Spin on Glass as an Orientation Control Layer for Block Copolymer Direct Self-Assembly

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Direct self-assembly (DSA) of a block copolymer (BCP) has been paid much attention because ten-nanometer-scale patterns can be obtained with low cost. However, to apply DSA of BCP to semiconductor device fabrication, guide patterns should be formed by photolithography and pattern transfer layers are necessary underneath to obtain etch selectivity. A spin on glass (SOG) film in tri-layer resist process is used as an anti-reflective coating and a pattern transfer layer in ArF lithography[1)]. In Addition, an orientation control layer is necessary to form perpendicular BCP lamellar or cylindrical patterns. In order to avoid the additional orientation control layer, SOG was employed as an orientation control layer. Figure 1 shows a schematic structure in the case of a chemical guide pattern. Pinning patterns are formed by photolithography.

SOG was synthesized by a sol-gel method from methyltrimethoxysilane ($CH_3Si(OCH_3)_3$). The SOG was spin-coated on a wafer and baked at 290°C for 1 hour. Polystyrene polymethylmethacrylate diblock copolymer (PS-b-PMMA) was spin-coated on the SOG film. The molecular weight (M_n) of PS-b-PMMA was 86.4 kg/mol (PS: 46.9 kg/mol, PMMA 39.5 kg/mol). The BCP film was annealed at 215°C for 24 hours.

The perpendicularly-oriented lamellar pattern was observed by an atomic force microscopy (AFM) phase image after micro-phase separation. The period of the BCP pattern was 51 nm, which corresponds to the calculated value from the BCP molecular weight. The PMMA area was removed by inductively coupled plasma etching with oxygen from the micro-phase separated pattern of the PS-b-PMMA. Figure 2 shows the cross-sectional scanning electron microscopy (SEM) image of the BCP pattern after PMMA removal. It was found that there was no residual in the space area of the etched pattern. Therefore, the lamellar pattern was perpendicular to the surface of the SOG film from top to bottom.

Consequently, the SOG film was confirmed to serve as an orientation control layer for BCP direct self-assembly. Low-cost BCP patterning with the guide patterns can be expected because the SOG can also be used as the upper layer of anti-reflective coating in tri-layer resist process and a pattern transfer layer.

Reference: 1) Y. Sato et al., J. Photopolym. Sci. Technol. **14**, 439 (2001).

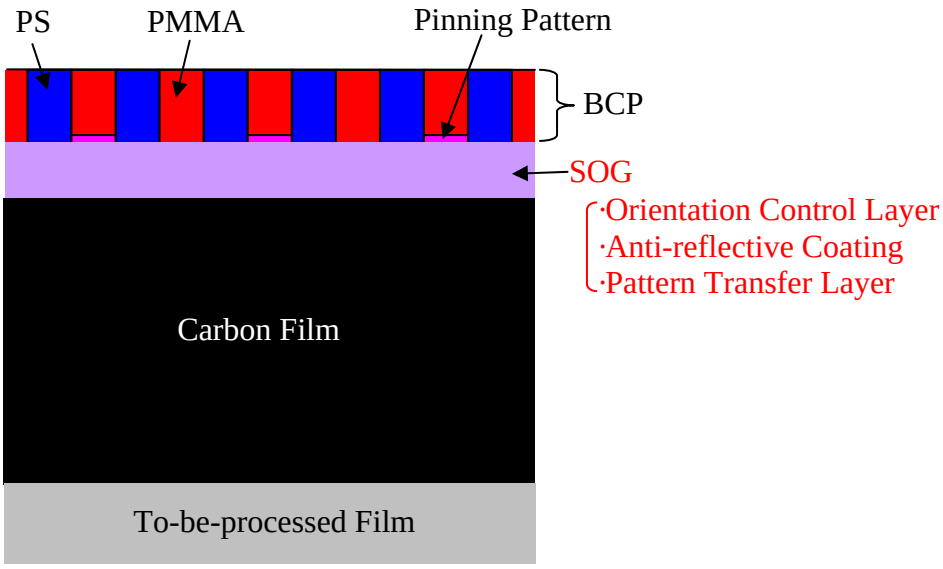

Figure 1: Schematic structure of a chemical guide pattern.

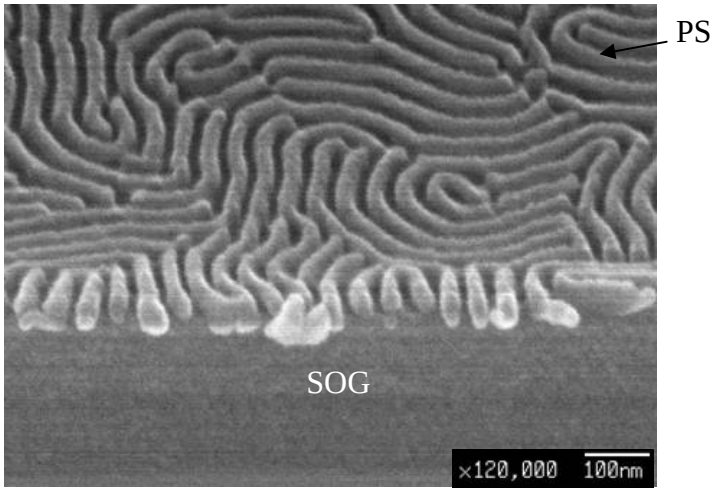

Figure 2: Cross-Sectional SEM image of a BCP pattern after PMMA etching of the BCP micro-phase separated pattern.