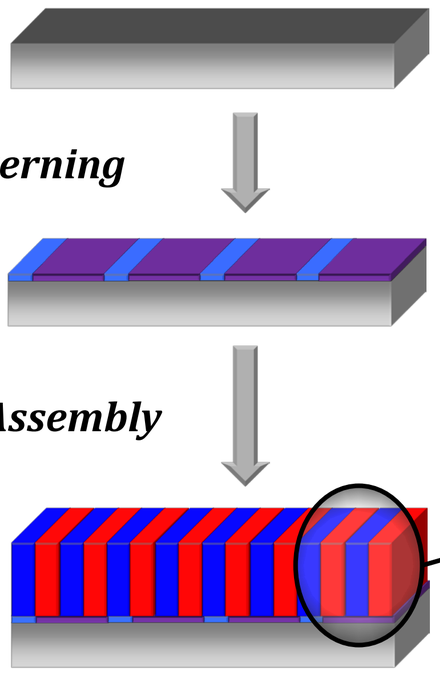
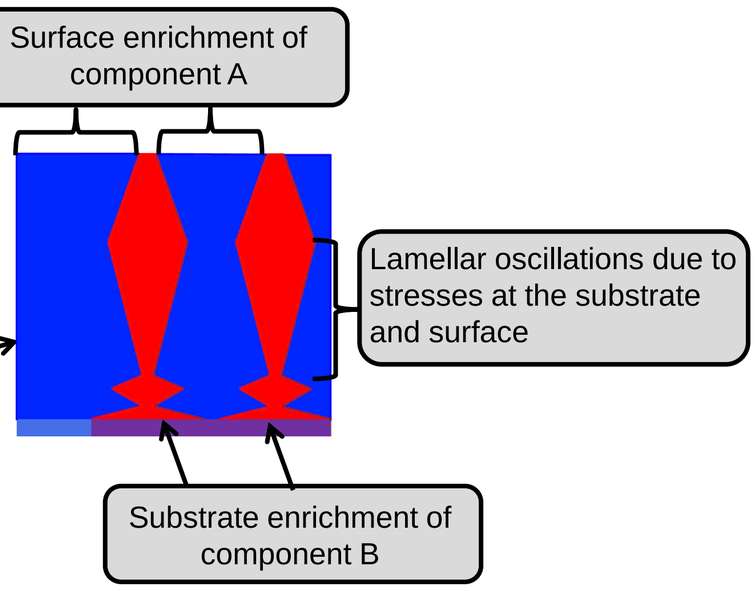
Soft X-Ray CD-SAXS for Directed Self Assembly Block Copolymers

Daniel Sunday, Wen-li Wu and R. Joseph Kline

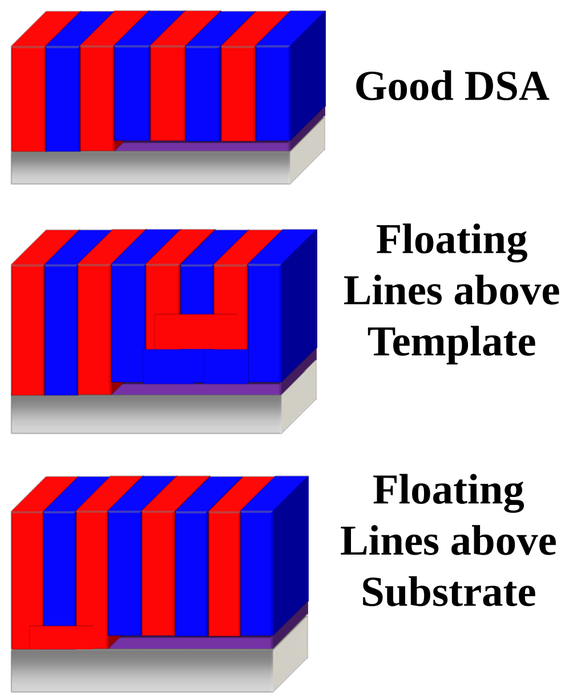
Directed Self Assembly of Block Copolymers



Stresses on the DSA BCP can lead to the formation of complex buried features that may adversely affect the etch process!



