

# Plasticizing effect of a baroplastic copolymer on polystyrene

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## Introduction

The environmental pollution caused by the leakage of the End-of-Life plastics has been a serious concern. One of the main factors is the low recyclability of plastics. Thermoplastics, constituting an excess of 90 % of total production, are conventionally subjected to shaping processes utilizing melt-molding techniques. However, the thermal degradation of polymer chains during the melt-molding process hinders the recycling of plastics. One effective strategy being considered for addressing this issue is the substitution of conventional plastics with baroplastics. Baroplastics are polymeric materials developed by Mayes et al. at MIT, exhibiting pressure-responsive properties, and are nano-phase polymeric multiphase system that reversibly undergoes phase transitions between phase-separated and phase-miscible states in response to pressure variations<sup>(1,2)</sup>. For example, a block copolymer consisting of poly(*n*-butyl acrylate) ( $T_g$ : -50°C) and polystyrene ( $T_g$ : 100°C) (PBA-*b*-PS) forms a phase-separated solid state at ambient conditions. However, under a pressure of 5,000 psi (34.5 MPa), it undergoes a phase transition into a miscible state and exhibits formability at ambient temperature. The low-temperature formability of baroplastics not only reduces the required energy during processing but also allows for a reduction in CO<sub>2</sub> emissions and suppresses the thermal degradation of polymer chains.

To extend this concept to existing plastics, this presentation reports on the investigation of whether the addition of baroplastics to polystyrene, a commonly used plastics, can lower its flow temperature under pressure.

## Experimental, Results & Discussion

A baroplastic block copolymer PBA-*b*-PS (PS: 50 wt%,  $M_w$ : 23 kDa) was available through sequential polymerization of the corresponding monomers using atom transfer radical polymerization. The block copolymer obtained was dissolved in chloroform with PS ( $M_w$ : 64 kDa) at predetermined mixture ratios, and the mixtures was obtained by reprecipitating it in hexane. The low-temperature formability of the obtained polymeric mixture was investigated on a capillary rheometer (Shimadzu CFT-500EX) at a constant pressure with a heating rate of 2°C/min.

Fig. 1 shows typical results of the rheological properties of the PS/block copolymer mixture (60/40 by wt.) and the pristine PS. While the PS flowed under a pressure of 50 MPa at around 80°C, by the addition of the block copolymer, the flow temperature was reduced to 65°C. At ambient conditions, the hard segments of the block copolymer are miscible with the PS matrix, which PBA forms microdomains through phase separation. Under the influence of pressure, PS and PBA would become miscible, leading to enhanced flexibility of the polymer chains within the PS matrix (Fig. 2). The obtained results suggest that PBA-*b*-PS is acting as a pressure-responsive plasticizer, or a *baroplasticizer*.

While the results obtained are still in the early stages of research, the concept of low-temperature flow under pressure using the pressure-responsive polymeric materials, baroplastics, holds potential for extension to various common plastics. This suggests significant prospects for enhancing the recyclability of plastics.

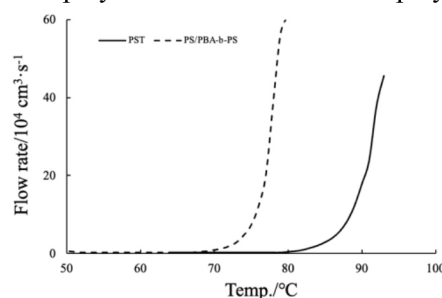


Fig. 1. Change in flow rate of PS and PS/PBA-*b*-PS mixture under 50 MPa as a function of temperature

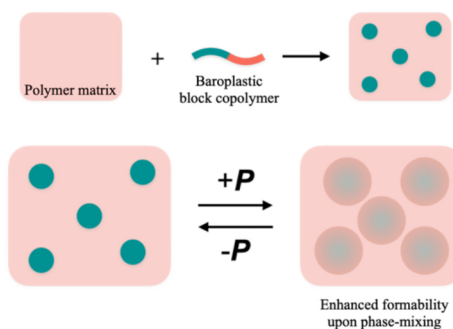


Fig. 2. Concept of enhanced formability of a polymer matrix under pressure by the addition of baroplastic block copolymers

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## References

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