Cross-sectional Characterization of Transferred DSA Holes using Focus Ion Beam

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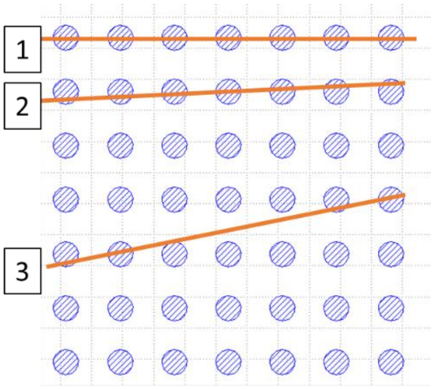
Block copolymer (BCP) directed self-assembly (DSA) is a next-generation lithography technique used for high-resolution patterning. The features produced by the self-assembled polymers are challenging to cross-section due to their small size (holes with CD = 20 nm). Without careful planning, it is easy to mill cross-section after cross-section in the focused ion beam (FIB) and not find any features. Here, we describe our strategy for inspecting the cross-section of features transferred from the BCP into an underlying hard material (e.g. SiO_2, Si). This approach allowed us to reliably capture the salient features of the DSA pattern transfer with minimal hassle. Note that BCP film itself cannot be directly cross-sectioned at room temperature in the FIB. The polymer cannot withstand ion milling unless the cryo system is used to freeze it.



At the guiding well layout stage, it is already important to consider how cross-sections will interact with the layout. To facilitate easy cross-sectioning, we use large, dense, gridded arrays of guiding wells. The figure to the left shows a small portion of the guiding well layout that we designed. On the figure, lines are drawn to represent different potential cross-sections, i.e. where the final cut will intersect with the guiding wells. Ideally, we would like to view the guiding wells in cross-section at many distinct points. For instance, Line 1 is not angled and thus intersects with the same point of each guiding well. By angling the cut, as shown in Line 2, we can intersect the guiding wells at many different points, which increases the likelihood the cross-section with find one of the hole-shrink patterns. Ideally, we would also like to avoid taking multiple cross-sections just to find the transferred DSA features. While Line 2 can slice the guiding wells at many distinct locations, it may not intersect any features at all if it lands just above or just below a row of guiding wells. For this reason, the steeper angle of Line 3 can be advantageous: no matter where the line lands, it will always intersect with something. To both obtain the fine slices of Line 2 and eliminate the need for multiple cross-section attempts, a large array should be used so that even at small angles, the cross-section can pass through more than one row of guiding wells. We were able to achieve this in 13.5 × 13.5 µm arrays of 80-nm guiding wells spaced a pitch of 174 nm in both the x- and y-directions.

Recommended FIB cross-section procedure with time estimates:

1. Rotate the guiding well layout to angle the cross-section as described above
2. Using the 1.4 nA electron beam, deposit 1 µm of Pt to protect the area to be cross-sectioned (~4 min for a 1.5 × 13 µm area)
3. Find eucentric height and tilt the sample to 52°
4. Using an ion-beam current of ~150 pA, perform a regular cross-section to a depth of 1.5 µm (~2 min for a 1.5 × 13 µm area)
5. Using an ion-beam current of ~40 pA, perform a cleaning cross-section to a depth of 1.5 µm (~1 min for a 200 nm × 13 µm area)
6. Using an ion-beam current of ~20 pA, perform a second cleaning cross-section to a depth of 1.5 µm (~4 min for a 200 nm × 13 µm area)
7. Image the cross-section in immersion mode with the electron beam at 5 kV and 25 pA