnology. The electro field induced lithography, a bottom-up method, is a popular and promising implementation technology due to its capability to generate a variety of pattern structures even without a pre-patterned mask. By using a laterally modulated electric field, the electro-hydrodynamic instability without contact between the resist and stamp induces spontaneous formations of micro- and nano-patterns through electrostatic pressure, so that a good variety of fine and hierarchical structures can be produced quickly, simply, and economically.

In this paper, by using the molecular simulation and the Navier-Stokes equation, the electro-hydrodynamic instability are described in the alignment of lamellar block copolymers and the electro-hydrodynamic driven nanopatterning in the electro-hydrodynamic lithography. The impact of simulation parameters on pattern formation is discussed. Pattern structures are performed from one stamp via the adjustment of electric field. The electric field is controlled by varying the parameters such as replication time, thickness ratio between resist film and air gap.

Figure 1 shows lamellae patterns in electric field by using the molecular simulation. The orientation-dependent polarization energy aligns the lamellas pattern parallel to the electric field lines because interfacial interactions are negligible under strong enough fields.

Figure 2 shows experimental data and the expected simulation data of the Navier-Stokes equation for the electro-field-induced lithography. In Fig. 2(a), a thin resist film with an air layer is situated between the substrate and the stamp, which acts as electrodes when the electric charge is applied. An applied potential difference between two electrodes gives rise to electric field across the dielectric material and the air layer. The dielectric discontinuity at the film-air interface in the capacitor gives rise to the formation of displacement charges that couple to the electric field, causing a destabilizing electrostatic pressure. The pressure makes an undulatory motion and pattern structures consisting of the dielectric material are formed by flow of the thin resist film.

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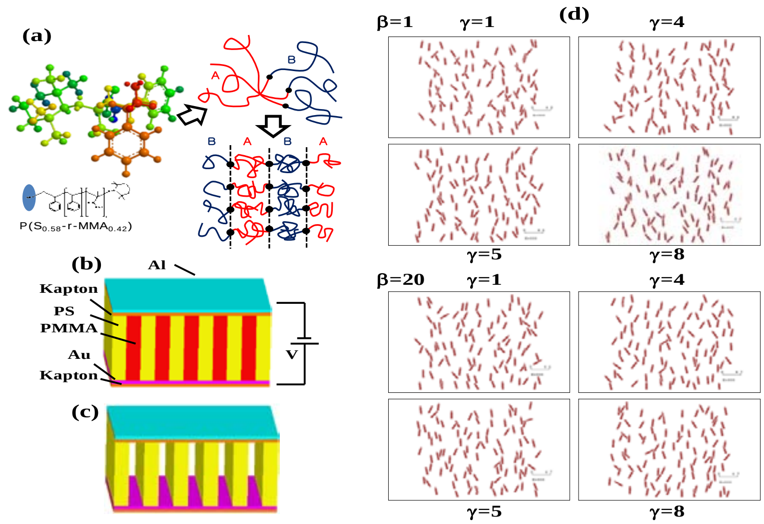

Figure 1: schematic representation of lamellar pattern fabrication: (a) model of field-theoretic polymer to string, (b) asymmetric diblock copolymer annealed above glass transition temperature of copolymer between two electrodes under applied electric field; (c) after removal of minor component, lamellae film is formed; (d) simulation results of reorientation and realignment from random distribution of lamellar patterns due to electric field. Dimensionless parameters are lamellar pattern-electric field interaction ($\beta = pE/kT$ *) and lamellar pattern-lamellar pattern interaction (* $\gamma = p^2/4\pi\varepsilon_0 d^3 kT$ *) in electric field.*

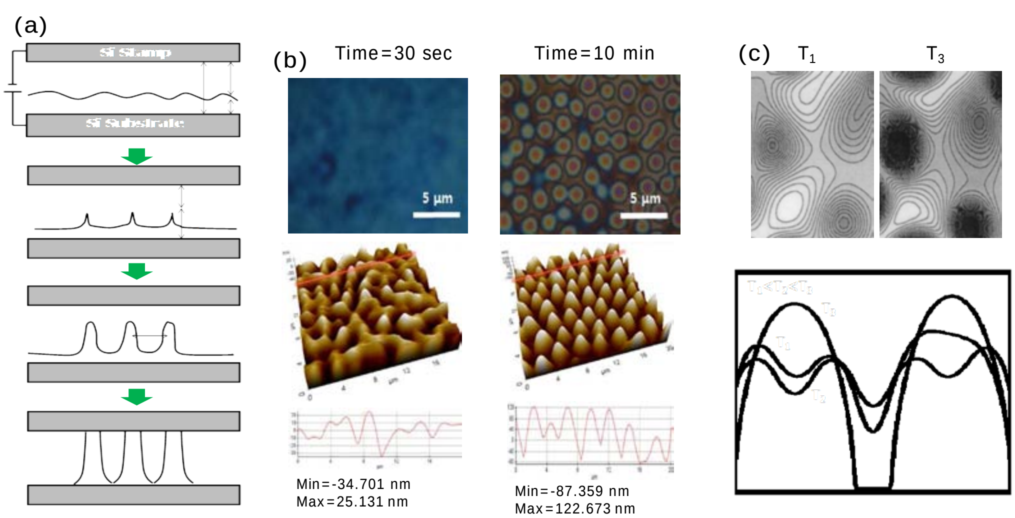

Figure 2: electro-field-induced lithography for (a) schematic diagram, (b) experimental data, and (c) expected simulation data.