Fundamental mechanisms of cell nucleation in plastic foaming

Anson Wong1,2 and Chul B. Park2*

1: Dow Chemical Company, Midland, Michigan, USA
2: Microcellular Plastics Manufacturing Laboratory, Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Ontario, Canada M5S 3G8
*Corresponding author: park@mie.utoronto.ca

In plastic foaming processes, cell nucleation, growth, deterioration and stabilization phenomena determine the final foam morphology and consequently its application and performance. Therefore, understanding the basic principles in cell nucleation processes is imperative to the development of plastic foaming technology. In this context, this paper elucidates the fundamental mechanisms of cell nucleation in plastic foaming.

The Classical Nucleation Theory (CNT) predicts the kinetic instability limit for cell nucleation. The CNT describes boiling or cavitation phenomena in many single component systems accurately. However, in plastic foaming processes, it was observed that cell nucleation often takes place at supersaturation levels much lower than those determined with the CNT. This is because some of its underlining assumptions could fall apart in plastic foaming processes. For example, microvoids exist in polymer–gas solutions as free volumes between polymer chains or gas cavities on solid particles (e.g., nucleating agents, impurities) as a result of incomplete wetting between polymer and the solid particles, even under high temperature and pressure. These microvoids could serve as seeds for bubble nucleation. However, the CNT does not consider the existence of gas cavities. Also, via in situ observation of plastic foaming processes, it was observed previously that the expansion of nucleated cells triggered the formation of new cells around them despite the lower gas concentrations in these regions. This is caused by local tensile stresses that are induced around heterogeneities in the presence of growing cells around them. The stress-induced nucleation was further verified by in situ observation of foaming processes under controlled extensional or shear stresses, and it is an important consideration in industrial foaming processes (e.g., extrusion foaming, foam injection molding processes) due to their dynamic nature. However, this effect is not well-described in the CNT. In this context, this paper describes a modified CNT that considers the effects of stress variations and existence of microvoids. These modifications enable the CNT to accurately describe the cell nucleation behavior in plastic foaming processes.