Iranian Polymer Journal (2018) 27:339–347
https://doi.org/10.1007/s13726-018-0614-9

ORIGINAL RESEARCH

Aluminum oxide particles/silicon carbide whiskers' synergistic effect on thermal conductivity of high-density polyethylene composites

Jiaming Fan[1,2] · **Shiai Xu**[1,2]

Received: 2 November 2017 / Accepted: 5 March 2018 / Published online: 28 March 2018

Abstract

Aluminum oxide (Al_2O_3) particles and silicon carbide (SiC) whiskers improved the thermal conductivity of high-density polyethylene (HDPE). To improve the dispersion of inorganic fillers in the matrix, 5 wt% of maleic anhydride-modified polyethylene was added into HDPE as a compatibilizer, and the hybrid matrix was denoted as *m*HDPE. The thermal conductivity, heat resistance, and tensile properties of resulting HDPE composites were characterized. The results showed that the thermal conductivity reached its maximum value of 0.8876 W/(m K) at 1/4 weight ratio of Al_2O_3/SiC, which was 110.3, 54.8, and 8.8% higher than that of pure HDPE, *m*HDPE/Al_2O_3, and *m*HDPE/SiC composites, in the order given, indicating that hybrid fillers have synergistic effect on the thermal conductivity of HDPE composites. Moreover, they also have a synergistic effect on the heat resistance and Young's modulus. As the SiC content increases, the heat resistance of the composites increases at first and then falls, and the maximum VST is reached at an Al_2O_3/SiC weight ratio of 3/2, which is 5.4 °C higher than that of HDPE. The maximum Young's modulus of the composites (1160 MPa) is obtained at an Al_2O_3/SiC weight ratio of 1/4, and the yield strength increases gradually as the SiC whiskers' content increases.

Keywords Polyethylene composites · Thermal conductivity · Aluminum oxide · Silicon carbide · Synergistic effect

Introduction

Polymer materials have many important advantages over traditional thermally conductive materials, such as light weight, easy processing, low cost, electrical insulation, and chemical inertness [1]. There is an increasing need for polymer materials with high thermal conductivity to improve the heat conduction and dissipation in the denser and faster circuits in electronic devices and in the plastic pipes in heat exchange applications. The thermally conductive polymer materials are also required in LED devices, electronic packing, batteries, and solar devices [2]. However, the thermal conductivity of most polymers is low except for those with a π–π conjugated structure, such as polyaniline, polypyrrole, and polypyridine, which allows for the motion of free electron [3, 4]. However, these polymers are too rigid and brittle to process, and it remains a great challenge to synthesize high intrinsic thermal conductive polymers. A promising approach to improve the thermal conductivity of polymers is to incorporate thermally conductive fillers into the polymer matrix. A wide variety of fillers have been used for this purpose, such as metals [5–7], carbon materials [8–10], ceramic materials [11], aluminum oxide (Al_2O_3) [12–14], silicon carbide (SiC) [15], aluminum nitride (AlN) [16, 17], silicon nitride (Si_3N_4) [18–20], and boron nitride (BN) [21, 22]. Li et al. [13] added Al_2O_3 into polypropylene by mechanical grinding and melt mixing to improve the thermal conductivity of the composites, and the results showed that the thermal conductivity of the composites increased as the filler loading increased. In addition, mechanical grinding enabled the fillers to disperse homogeneously in the polymer matrix, which would improve the thermal conductivity of the composites at filler loadings higher than 20 vol%. Kozako et al. [12] found that the thermal conductivity of epoxy/alumina composites was 4.3 W/(m K) at a filler loading of 60 vol%.

Many attempts have also been made to improve the thermal conductivity of polymer composites by incorporating hybrid fillers into the polymer matrix [23, 24], such as Al_2O_3

✉ Shiai Xu
saxu@ecust.edu.cn

[1] School of Chemical Engineering, Qinghai University, Xining 810016, China

[2] School of Materials Science and Engineering, East China University of Science and Technology, Shanghai 200237, China