Faithful Replication of Large-Area Nanostructures via Pulsed Direct Current High-Voltage Electrohydrodynamic Phase Instability

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As the conventional lithography confronted the physical barrier in reducing the feature size, intensive efforts for alternative lithographic methods have been dedicated to improving the feasibility of the well-ordered nanostructure fabrication over a large area. Among various types of nanopatterning techniques, electrohydrodynamic lithography (EHL) has been considered a promising tool for replicating nano-sized features in a cost-effective manner [1-3]. However, EHL is still facing technical challenges to achieve highly faithful pattern replications over a large area. In addition, poor reproducibility, limited pattern height, precise control of parameters, and limited available substrates are the outstanding issues to be resolved. In this regard, we introduced a new lithographic approach based on electrohydrodynamic instability induced by employing pulsed high-voltage (> 6.0 kV) with micro-level air gap (> 1.0μm). Compared to the conventional EHL, the high-voltage method (HV-EHL) using stronger electric field (> $10^8 V/m$) enhances the overall fidelity including the pattern height [4]. Nonetheless, HV-EHL offsets this influence due to the reduced characteristic time that determines the patterning time for fully-developed pattern (See Figure 1). Accordingly, under the non-constant air gap condition, the patterned area can be extended over the entire surface of the resist. To support this, we confirmed that the parameter constraints for perfect replication is more relieved in HV-EHL, which implies the more facile replication process in our approach. Our pulsed high-voltage EHL is not only a technical improvement but also an innovative lithographic approach to achieve both lithographic requirements and industrial needs by the capability of fabricating a number of functional nanoscale patterns on a large scale in a facile and cost-effective fashion.

References:

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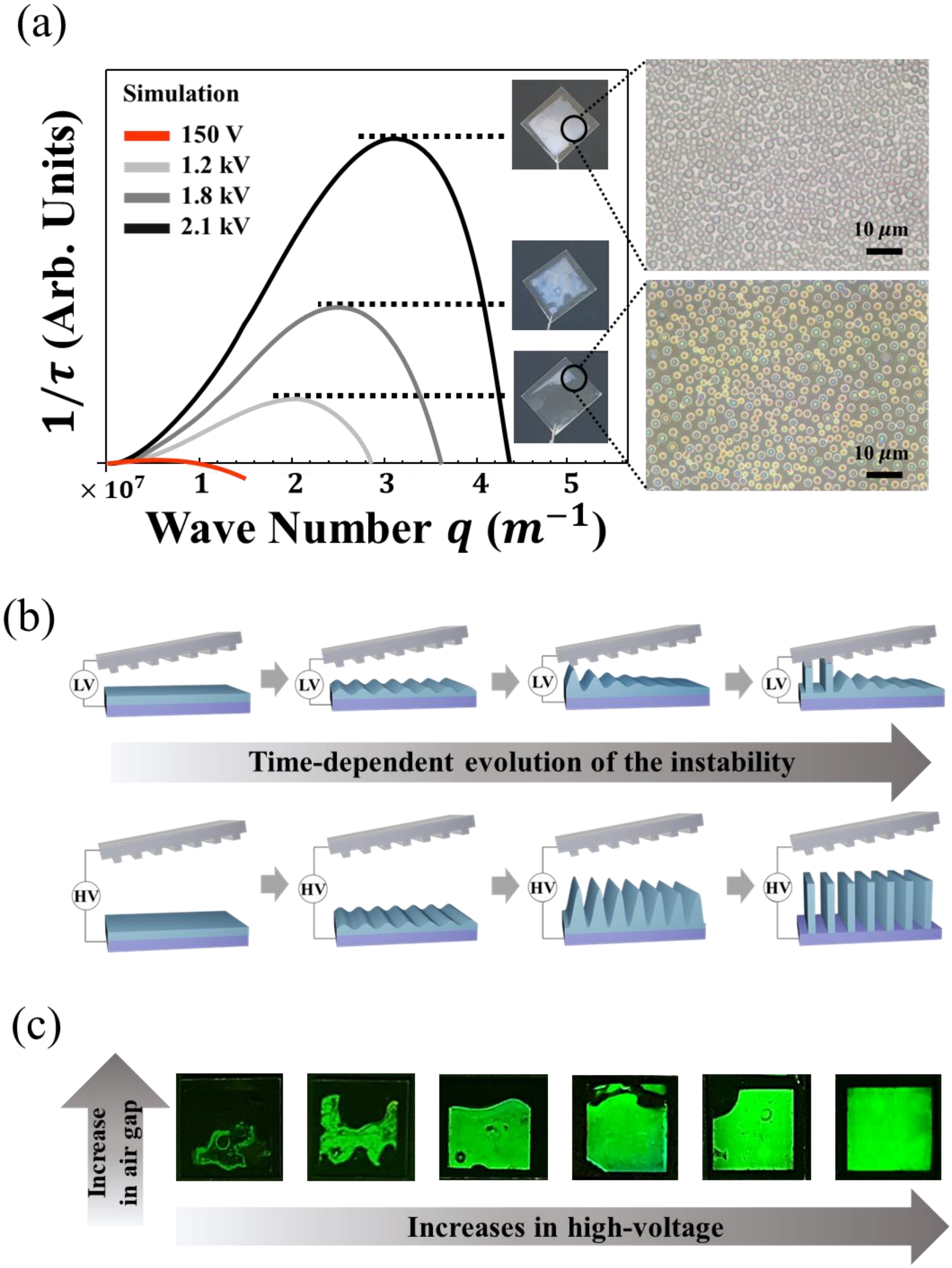

Figure 1. Pattern growth velocity and patterned area as a function of voltage (a) The plots of the reciprocal time constant ($1/\tau$) as a function of the wavenumber (q). As seen, the maximum value increases drastically with increasing voltage (150 V, 1.2, 1.8 and 2.1 kV, respectively). Notably, these plots are based on the *dispersion relation* given by $\frac{1}{\tau} = -\frac{{h_0}^3}{3\eta}\left(\gamma q^4 + \frac{\partial p_{el}}{\partial x} q^2\right)$. The inset photographs indicate that the patterned area is enlarged as the high-voltage increases. The corresponding optical images show the different stages of the time-dependent evolution. (b) Two schematics illustrate that the pattern replication with different growth velocity in the LV- and HV-EHL (top and bottom). (c)

Photographs of diffraction patterns from the monochromatic illumination: the patterned areas tend to be enlarged as the high-voltage increases.