European Polymer Journal 95 (2017) 382–393

Contents lists available at ScienceDirect

European Polymer Journal

journal homepage: www.elsevier.com/locate/europolj

Low-density and structure-tunable microcellular PMMA foams with improved thermal-insulation and compressive mechanical properties

Guilong Wang[a,b,*], Jinchuan Zhao[b,c], Guizhen Wang[d], Lun Howe Mark[b], Chul B. Park[b,*], Guoqun Zhao[a,*]

[a] Key Laboratory for Liquid-Solid Structural Evolution and Processing of Materials (Ministry of Education), Shandong University, Jinan, Shandong 250061, China

[b] Microcellular Plastics Manufacturing Laboratory, Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Ontario M5S 3G8, Canada

[c] Center of Precision Engineering, School of Mechatronics Engineering, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China

[d] Key Laboratory of Chinese Education Ministry for Tropical Biological Resources, Hainan University, Haikou, Hainan 570228, China

ARTICLE INFO

Keywords:
Microcellular foam
Thermal insulation
Mechanical properties

ABSTRACT

Polymer foams play an increasingly significant role in the field of thermal insulation due to their low thermal conductivities. As thermal insulation materials, their performances are primarily determined by the cellular structure. However, the correlation between the foam's properties and its cellular structure is still not fully understood. This greatly limits the development of high-performance polymer foams with optimal cellular structures. Hereby, we report the fabrication of poly (methyl methacrylate) (PMMA) foams with widely tunable cellular structures by using CO_2 as the blowing agent. In particular, the microcellular PMMA foam with a void fraction of 0.956 and with an average cell size of 4.7 μm was obtained, which, to the best of knowledge, is by far the largest void fraction of polymer foam with a cell size of less than 5 μm. The PMMA foam presents an excellent thermal-insulation behaviour with a thermal conductivity of as low as 29.9 mW/m K. Meanwhile, the PMMA foam exhibits excellent mechanical properties due to its extremely small cell sizes. Moreover, the dependences of thermal and mechanical properties on cellular structure are obtained by independently analyzing the effects of cell size and void fraction. All these results demonstrate a promising method to fabricate environmentally friendly and economical thermal insulation materials with improved thermal-insulation and compressive mechanical properties.

1. Introduction

Excessive consumption of the fossil fuels has brought our modern world a series of environmental and ecological problems including the environmental pollution, global warming, and ecological deterioration. In this context, worldwide agreements have been made to achieve sustainable development by developing sustainable energy, and improving energy efficiency as well as reducing the greenhouse gas emissions [1,2]. Polymer foams acting as an excellent thermal-insulation material play a pivotal role in

* Corresponding authors at: Key Laboratory for Liquid-Solid Structural Evolution and Processing of Materials (Ministry of Education), Shandong University, Jinan, Shandong 250061, China (G. Wang).

E-mail addresses: guilong@sdu.edu.cn (G. Wang), park@mie.utoronto.ca (C.B. Park), zhaogq@sdu.edu.cn (G. Zhao).

http://dx.doi.org/10.1016/j.eurpolymj.2017.08.025
Received 14 May 2017; Received in revised form 8 August 2017; Accepted 12 August 2017
Available online 12 August 2017