Visualization of polyolefin interface in the molten state for recycling

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As the importance of carbon neutrality grows, several initiatives in polymer materials are being pursued, including using biomass as a raw material, chemical recycling to convert used materials back into monomers or decomposed products, and material recycling that preserves the polymer's molecular structure (Figure 1). Among polymers, polyolefins (PO) are especially significant due to their large production volume. Polyethylene (PE) and polypropylene (PP), both key POs, make up about 47% of domestic plastic production (Source: The Japan Plastics Industry Federation 2023 Statistics).

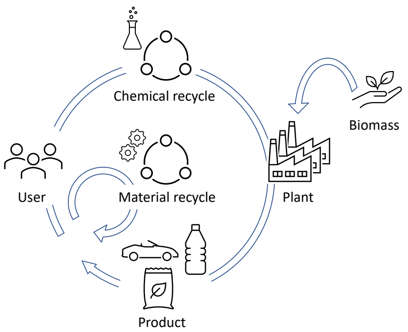

Figure 1. Conceptual diagram of carbon neutrality in polymer materials such as material recycling.

For achieving carbon neutrality in POs, material recycling is crucial since it can be implemented using general-purpose facilities suited for mass production. In fact, material recycling has the greatest CO_2 reduction effect among all recycling methods (Source: Plastic Waste Management Institute 2023 Report). This involves collecting, grinding, and melt-kneading post-use plastics, but several technical issues remain. One major challenge is the difficulty in sorting different plastics, leading to the unavoidable coexistence of immiscible polymers, which significantly degrade the physical properties of recycled materials. This issue is compounded when inorganic substances such as glass and talc, or carbon fibers are present.

This study aims to visualize the PO/different material interface, which is critical for PO recycling. Modified PO, which stabilizes this interface, is important as a compatibilizer, but its structure at these interfaces is difficult to observe due to insufficient contrast. To address this, we used deuterated paraffinic mineral oil (d-MO), which our team successfully deuterated (Polymer Chemistry, 2020). Since it has been revealed that d-MO has the same solubility as PE, we can use it instead of PE to visualize the modified PO using contrast-variated small-angle neutron scattering (SANS). It is important to capture the interface structure formed in the molten state, especially in material recycling. Therefore, we installed high-temperature sample environment equipment as shown in Figure 2a. The scattering profiles in the molten state of modified PO were effectively obtained for each ratio of d-MO to normal mineral oil (h-MO) as shown in Figure 2b. These data show that this method can effectively evaluate interfacial structures in the molten state of modified PO. Future work will involve exploring the effects of

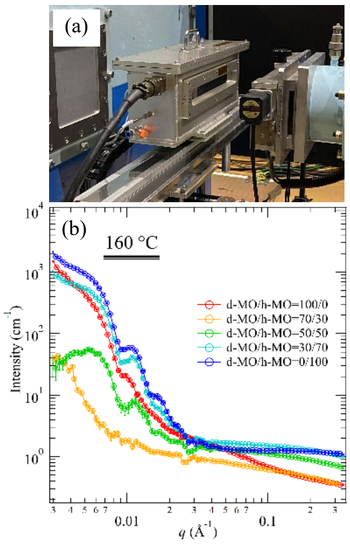

Figure 2. The high-temperature sample environment equipment (a) and SANS profiles obtained at 160 °C.

temperature and concentration and extending the method to systems where silica particles are coated with another polymer. These studies aim to clarify the structure of modified PO at various interfaces and provide guidelines for designing new compatibilizers.