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Mutual and Thermal Diffusivities in Polystyrene Melts with Dissolved Nitrogen by Dynamic Light Scattering (DLS)

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Thermoplastic foams are used in a broad variety of applications as they offer several advantages, such as comparatively low densities associated with a reduction in component weight. For technical applications, most foam parts are produced by injection molding or extrusion with physical or chemical blowing agents. In such processes, the resulting foam properties are governed by the nucleation and bubble growth behavior, which are both strongly influenced by the thermophysical properties of the blowing-agent-loaded polymer melt. Besides viscosity, solubility, and interfacial tension, especially knowledge on diffusion coefficients in corresponding mixtures is necessary for understanding and characterizing the bubble growth processes during foaming of thermoplastic polymers.

The present contribution demonstrates for the first time the applicability of dynamic light scattering (DLS) for the characterization of molecular mass and thermal transport in binary mixtures consisting of a macromolecular polymer and a dissolved gas by the determination of the mutual or Fick diffusion coefficient D_{11} and the thermal diffusivity a. In comparison to conventional techniques for the study of transport properties, the DLS method is applied in macroscopic thermodynamic equilibrium and does not need any calibration procedure. As model system, a mixture of technical-grade polystyrene and nitrogen was selected. It was evidenced that the obtained experimental signals are associated with hydrodynamic fluctuations. Their analysis allows the determination of a and D_{11} with typical expanded experimental uncertainties ($k = 2$) of (12 and 7)%, respectively. For temperatures T between (423 and 555) K and pressures p between (0.1 and 5.8) MPa, a slightly decreases with increasing p and T. The values for D_{11} tend to decrease as a function of p between about (1 and 5) MPa at given T, but are within combined uncertainties. In contrast, D_{11} shows a significant Arrhenius-like increase as a function of T between about (423 and 555) K. The behavior of D_{11} as a function of T and p is further discussed in connection with the viscosity η, where in this work always an inverse relationship is found. The present experimental data demonstrate that the DLS method allows the accurate determination of a and D_{11} in binary mixtures consisting of polymer melts and dissolved gases. Moreover, the data may further stimulate theoretical and experimental investigations aiming at the improvement of existing or establishing new bubble-growth models allowing an improved prediction of the resulting foam properties.

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