

Supercritical carbon dioxide aided extrusion foaming of biodegradable polymers

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Introduction

In this work, polylactic acid (PLA) foams, as potential green replacements for polymeric foams of petrolchemical origin, were investigated. Recently, PLA foams have been considered as the most promising bio-based and biodegradable substitutes for polystyrene (PS) and polyethylene (PE) foam products, which currently hold the majority ratio in the packaging industry. This is mainly due to the competitive material and processing costs of PLA accompanied with comparable barrier and mechanical properties and environmental friendly character [1]. Besides the packaging industry, there is a wide range of potential application fields for PLA foams, such as construction and transportation, where these could effectively serve as lightweight heat and sound insulating elements, panels and sandwich composite cores. For these fields of application, flame retardancy will be crucial in order to ensure safety standards and regulations.

Experimental

High porosity microcellular PLA foams were produced by continuous, supercritical carbon dioxide (sc-CO₂) assisted extrusion process. To obtain dense and uniform cell structures, epoxy-functionalized chain extender (CE) and talc were applied. Besides, nanoclay and phosphorous based flame retardants were used in order to lower the combustion intensity. The effect of these additives was investigated on the morphology and mechanical properties of the PLA foams. The materials were compounded using a twin-screw extruder (Labtech LTE 26-44) and then pelletized prior to foam extrusion. Supercritical-CO₂-aided melt extrusion was performed on a modular twin-screw extruder (Collin Teach-Line ZK 25T). As physical foam-forming agent, sc-CO₂ was injected into the extruder using a double syringe pump. When CO₂ is supercritical (over 74 bar and 31 °C), its solubility and diffusivity in PLA increases significantly. CO₂ dissolves in the polymer melt and acts as a plasticizer, that is why lower processing temperatures are applicable. In our experimental work, the produced PLA foams were comprehensively characterized by morphological (SEM, porosity measurement), thermoanalytical (DSC) mechanical (compression strength) and flammability (UL-94, cone calorimetry) test methods.

Results and discussion

Highly porous ($\epsilon > 95\%$), microcellular PLA foam structures were obtained (Figure 1). The DSC measurements revealed that the degree of crystallinity significantly increased with porosity. It is likely due to the lower applicable temperature profile and the strain-induced

crystallization of the highly expanded PLA material. The addition of CE and talc promoted the formation of uniform cell-structure and this resulted in outstanding compression strength. As a result of the flame retardant additives, the charring of PLA was successfully promoted, and the flammability of the foams was significantly reduced.

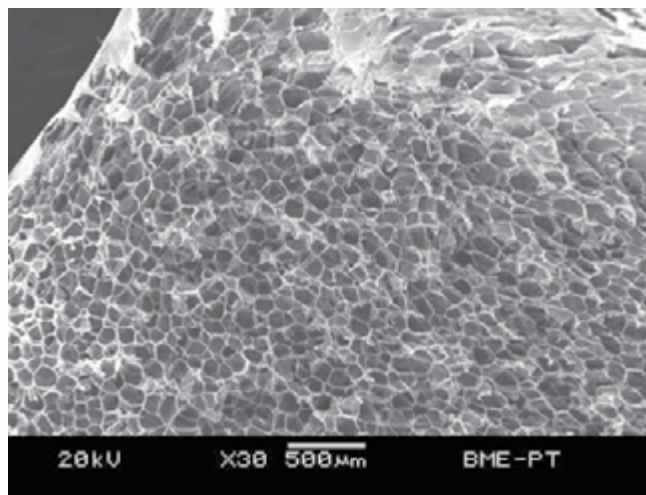


Fig. 1 SEM image of microcellular PLA foam

Conclusions

The aim of our research was the development of novel, fire-safe biopolymer foam structures and the investigation of their applicability in technical fields. The biopolymer foams were manufactured by supercritical fluid assisted extrusion, which is a continuous and mild processing method that could be easily scaled-up even towards real industrial applications.

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References

1. Nofar M, Park CB. Poly (lactic acid) foaming. Prog Polym Sci 2014;39:1721-1741.