





Article

Analysis of the Foaming Window for Thermoplastic Polyurethane with Different Hard Segment Contents

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Abstract: A series of thermoplastic polyurethanes (TPUs) with different amounts of hard segments (HS) (40, 50 and 60 wt.%) are synthesized by a pre-polymer method. These synthesized TPUs are characterized by Shore hardness, gel permeation chromatography (GPC), differential scanning calorimetry (DSC), wide angle X-ray diffraction (WAXD), dynamic mechanical thermal analysis (DMTA), and rheology. Then, these materials are foamed by a one-step gas dissolution foaming process and the processing window that allows producing homogeneous foams is analyzed. The effect of foaming temperature from 140 to 180 °C on the cellular structure and on density is evaluated, fixing a saturation pressure of 20 MPa and a saturation time of 1 h. Among the TPUs studied, only that with 50 wt.% HS allows obtaining a stable foam, whose better features are reached after foaming at 170 °C. Finally, the foaming of TPU with 50 wt.% HS is optimized by varying the saturation pressure from 10 to 25 MPa at 170 °C. The optimum saturation and foaming conditions are 25 MPa and 170 °C for 1 h, which gives foams with the lowest relative density of 0.74, the smallest average cell size of 4 µm, and the higher cell nucleation density of 8.0×10^9 nuclei/cm³. As a final conclusion of this investigation, the TPU with 50 wt.% HS is the only one that can be foamed under the saturation and foaming conditions used in this study. TPU foams containing 50 wt.% HS with a cell size below 15 microns and porosity of 1.4–18.6% can be obtained using foaming temperatures from 140 to 180 °C, saturation pressure of 20 MPa, and saturation time of 1 h. Varying the saturation pressure from 10 to 25 MPa and fixing the foaming temperature of 170 °C and saturation pressure of 1 h results in TPU foams with a cell size of below 37 microns and porosity of 1.7–21.2%.

Keywords: thermoplastic polyurethane; foams; gas dissolution foaming; foaming window; hard segment

1. Introduction

Foamed polymers are widely used in almost all industrial sectors, due to their interesting value-added properties, such as low density, low thermal conductivity, and adaptable mechanical properties depending on their relative density. Polyurethane (PU) is the polymer par excellence for foaming mainly because of the high applicability of PU foams, which is based on the possibility of tailoring the final properties of the material by adequately changing the types or quantities of the initial components (isocyanate, polyol, surfactants, catalysts, and blowing agents). Moreover, the simplicity of the PU foaming technology