Evolution of Line Edge and Line Width Roughness in a Frequency Doubling Directed Self Assembly Process

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Self assembly of diblock copolymers on pre-patterned surfaces can produce numerous technologically interesting nanostructures, including sub-50 nm pitch line-space arrays that may ultimately find use in semiconductor lithography. Many challenges must be addressed for a patterning method to be considered viable for large-scale adoption. Here, we focus on patterning fidelity and variability as manifested by line edge and line width roughness (LER and LWR, respectively) in a frequency doubling self assembly process directed by a chemically pre-patterned surface. We report that, as currently implemented, the DSA process is capable of producing 40 nm pitch patterns with sub-2 nm 3σ LWR, but that current experimental implementations introduce extrinsic imperfections that prevent an experimental measurement of the intrinsic LER and LWR capabilities of DSA. We will also discuss alternate experimental methods for reducing extrinsic contributions to LER and LWR.

We describe the evolution of LER and LWR for multiple steps in the directed self assembly (DSA) process (fig. 1.) Chemical pre-patterns at 80 nm pitch are produced using EUV lithography. A poly(styrene-block-methyl methacrylate) (PS-b-PMMA) diblock copolymer is coated and annealed on the pre-pattern to produce a frequency-doubled 40 nm pitch line-space array. Following PMMA removal, the PS features are transferred into a silicon substrate using an anisotropic plasma etch.

EUV-patterned PMMA used to generate the chemical pre-pattern shows LER/LWR 2.5/3.8 nm (3σ) (fig 2.) The PMMA pattern displays unusual power spectral density characteristics due to extrinsic process imperfections including substrate imperfections and imperfections in the 5 nm thick cross-linked poly(styrene) layer used to direct block copolymer assembly.

Following coating, annealing and development of the frequency-doubled PS array, LER matches the LER of EUV-patterned PMMA near 2.5 nm 3σ. In contrast, LWR is reduced to 1.8-2 nm 3σ. These values reflect two phenomena: 1) uniform line widths are produced in the DSA process, but 2) the resulting lines meander about their mean positions. The extrinsic process imperfections introduced during EUV patterning contribute to line meander in frequency-doubled PS features, and are manifested as domains of correlated multi-line meanders (fig 3.)

Anisotropic etch transfer to a silicon substrate largely maintains the roughness seen in developed PS. Preliminary process optimization attempts suggest approaches for further improving LER and LWR following etch.

In sum, we observe that frequency doubling DSA shows very promising LWR. At the same time, LER and line meander are sensitive to imperfections of the lithographic pre-pattern. Process implementations that reduce these extrinsic imperfections can be expected to yield improved overall DSA process performance.

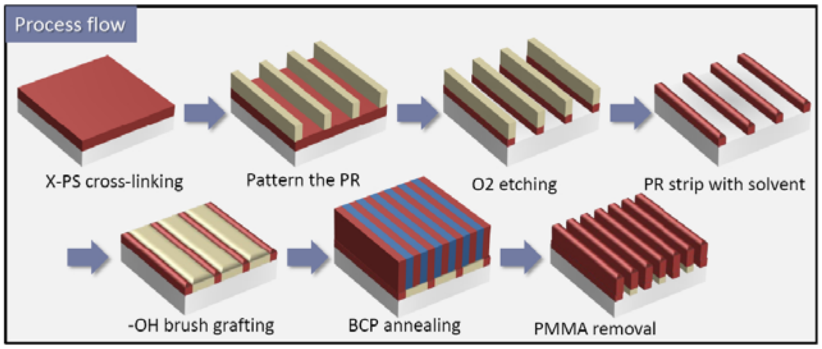

Fig. 1. Schematic of the frequency doubling self assembly process used in this study. (Liu. C. *et al.*, manuscript in review.)

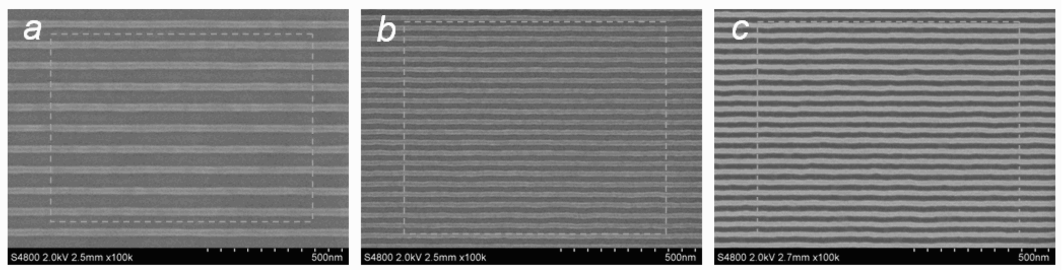

Fig. 2. SEM micrographs of a) PMMA pre-pattern; b) frequency doubled PS pattern following DSA and development; and c) post-etch pattern transfer into silicon.

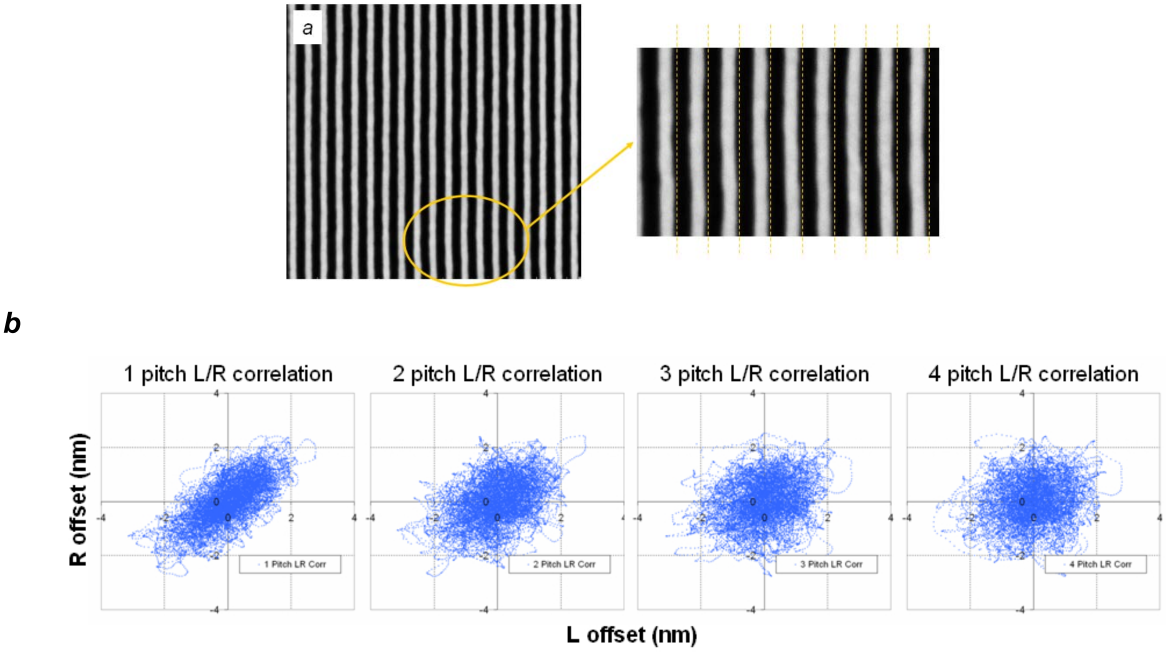

Fig. 3. a) Representative domain of correlated multi-line meanders introduced by extrinsic imperfections; b) multi-pitch edge correlations for PS lines.