Theoretical Understanding of Electrohydrodynamic Lithography for sub-100 nm Pattern Replications

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Abstract

Electrohydrodynamic lithography (EHL) has recently emerged as a versatile pattern transfer technique utilizing electrohydrodynamic film instability.[1~3] The theoretical modeling of EHL predicts that the structure on length scales below 100 nm can be easily fabricated by harnessing the physical parameters that affect the film instability. However, few experimental works on this scale is available. To achieve high fidelity for pattern transfer on such scale, adjusting an intrinsic wavelength and a periodicity of the pattern to be similar and employing a master pattern with high aspect ratio are highly desirable.[4~5] However, theoretical understanding on how the physical parameters are subtly influencing one another to realize a desirable pattern replication is still far from satisfaction. In this study, we attempted to construct a diagram revealing a subtle influence between the governing parameters through a computer simulation based on a finite element method by investigating the dependence of the amplitude of the waves upon the ratio between intrinsic wavelength and the periodicity of pattern. We identified the boundaries demarcating between a proper pattern replication region and an improper replication region. These theoretical predictions are in great agreement with our experimental results. Our theory and experiments show that the pattern transfer technique developed here is well suited for the fabrication of sub-100 nm surface patterns.

References

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Figures

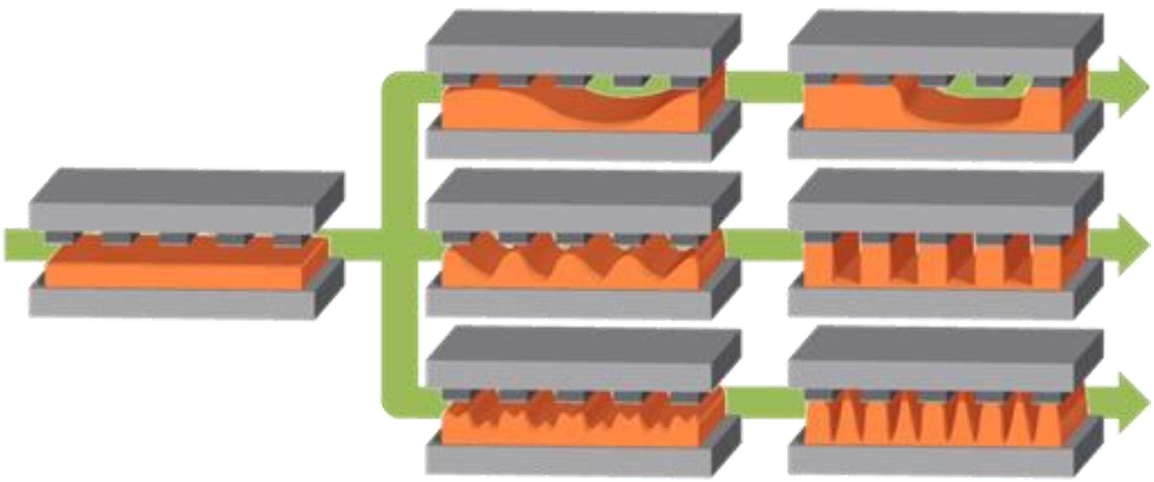

Figure 1 A schematic of pattern replication process that depicts dependence of experimental parameters.

