Nanoplatelet reinforcement of cavity cell walls in polymer foams using carbon dioxide supercritical fluid

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ABSTRACT: Reinforcing the cavity cell walls of polymer foams using nanoparticles can offer a new era for the property-structure-processing field in the development of functionalized ultra-light components and devices manufactured from foam. When the nanoparticles are exfoliated in polymers, the viscosity substantially increases and thus mixing or foaming usually becomes almost impossible. We use CO₂ supercritical fluid (CO₂ SCF) for the mixing and foaming of poly(ethylene-vinyl acetate) copolymer (EVA) with montmorillonite (MMT) nanoplatelets. The in situ evaporation of CO₂ induces robust cavity cells of the EVA/MMT nanocomposite foam in a stable form of spherical shapes, which are seldom achieved by other methods. As the bubble grows and becomes stabilized in CO₂ SCF, the exfoliated MMT nanoparticles are aligned at the cell walls by the Gibbs adsorption principle to minimize the surface energy at the gas–liquid interface and increase the rupture strength of the cavity walls. It is demonstrated that the developed methodology can be successfully used for foaming EVA containing high vinyl acetate (VA) content (>40%). Since EVA is too soft to construct cell walls of foam using conventional methods, the applicability of the developed methodology is extensively broadened for superior adhesion and compatibility with other materials. © 2018 Wiley Periodicals, Inc. J. Appl. Polym. Sci. 2018, 135, 46615.

KEYWORDS: foams; Gibbs adsorption; nanoparticles

INTRODUCTION

Polymeric foams are ultra-light structural materials widely used in automobiles, electronic devices, architecture, and construction industries due to their excellent strength/weight ratio, superior insulation, and energy absorbing performance.¹ Various polymers have been used as foam materials including polypropylene, high-density polyethylene, polyurethane, and ethylene vinyl acetate copolymer (EVA or PEVA), and so on.²–⁵ Among these polymers, EVA foams have been widely used as their properties can be adjusted by changing the vinyl acetate (VA) content.¹,⁶ As the VA content increases, EVA crystallinity decreases and polarity increases due to the relative bulkiness and the polar nature of the acetoxy side chain, giving soft and adhesive characteristics.⁷–⁹ On the other hand, EVA at a low VA content (e.g., <30%) is stiff and inert, and is mostly used as a structural application due to its excellent resilience, thermal and acoustic insulation, and cushioning performance. This low-VA content EVA usually lacks adhesion, wetting, printing, and compatibility due to its low polarity. When the VA content is over 40%, the EVA changes and more closely resembles poly(vinyl acetate) (PVA). EVA therefore has good adhesive wetting characteristics, which is fairly advantageous in processes such as mixing, coloring, surface finishing. More importantly, it is useful for the assembly of various products such as footwear, sporting goods, automobile modules, and so on.⁷,⁸ However, because of its high-VA content, EVA is very soft, and conventional methods are therefore insufficient to form foams because the cell walls are not sufficiently strong to withstand cavity rupture during cell growth.¹⁰ Therefore, the development of EVA foams containing over 40% VA would introduce a