

Mapping Resist Flow into Nanoscale Channels during Nanoimprint Lithography

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Nanoimprint lithography (NIL) processes impart large deformation fields into a material as it is squeezed into the nanoscale cavities of the NIL mold. The large strain fields in the small gaps of the mold can lead to significant shear stresses on the material as it fills the mold. This is especially true in thermal NIL where highly viscous polymer melts are often encountered. Previously we have shown that these shear fields can impart residual stresses to the nanoscale patterns and discussed methods by which one can reduce the severity of these stresses.¹ Here we provide an experimental technique to help visualize the flow fields that the material experiences during the imprint process. This approach can be used to help validate finite element models of the flow processes in NIL, understand stress distributions within the imprinted pattern, and examine the effects of imprint –induced flow fields on the phase behavior of multi-component resists.

Recently we have shown that x-ray reflectivity (XR) can be used to characterize the physical shape of patterns created by NIL.² When the length scale of the patterns is smaller than the coherence length of the x-rays, the effective medium approximation holds and scattering length density of the lines and spaces in the patterned region are averaged together. In this limit the depth profile of the scattering length density (SLD) can be used to extract the pattern profile. Here we extend this approach by applying both neutron reflectivity (NR) and XR on the same patterns. The advantage here is that an isotopically substituted version of the polymer can be used where the hydrogen (H) are replaced with deuterium (D). This results in a large difference in the neutron SLD of the H and D versions of the polymer with negligible difference in the x-ray SLD. Here we imprint both bilayer and uniform blend films of the H and D polymers. The XR measurements are used to determine the shape of the pattern while NR measurements are used to quantify the H and D ratios of the material in the pattern, and thus the composition, as a function height through the pattern. We demonstrate this concept using different molecular masses of the H and D polymers that have intrinsically different viscosities and utilize this approach to track where the different components go as shown in Fig 1.

¹ Y. Ding, H. W. Ro, K. J. Alvine, B. C. Okerberg, J. Zhou, J. F. Douglas, A. Karim, C. L. Soles, *Adv. Funct. Mater.* **18**, 1854 (2008)

² H. J. Lee, C. L. Soles, H. W. Ro, R. L. Jones, E. K. Lin, W.-I. Wu, D. R. Hines, *Appl. Phys. Lett.* **87**, 263111 (2005)

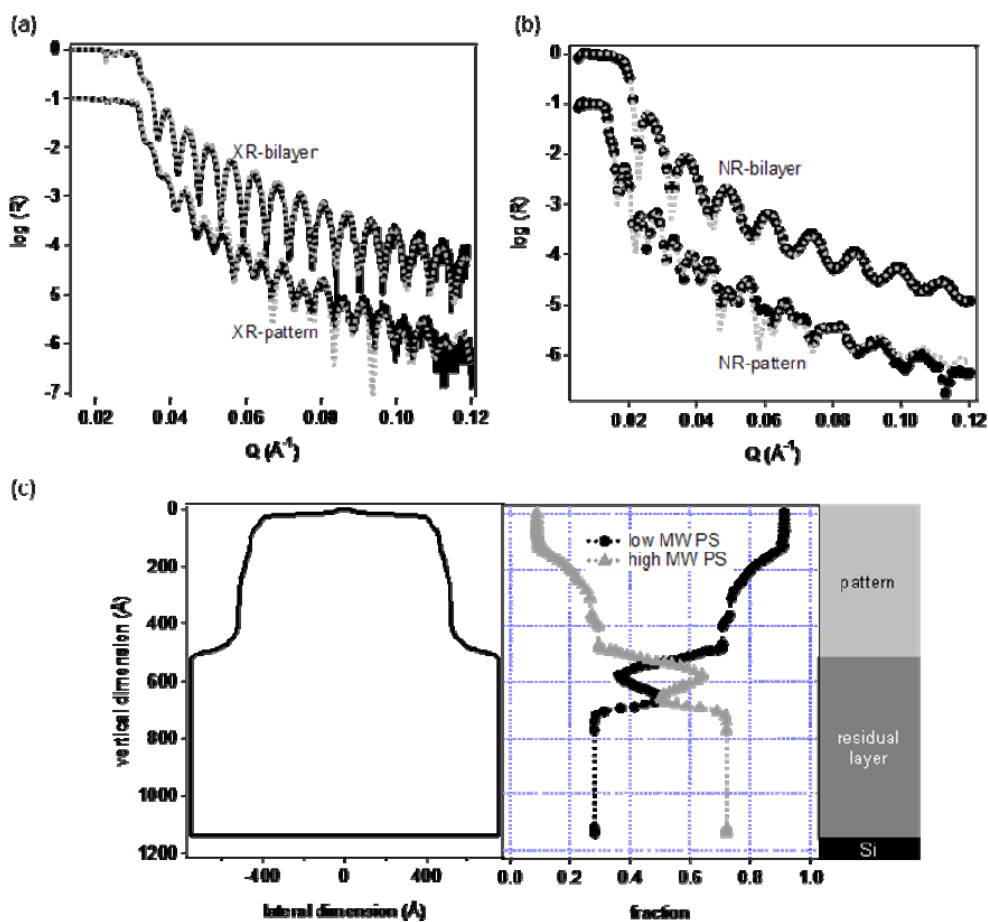


Figure 1. Parts (a) and (b) show the XR and NR data, respectively, for both the initial bilayer film before imprinting (upper curve in each panel) and the imprinted pattern (lower curve in each panel). In each curve, the fits to the reflectivity data are given by the dotted lines. The initial polystyrene (PS) bilayer film consists of a low molecular mass (30 kg/mol) d-PS layer on top of a high molecular mass (1571 kg/mol) h-PS underlayer. From the fits of the XR data one can obtain the pattern cross-section of one of the periodic line space patterns as show in the left hand panel of part (c). The right hand panel of part (c) shows the composition profile in the imprint of the low molecular mass (MW) d-PS and the high MW h-PS as a function of height through the patterned region (at each height the fractions of the d-PS and h-PS add to unity). These results demonstrate that low molecular mass d-PS primarily resides at the top of the pattern while the high molecular mass h-PS is found mostly in the residual layer.