Effect of process parameters on block-copolymer patterns by electrohydrodynamic printing and self-assembly

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Techniques for directed self-assembly (DSA) based on chemically and topographically patterned substrates can yield the uniform and long-range order patterns. However, these DSA technologies have patterning limitation of spin coating to define arbitrary patterns with various sizes, periodicities, and morphologies in a wafer. The electrohydrodynamic (EHD) printing has great potential in complex and high-resolution printing because it generates droplets that are much smaller than EHD nozzles. Printed patterns are complete with spreading of the droplets on substrates and the droplet spreading is determined by surface wettability between the droplet and solid substrate. A combination of DSA and EHD jet printing can be used to create block copolymer films with complex structures and tunable periodicities across a large substrate. For fine and well-defined patterns by using EHD printing, it is important to consider the relationship between printing conditions and the physical behavior of electrically charged ink. Hence, it is interesting and required to understand the relationship between final patterns and each EHD and DSA step, as well as the optimization of process parameters.

In this paper, the combined technology of EHD and DSA is modeled to reduce complexity. Simulation results are compared with experimental results. Simulation parameters for simulated profiles are analyzed. Through these easy-to-optimize parameters, the combined technology can be effectively predicted.

Figure 1 represents the schematic of the EHD jet printing process used to paint hierarchical micrometer-to-wafer-scale-sized patterns with block copolymer inks. Figure 2 represents simulation parameters of EHD jet and DSA processes. Simulation structure is included EHD printing for EHD jet process and self-assembly, exposure, and development processes for DSA. Figure 3 represents comparison of simulation results to experimental results [1] for EHD. Parameters such as working distance and voltage affect line width and volume of ink jet. Figure 4 represents comparison of simulation results to experimental results [1] for DSA. Simulation conditions are 400 molecules, molecular chains of 10-nm PS and 10-nm PMMA for 10-nm critical dimension (CD) and 20-nm PS and 20-nm PMMA for 20-nm CD, $\gamma = 4.5$, rc = 1, $k_BT = 1$, $a_{P,P} = 25$, $a_{P,PMMA} = 45$, and $a_{PMMA,PMMA} = 25$ for coarse-grained molecular dynamics.

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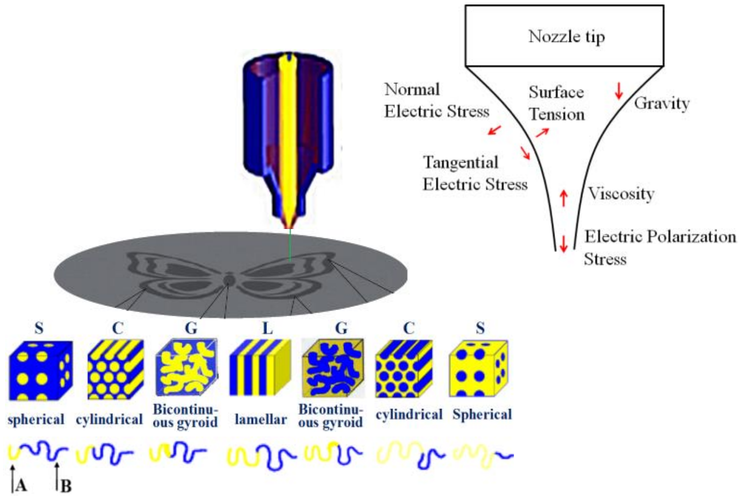

Fig. 1. Schematic of the EHD jet printing process.

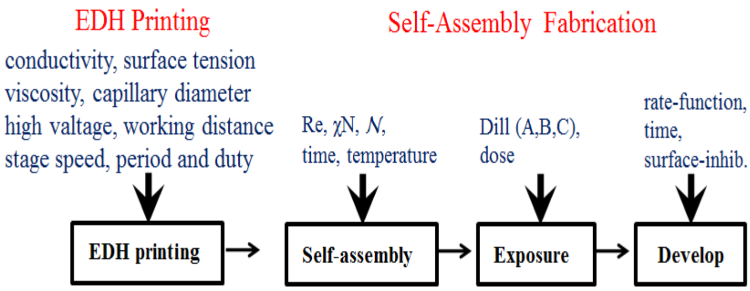

Fig. 2. Simulation parameters of EHD jet and DSA processes.

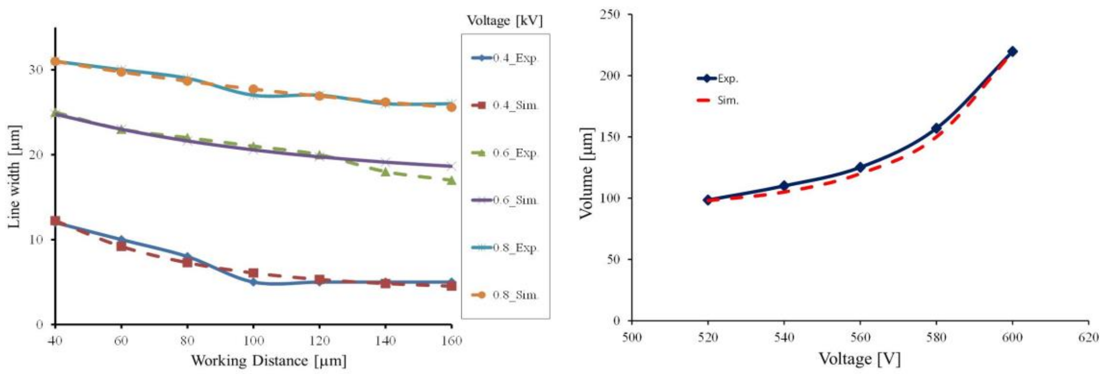

Fig. 3. Comparison of simulation results to experimental results [1] for EHD.

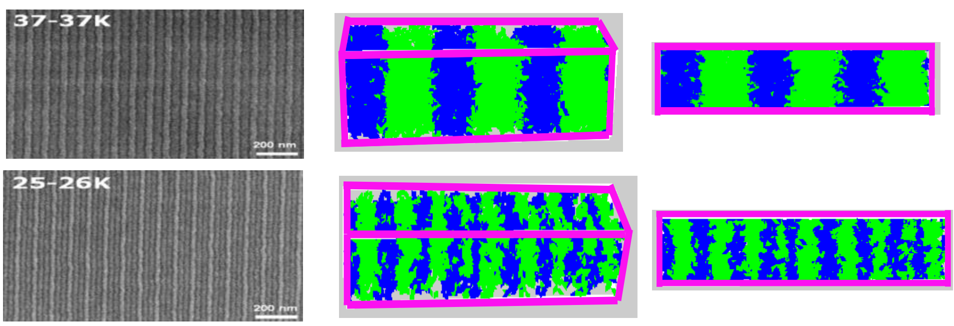

Fig. 4. Comparison of simulation results to experimental results [1] for DSA.