Nondestructive, Quantitative Synchrotron Grazing Incidence X-ray Scattering Analysis of Cylindrical Nanostructure in Supported Thin Films

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Block copolymer thin films with well defined nanostructures have recently received considerable attention for their potential nano-fabrication applications [1,2]. In these applications, controlling the morphology of the block copolymer thin film, particularly the orientation and ordering of the phase-separated microdomain, is essential. For characterizing the structures and orientation, microscopy tools such as transmission electron microscopy, scanning electron microscopy and atomic force microscopy are commonly used [3]. With these tools, images such as those that show local structures near the surface have been obtained, thus enabling discussion of the underlying physics. From the viewpoint of fabrication, this approach is often sufficient, but from the scientific point of view, X-ray scattering measurements are required because only they provide information on a larger scale at high resolution. In particular, grazing incidence X-ray scattering (GIXS) has emerged as a powerful technique for characterizing internal structure of thin film [4]. The X-ray beam impinges at a grazing angle onto the sample slightly above the critical angle, so that the film is still fully penetrated by X-ray. Analytical solutions of GIXS patterns based on the distorted wave Born approximation have been developed to describe the complicated reflection and refraction effects [4], which are not found in conventional transmission X-ray scattering.

Recently we derived a GIXS formula under the DWBA for analysis of the structures in thin films deposited on substrates [4,5]. Using the derived GIXS formula, the GIXS patterns obtained for polystyrene-*b*-polyisoprene diblock copolymer thin films with various morphologies (hexagonal, hexagonal perforated layer, and gyroid structure) deposited on silicon substrate were characterized quantitatively [5]. A representative GIXS pattern and its analyzed one are shown in Figure 1.

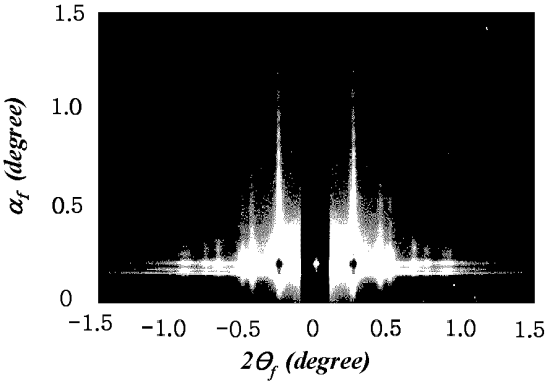

Figure 1. 2D GIXS patterns measured for a UV-etched film of PS-b-PMMA block copolymer.

Here, we attempted the quantitative analysis of the two-dimensional (2D) GIXS patterns of polystyrene-*b*-polymethylmethacrylate (PS-*b*-PMMA) diblock copolymer films deposited on silicon substrates. The analysis of the GIXS patterns with using the GIXS theory was successfully carried out, and found that PS-*b*-PMMA thin films deposited on silicon substrates reveal cylinder microdomains perfectly oriented normal to the substrate surface.

This study was supported by the Korea Science & Engineering Foundation (National Research Lab Program and National Creative Research Initiative Program) and by the Ministry of Education (BK21 Program). Synchrotron GIXS measurements were supported by the Ministry of Science and Technology and POSCO.

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