High-Pressure Torsional Braid Analysis for Rational Selection of Polymer Foaming Conditions with Physical Blowing Agents

Erdogan Kiran[1, S, C] and Dawn Dokyung Rhee[1]

[1]*Chemical Engineering, Virginia Tech, Blacksburg, VA, U.S.A.*
ekiran@vt.edu

Pressure-induced foaming of polymers with physical blowing agents such as carbon dioxide or nitrogen is a complex process. With sorption of these gases under pressure during saturation, and later with their desorption during depressurization, rheological and thermophysical properties such as the rigidity, glass transition or vitrification, and in case of semicrystalline polymers, the melting or crystallization temperatures are altered. These influence the foaming outcomes. Thus, assessment of changes in the rigidity, T_g, T_m, and T_c of polymers in the presence of physical foaming agents under pressure is of critical importance in developing successful strategies for foaming. High-pressure Torsional Braid Analysis (HP-TBA) is a relatively new unique technique that allows such assessments.

HP-TBA is a supported torsional pendulum technique in which a polymer impregnated multi-filament glass braid is suspended in a high-pressure chamber. The lower end of the braid is attached to an inertial mass (which incorporates an imbedded magnet) which is subjected to an oscillation with the aid of an external electromagnet. Two dedicated sensors positioned outside the high-pressure chamber follow the angular motions (oscillations) of the inertial mass.

The manner in which the oscillations are monitored is a function of pressure or temperature. The amplitude readings are fitted to a damped sine wave equation of the form $y = \exp(\alpha t)\sin(\omega t)$. The damping coefficient α, and the frequency of oscillations ω provide the needed information to assess the changes in rigidity and mechanical loss that accompany the onset and progress of the polymer chain motions that are associated with the thermal transitions. The technique allows the determination of the glass transition as well as the melting transition since the glass braid employed eliminates the need for the polymer to be self-supporting.

In this presentation we will describe this powerful technique with examples of glassy and semi-crystalline polymers documenting the changes in glass transition, melting and crystallization temperatures in compressed carbon dioxide and nitrogen.