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Division of Multidisciplinary Chemistry – Polymer Materials Science –

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Scope of Research

The structure and molecular motion of polymer substances are studied, mainly using scattering methods such as X-ray, neutron, and light with intent to solve fundamentally important problems in polymer science. The main projects are studied on 1) the morphologies and the dynamics of self-assembling processes in block copolymers, 2) the hierarchical structures in crystalline polymer and rubber-filler systems, 3) the viscoelastic effects in glassy materials, 4) formation processes and ordering structures in polymer thin films.

KEYWORDS

Polymer Physics

Self Assembly

Hierarchical Structure

Polymer Properties

Softmatter



Recent Selected Publications

Jeon, J.; Doi, K.; Kim, H. D.; Ogawa, H.; Takenaka, M.; Ohkita, H., Correlating the Structures and Photovoltaic Properties in Phase-Separated Blends of Conjugated Donor Polymers and Acceptors, *Polym. J.*, doi: 10.1038/s41428-022-00718-9 (2022).

Ogawa, H.; Aoki, M.; Ono, S.; Watanabe, Y.; Yamamoto, S.; Tanaka, K.; Takenaka, M., Spatial Distribution of the Network Structures in Epoxy Resin via the MAXS-CT Method, *Langmuir*, **38**, 11432-11439 (2022).

Arakawa, M.; Kishimoto, M.; Nakanishi, Y.; Mita, K.; Takenaka, M., Spatial Inhomogeneity of Chain Orientation Associated with Strain-Induced Density Fluctuations in Polyethylene, *Polym. J.*, **54**, 243-248 (2022).

Nakanishi, Y.; Uchida, K.; Mita, K.; Kamitani, K.; Kojio, K.; Takahara, A., Morphological Study of Isotactic Polypropylene Thin Films on Different Substrates Using Grazing Incidence Wide-Angle X-Ray Diffraction, *Polymer*, **245**, 124665-1-124665-9 (2022).

Spatial Inhomogeneity of Chain Orientation Associated with Strain-Induced Density Fluctuations in Polyethylene

We found the spatial inhomogeneity of chain orientation on the submicron scale in polyethylene (PE) under strain by scanning transmission X-ray microscopy (STXM). Strain is expected to induce the spatial inhomogeneity of chain orientation as well as density fluctuations, and the spatial inhomogeneity might also affect the mechanical behavior. However, wide-angle X-ray scattering can be used to explore the spatially averaged local structure, and the spatial inhomogeneity of chain orientation on the submicron scale has not yet been investigated. To clarify the spatial inhomogeneity of chain orientation, we observed near-edge X-ray absorption fine structure (NEXAFS) spectra at the carbon K-edge of stretched PE, with a resolution on the order of 10 nm, by STXM and investigated the spatial inhomogeneity of chain orientation as well as density fluctuations. The intensity of the NEXAFS spectra revealed that the chains were more oriented in the low-density region under stretching. The orientation was induced by the stretching of the polymer chains mechanically melted.

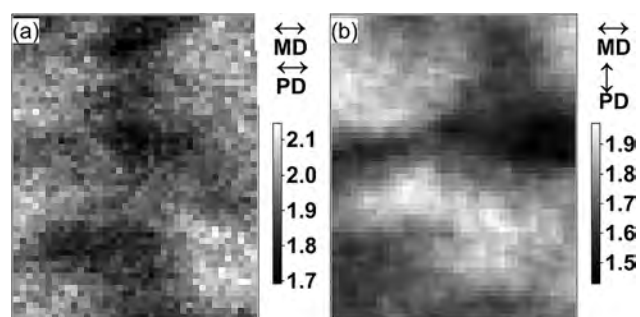


Figure 1. Optical density images of HDPE at 287.5 ± 0.2 eV corresponding to the peak of the C–H bond. The polarization direction (PD) of the incident X-rays was set to be (a) parallel and (b) perpendicular to the stretching direction (MD).

Spatial Distribution of the Network Structures in Epoxy Resin via the MAXS-CT Method

We have succeeded in visualizing the spatial heterogeneity of the reaction ratio in epoxy resins by combining medium-angle X-ray scattering (MAXS) and computed tomography (CT). The reaction ratio is proportional to the degree of cross-linking between epoxy and amine in epoxy resins. The reaction ratio and its spatial inhomogeneity affects the toughness of epoxy resins. However, there has been no non-destructive method to measure the spatial inhomogeneity of the reaction ratio although we can measure only the spatially averaged reaction ratio by FT-IR. We found that the scattering peak reflected the cross-linking structures in the q region of MAXS and that the peak intensity is proportional to the reaction ratio. By reconstructing CT images from this peak intensity, we visualized the spatial heterogeneity of the reaction ratio. The application of this method may not be limited to epoxy resins but may extend to studying the heterogeneity of cross-linked structures in other materials.

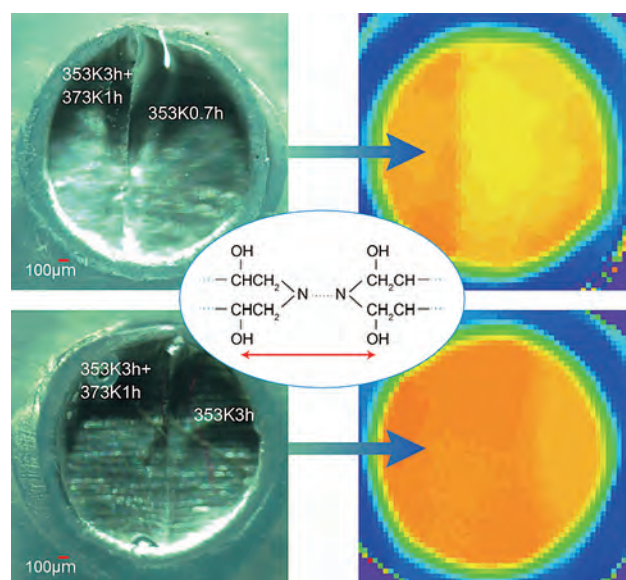


Figure 2. Optical microscopy and MAXS-CT images of samples with different cross-linking reaction ratios in epoxy resin.