Surface Morphology may not reflect internal morphology

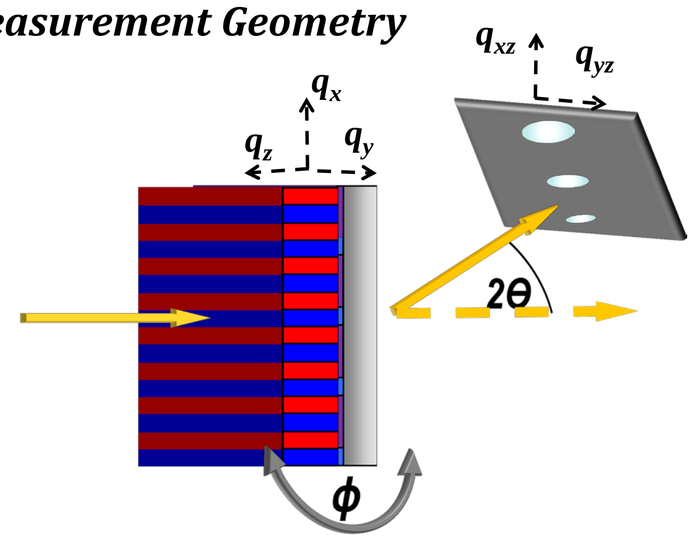


- Potential solution for sub 10 nm patterning
- Template pitch can be amplified 4x
- Current metrologies focus on registration with template and surface structure

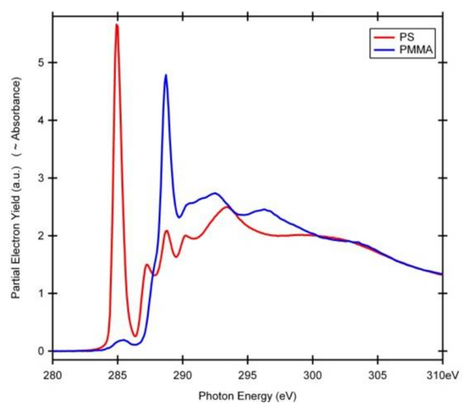
Need to develop a metrology capable of evaluating the internal 3D structure of DSA BCP's!!

Critical Dimension Small Angle X-ray Scattering

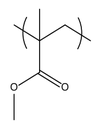
Measurement Geometry



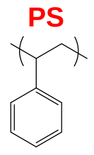
Enhanced Contrast via Soft X-rays



PMMA



PS

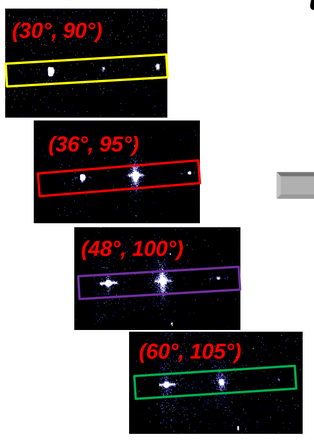


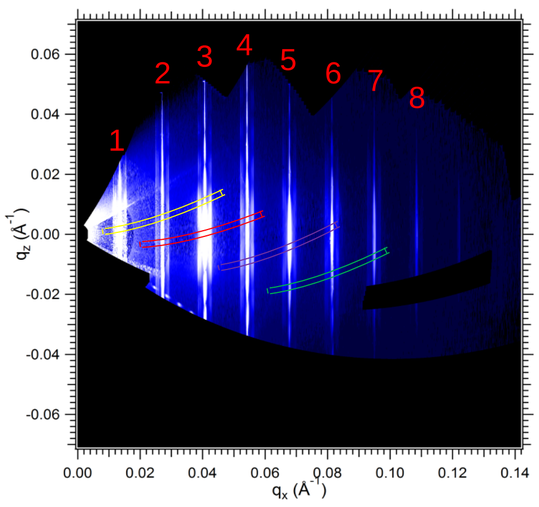
Contrast is enhanced by using energies near the absorption edge (~285 eV for Carbon)

Exact location of Carbon absorption edge shifts as a function of component composition (π vs σ bonds). Scattering contrast becomes bond specific.

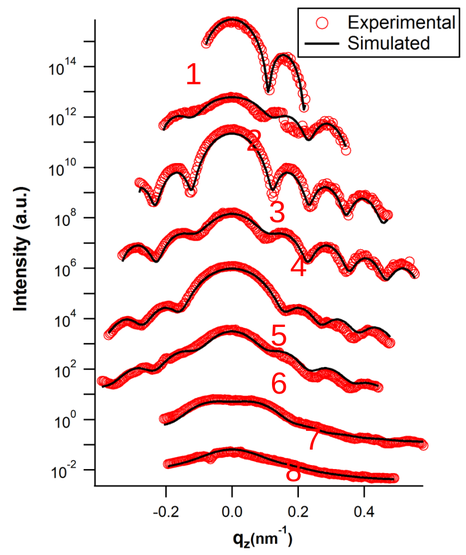
(2θ, ϕ)

