Linking Thermophysical Properties to Foaming Outcomes for Rubbery Elastomers using High-Pressure Torsional Braid Analysis

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Understanding the mechanical and thermal properties of rubbery, semi-crystalline polymers exposed to compressed gases is of importance in polymer modifications such as foaming with carbon dioxide or nitrogen as physical blowing agents. In foaming, if the rigidity of the polymer + carbon dioxide solution is too high or the polymer has not traversed the melting transition, bubble nucleation and growth are limited, and likewise, if the rigidity of the solution is too low, the gas escapes the polymer during depressurization. The rational selection of the foaming conditions (temperature and pressure) of a polymer material therefore requires knowledge of the polymer + carbon dioxide system rigidity and the depression in the melting temperature as a function of carbon dioxide pressure at a given temperature.

High-Pressure Torsional Braid Analysis (HP-TBA) is a recently developed technique for the assessment of the thermal behavior and the changes in relative rigidity of polymer materials exposed to compressed or supercritical fluids. The HP-TBA is a torsional pendulum that consists of a polymer impregnated fiber glass braid housed inside a high-pressure vessel. The braid has a pendulum mass on the end that is externally rotated and the damped sinusoidal oscillations of the pendulum are recorded over time and can be fitted to the equation y= e^(-αt) sin(ωt). Measurements can be made with respect to temperature or pressure by holding one of the variables (P or T) constant. From the damped oscillations the damping coefficient (α), frequency (ω), and the period of the oscillations (2π/ω) can be determined; these parameters are linked to the storage modulus or relative rigidity, loss modulus, and mechanical damping. Carbon dioxide acts a diluent in most polymer materials – providing chain mobility and therefore lowering the observed thermal transition temperature (Tg or Tm). The modulus, or rigidity, of the polymer determines the nature of the damped oscillations, and as the polymer approaches Tg or Tm a sharp decrease in modulus can be observed in addition to a peak in the mechanical damping.

In this talk, the unique experimental system, and the recent results with rubbery polymers will be discussed highlighting the ability to select the foaming conditions based off of the knowledge of the depression in the melting transition temperature and the reduction in rigidity as a function of carbon dioxide pressure.