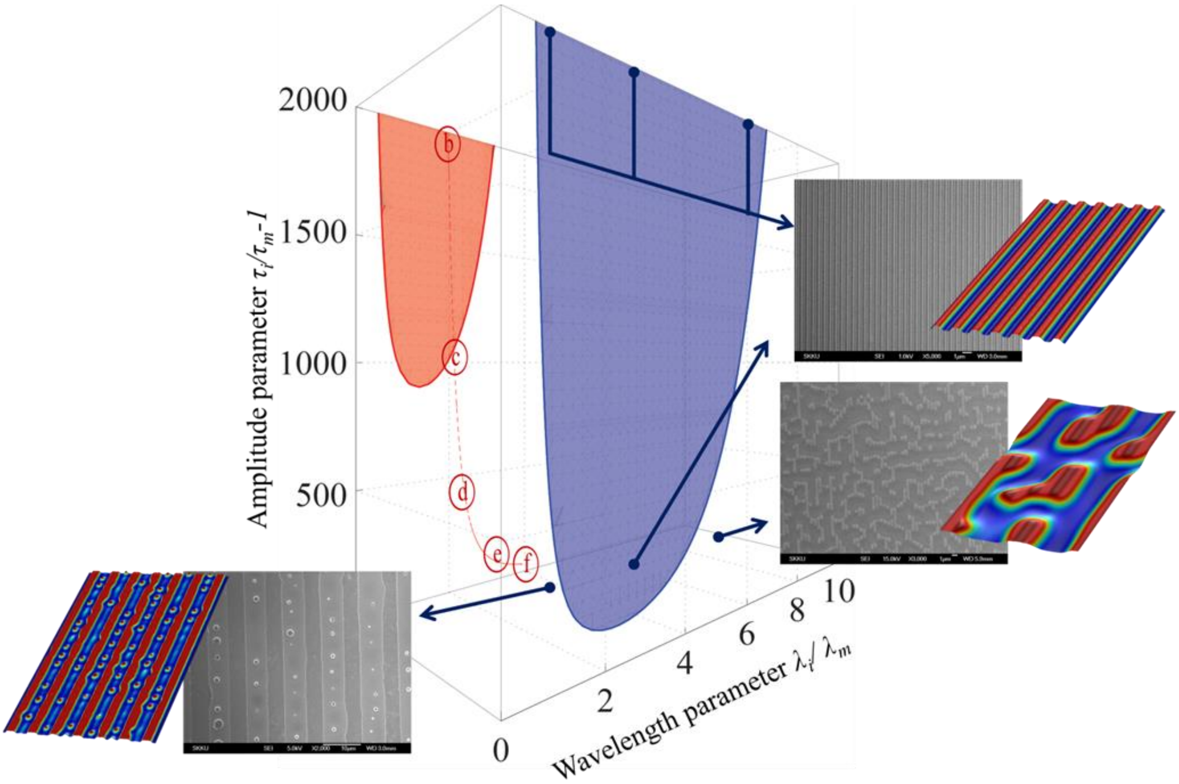

Figure 2 The diagram describing the relationship between the wavelengths, the amplitudes and the final replica of pattern array. The regions in purple and orange represent a proper replication condition for line pattern and hexagonal hole array pattern respectively. The inset figures show the experimental and computer simulation results for line pattern replication under respective conditions. Experimental results on the left are based on the 5 μm wide line pattern array, whereas the results on the right are based on 300 nm wide line pattern array.