400+ images converted to $I(q_x,q_z)$





Vertical (q_z) cuts taken around each peak



Inverse Fitting Approach

$I(q_{xz},q_{yz})$ ->$I(q_x,q_z)$

$$q_z = q_{xz} * \cos\left(\varphi - \frac{2\theta}{2}\right)$$

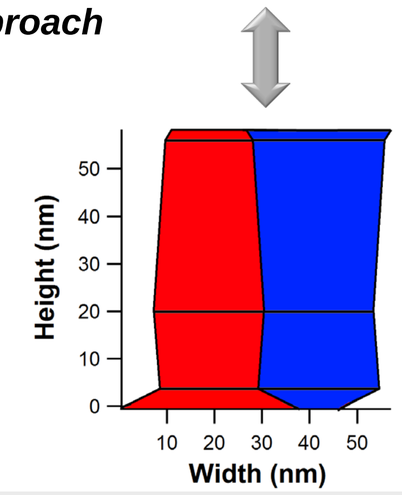
$$q_x = q_{xz} * \sin\left(\varphi - \frac{2\theta}{2}\right)$$

The BCP lamella shape is approximated by a stack of trapezoids. The simulated intensity is compared to experimental intensity and the structure is iterated until a satisfactory χ2 is achieved.

$$I_o(\boldsymbol{q}) = \int_A \int \rho(\boldsymbol{r}) * S(\boldsymbol{r}) e^{-i\mathbf{qr}} d\boldsymbol{r}$$

$$I(\boldsymbol{q}) = I_o(\boldsymbol{q}) \times e^{-\boldsymbol{q}^2 DW^2}$$

DW = Debye Waller Factor, accounts for interfacial roughness



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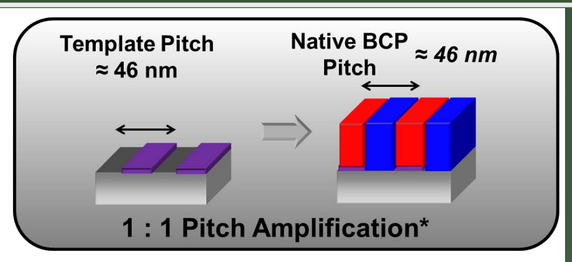
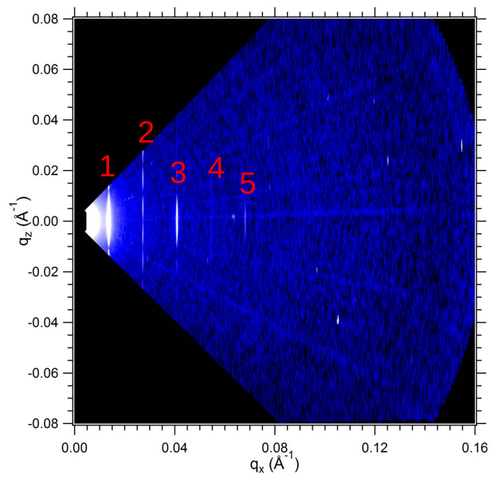
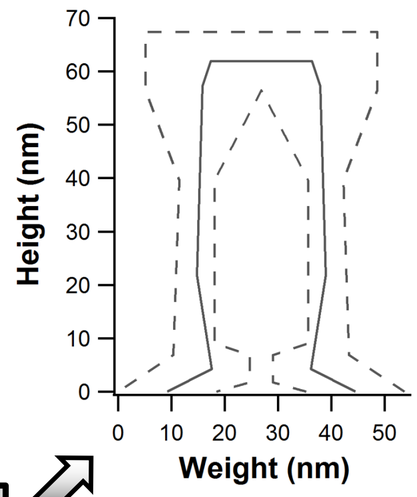


Hard vs Soft X-rays

(1:1 Template : BCP Pitch)

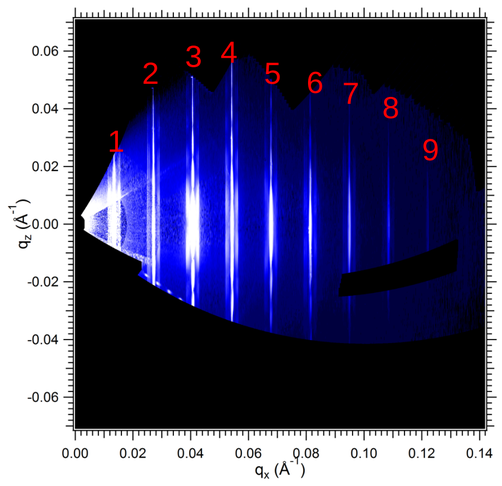
Hard X-rays (17 KeV)

