

## Pattern Transfer Using Poly(styrene-methylmethacrylate) Block Copolymer Films and Reactive Ion Etching

Chi-Chun Liu and Paul F. Nealey\*

*Dep. of Chem. and Bio. Eng., Univ. of Wisconsin-Madison, Madison, WI 53706*

Yuk-Hong Ting and Amy E. Wendt

*Dep. of Elec. and Comp. Eng., Univ. of Wisconsin-Madison, Madison, WI 53706*

The use of block copolymer films as templates for manufacturing electronic circuits and other devices<sup>1</sup> has drawn increasing attention because of 1) the demonstrated ability to create nanoscale features with many of the essential attributes of the photolithographic process including pattern perfection,<sup>2</sup> registration<sup>2,3</sup> and overlay, and non-regular device-oriented geometries<sup>4</sup>, 2) potential for improved critical dimension control<sup>5</sup> and line edge roughness, 3) scalability to 10 nm and below, and 4) sub-lithographic patterning. In the most general case, for a block copolymer to serve as a usable template for pattern transfer, one block of the copolymer has to be selectively removed from the copolymer thin film to form the pattern template, and then the remaining block must serve as an etch mask. In this study, we used a lamellar-forming poly(styrene-*b*-methylmethacrylate) (S-*b*-MMA) copolymer to study both the template formation and the effects, and the interplay, of etch selectivity and lateral etch rate on the fabrication of line patterns in the underlying substrate.

In the template forming process it is necessary to generate high aspect ratio features with vertical sidewalls. In our case, the methylmethacrylate (MMA) block removal step could be either a blanket UV exposure plus selective solvent development or a plasma etching process. We opted for the plasma process primarily because with line structures, the solvent process leads to pattern collapse for structures of relevant aspect ratio. (Fig. 1)

Two important factors of the plasma etching process need to be carefully characterized: selectivity and lateral etch rate. (Fig. 2) Higher selectivity styrene/MMA selectivity, in which the MMA etches faster than the styrene, results in more styrene remaining in the template and is favorable to achieve deeper patterns in the substrate. Less than desired selectivity can be offset by using thicker films to achieve deeper pattern transfer, but then the lateral etch rate can result in a widening of the opening and therefore a loss of the CD control of the template and the transferred features. Thus, there is interplay between selectivity and lateral etch rate that limits the copolymer film thickness that can be used.

The characterization experiments were performed on a capacitive Reactive-Ion Etching (RIE) tool. We chose oxygen and argon plasmas as the chemical and physical etching gases, respectively. Our results suggest that although the argon plasma had a higher selectivity on blanket test wafers, by comparing the behavior on patterned copolymer, the oxygen plasma had better etch selectivity, resulting in greater retention of the template during the etch. Further etching into silicon substrate using this template yielded a very smooth line and a vertical sidewall profile. (Fig. 3)

Although the etch process demonstrated effective pattern transfer, the selectivity and lateral etch rate data that we have in hand suggest that the S-*b*-MMA copolymer may not be the most suitable material for pattern transfer applications, and delineate design parameters for copolymers for the intended applications.