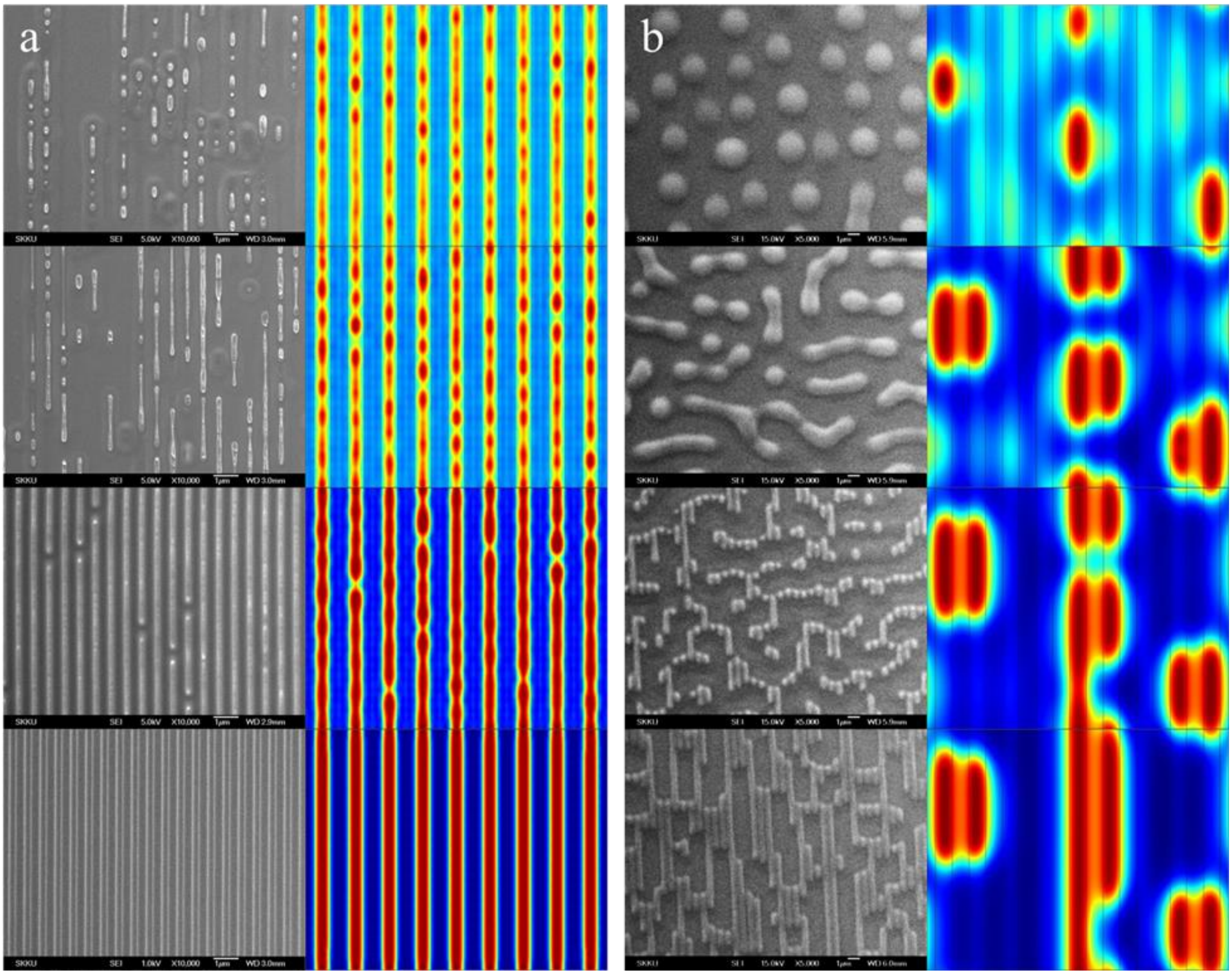

Figure 3 Time dependent line pattern replication process in $\lambda_t \sim \lambda_m$ (a) and $\lambda_t > \lambda_m$ (b) condition. As the characteristic wavelength gets larger, the transferred pattern also tends to be larger, to form a thicker line.

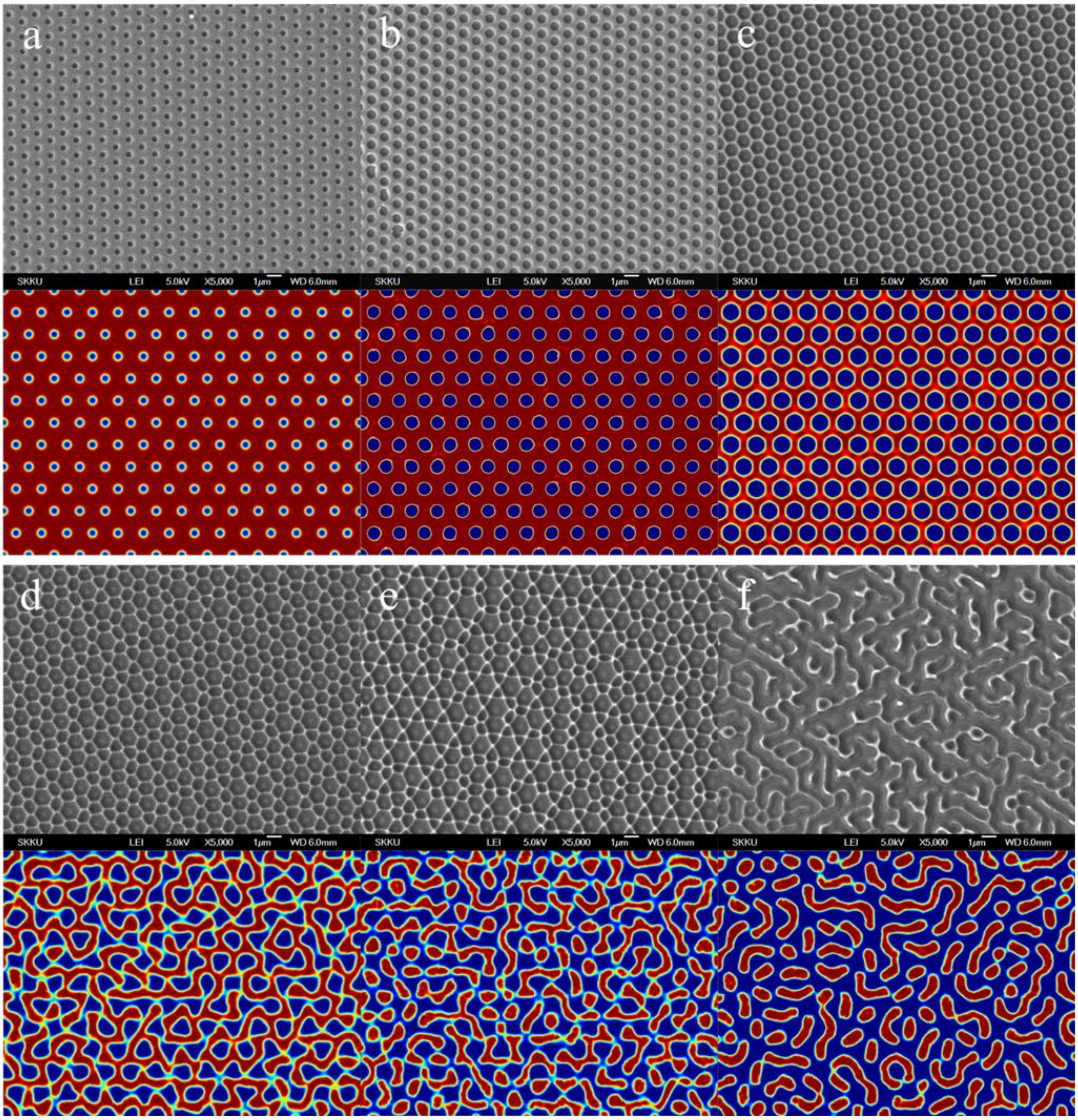

Figure 4 Experimental and simulation result of hexagonal hole array pattern. As the gap decreases from a to f, hexagonal shape disappears.