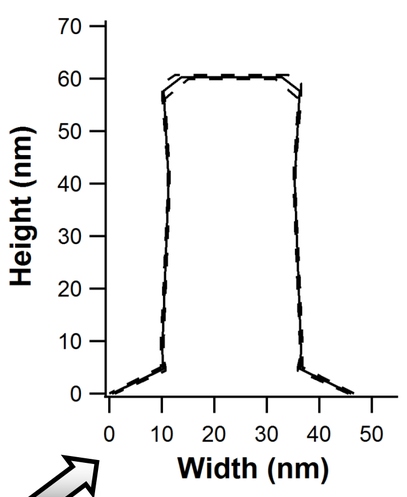




Small number of peaks and poor differentiation from background results in a poorly defined fit, large uncertainty

Soft X-rays (282 eV)



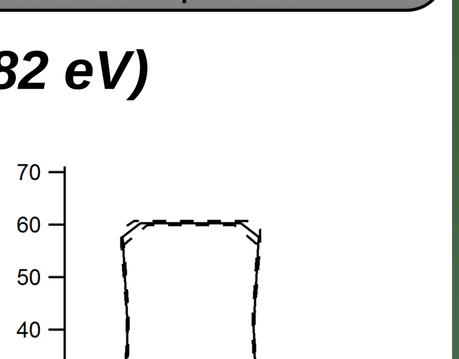


Additional peaks and improved peak definition in soft x-ray measurements result in dramatic decrease in fit uncertainty

** Sampled Prepared by Gila Stein (University of Houston)*

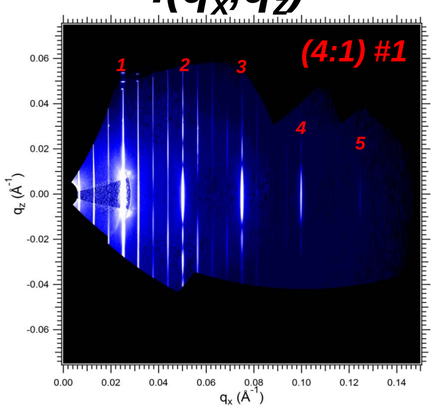
Complex Chemical and Topographical Template

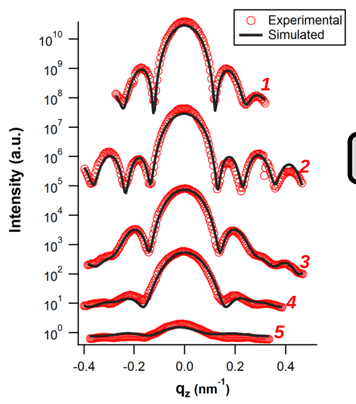
(4:1 Template : BCP Pitch)