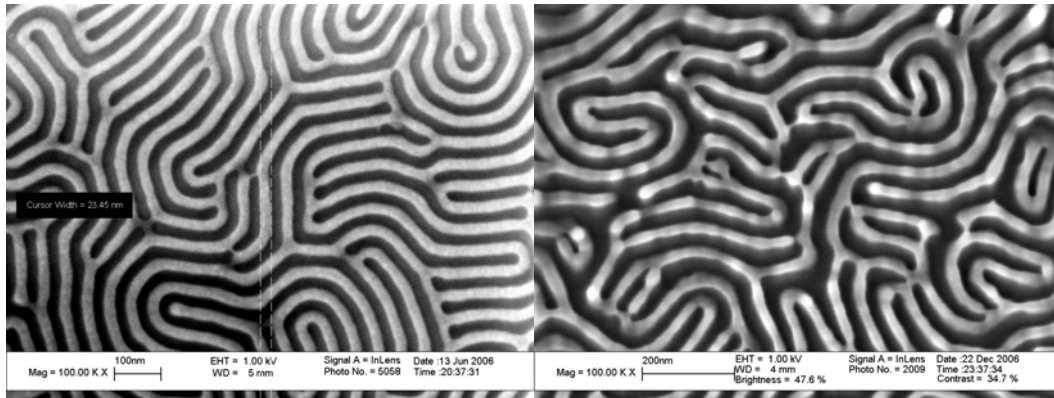


Fig 1: Top-view SEM image comparison of dry (left) and wet (right) process of template forming process. O<sub>2</sub> plasma etching gives better quality template than UV exposure plus acetic acid.

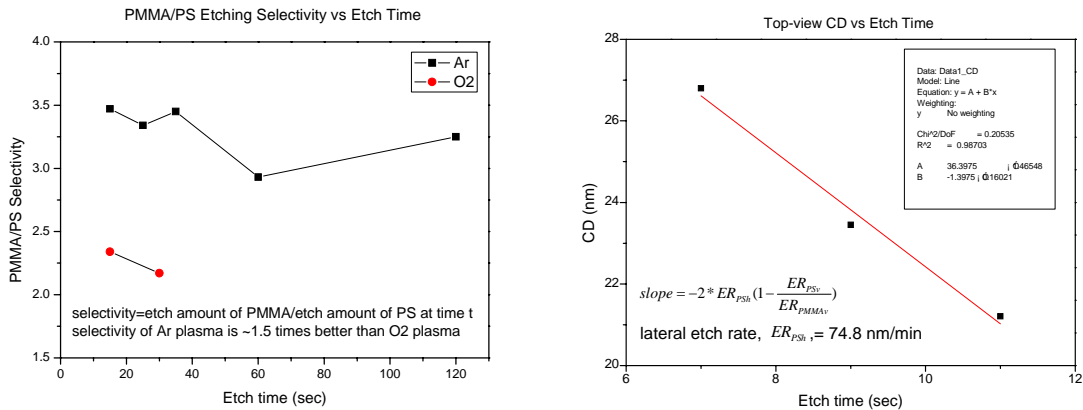


Fig 2: PMMA/PS etching selectivity (left) and lateral etch rate calculation (right). Ar has better selectivity on blanket test wafer but this advantage did not appear on patterned samples. Lateral etch rate was calculated from the slope of CD-vs-etch-time plot once the blanket etch rate was known.

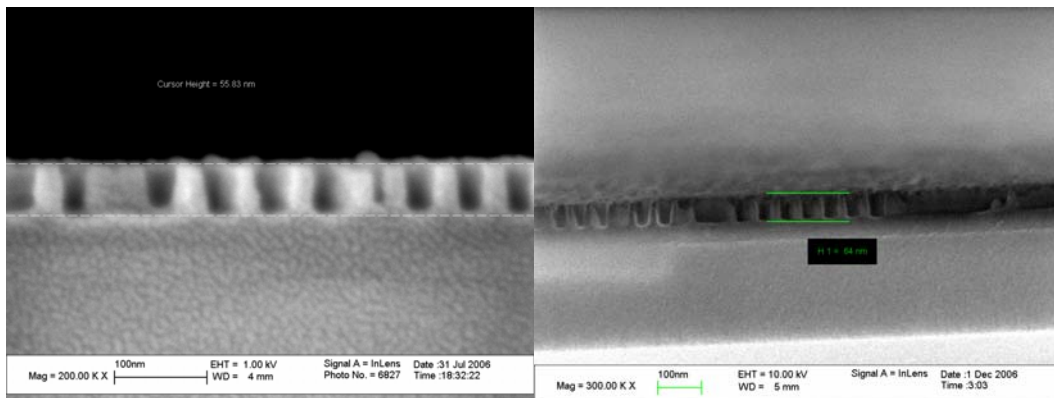


Fig 3: Using template produced by O<sub>2</sub> plasma, a vertical and smooth trench can be obtained on both silicon (left) and poly-silicon (right) films.

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