Morphological Changes During Tensile Deformation of Polyethylene Detected by Small-Angle Neutron Scattering Measurement

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Molecular weight distribution (MWD) significantly influences the mechanical properties of polymeric materials. It has been pointed out that the excellent drawability and toughness exhibited by polymeric materials are closely related to the shape of MWD. In particular, for semi-crystalline polymers such as polyethylene (PE), the relationship between MWD and mechanical properties is confused because of the complicated morphology composed of lamellar crystalline structure. The direct observation of the structure and mechanical response of each molecular weight component during deformation is quite important to understand the relationship between MWD and mechanical properties. The deuterium isotope method using small-angle neutron scattering (SANS) has been used as a technique to extract the structural state of deuterated or hydrogenated molecular chains. Recently, C. Lopez-Barron et al. performed SANS results during uniaxial stretching of PE in which only high or low molecular weight components were deuterated.[1] It was found that the high-molecular-weight component showed a higher orientation degree than the low-molecular-weight component. However, in most previous studies, samples with a very broad MWD ($M_w/M_n > 2$) were used, making it difficult to evaluate specific molecular weight component.

In this study, deuterated PEs (DPEs) with narrow MWD ($M_w/M_n < 1.3$) and different molecular weights were synthesized using a phenoxy-imine catalyst, and partially deuterated PE in which only specific molecular-weight component is deuterated was prepared by blending dPE and hydrogenated PE (HPE) with broad MWD. The blend samples were melt pressed at 210 ºC and 20 MPa followed by quenching in iced water to prepare sample sheets with 200 μm thickness. Two-dimensional SANS pattern was obtained with a wavelength of 7 Å, camera lengths of 1 m and 8 m, and an exposure time of 2 h.

Figure 1 shows the one-dimensional SANS profiles of blends of HPE and DPE with different molecular weights. Here, the number attached in the sample code represents the weight-average molecular weight of 10,000 units. The intensity of scattering in the low-angle region increased with increasing molecular weight. The radius of gyration (R_g) of HPE calculated from the Guinier plot was approximately 16 nm, which was almost the same as R_g estimated from the weight-average molecular weight. Moreover, R_g values of DPE molecular chains were close to R_g estimated from their weight-average molecular weight. These results suggest that R_g of each molecular chain was determined by the molecular weight, and not affected by blending with other molecular chains. Unfortunately, the SANS measurements under tensile test cannot be performed due to machine trouble. Therefore, we plan to perform SANS measurements under tensile deformation in the next machine time.

[1] C. R. Lopez-Barron *et al.*, Macromolecules. **50**, 3627 (2018).

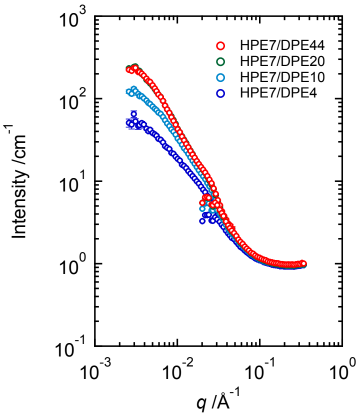

Fig. 1. One-dimensional small-angle neutron scattering profile all blend samples.