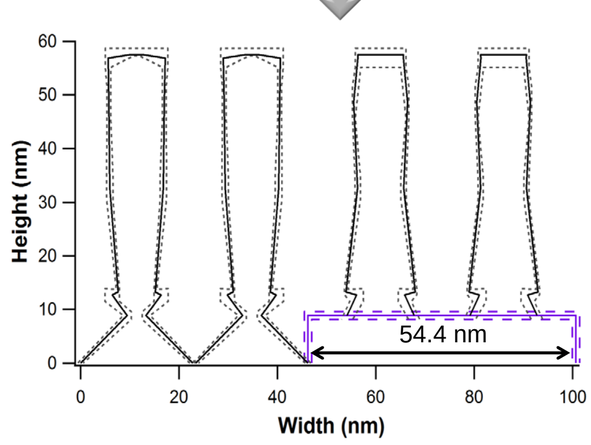


5 Primary peaks @ ~25 nm pitch
Satellites @ ~100 nm superlattice pitch

$I(q_x,q_z)$





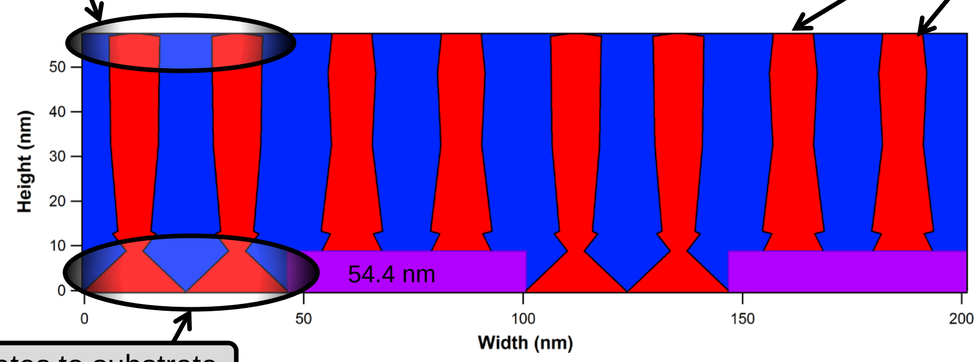


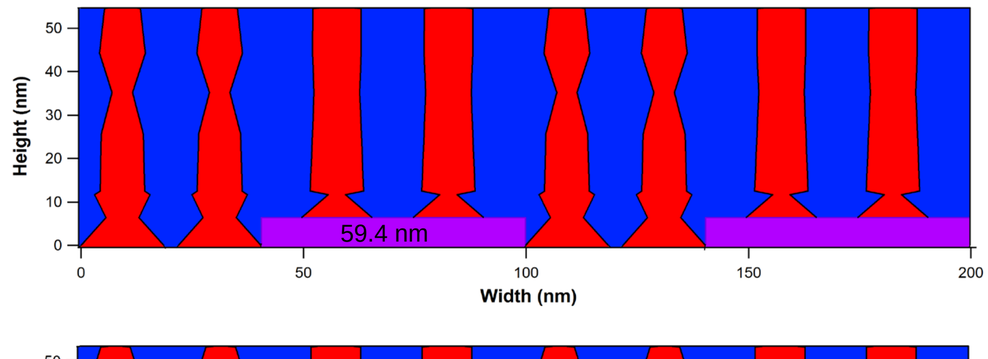
Model fit included separate lamella shapes on the substrate vs on the template

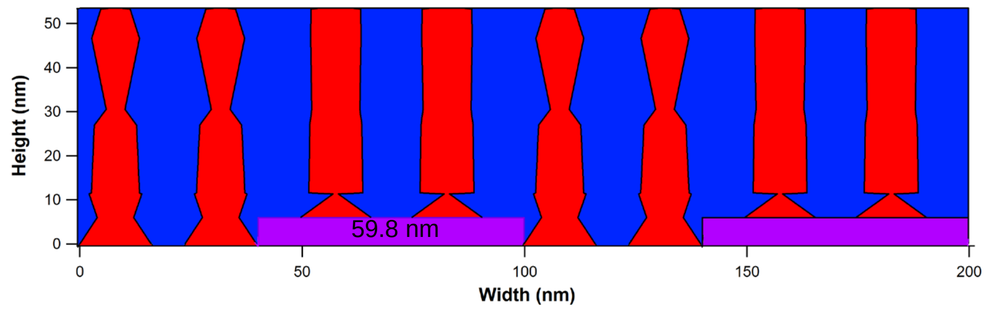
PS enriched at surface
70% PS at surface confirmed via NEXAFS

On-Template lamellar shapes remain consistent

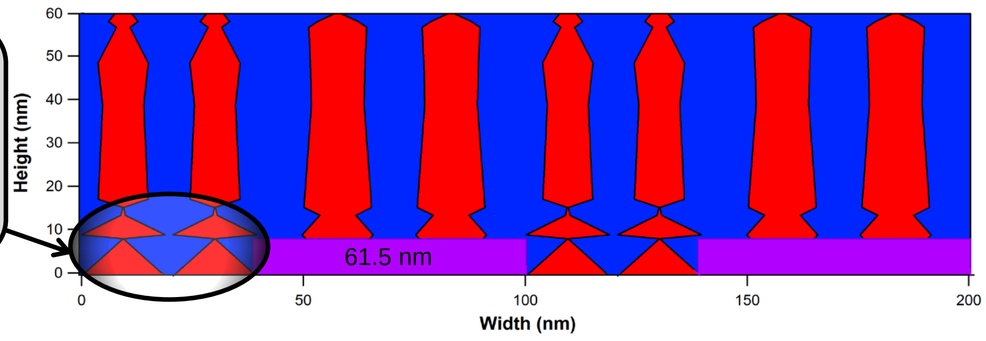
PMMA segregates to substrate







Increasing template width results in the disruption of the lamellar structure and the formation of undesirable features



Increasing Template Width

*** Sampled Prepared by Joy Cheng(IBM)*

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