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Control of optical properties for rubber-toughened polymer blends

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Transparent polymers have been widely used in various fields such as industrial, medical, and household applications. Because most decorating plastics in an automobile interior are painted, intense attention has been focused on the reduction of volatile organic compounds. In particular, the demand for paintless products is rapidly increasing these days to reduce the risk of our health and environmental problems. In the field of automobile parts, transparent glassy polymers are greatly investigated to be used instead of painted products, because they can provide good quality of colors by the addition of various pigments. One of the most famous candidates among transparent polymers is poly(methyl methacrylate) (PMMA) because of its remarkable optical properties and good weatherability. However, the improvement of mechanical toughness of PMMA is inevitable to widen the applications especially for automobiles.

After commercialization of high-impact polystyrene, the rubber-toughened technology was studied to improve the toughness of plastics. However, it is significantly difficult for rubber-toughened polymer blends to reduce light scattering owing to the refractive index difference between two phases. In general, both minimizing the refractive index difference and reducing the size of dispersed particles are required to provide transparency. Moreover, the transparency of a rubber-toughened polymer blend depends on the ambient temperature. This phenomenon is attributed to the difference in the temperature dependence of the refractive index, because the thermal expansion coefficient of a rubbery material is usually larger than that of a glassy polymer. In this study, a modification method of optical properties by adding a plasticizer to binary blends for PMMA and rubber is investigated.

In the case of immiscible binary polymer blends composed of PMMA and rubber, the transparency and its temperature dependence are found to be the most important factor. However, the transparency of the binary blend depends on the ambient temperature to a great extent. The addition of the plasticizer is found to enhance the transparency because it reduces the refractive index difference between PMMA and rubber phases. Moreover, uneven distribution of a plasticizer can be responsible for the excellent transparency. The plasticizer addition improves the transparency not only at room temperature but also in the wide temperature range, even though a simple binary blend of PMMA and rubber shows the strong temperature dependence of transparency owing to the difference in the temperature dependence of refractive index between both phases, which is greatly affected by the difference in the thermal expansion behavior. A plasticizer addition increases the linear expansion coefficient of PMMA, whereas it barely affects the thermal expansion of rubber. As a result, the difference in the refractive index between both phases becomes small, leading to weak temperature dependence of transparency.

In this thesis, a new material design of a transparent rubber-toughened polymer blend is demonstrated using PMMA and rubber. Although the thermal and mechanical properties such as heat deflection temperature, toughness, and yield stress should be checked in detail prior to application, this will be used for industrial applications, including automobile parts.

Keywords: ruber-toughened technology; transparency; plasticizer; refractive index; linear coefficient of thermal expansion