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The Effects of UV Irradiation Exposure on the Structure and Properties of Polypropylene/ZnO Nanocamposite Fibers

Z. Karami, M. Youssefi*, and S. Borhani

Department of Textile Engineering, Isfahan University of Technology, Isfahan 84156-83111, Iran
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Abstract: Unfilled polypropylene and polyropylene/ZnO nanocomposite fibers were produced using a melt spinning apparatus; then the fibers were exposed to UV irradiation. The structure and properties of the fibers were examined using scanning electron microscopy, tensile measurements, wide angle X-ray diffraction (WAXD), Fourier transform infrared (FTIR) spectroscopy, birefringence measurements and differential scanning calorimetry (DSC). Following 150 hours of exposure to UV irradiation, some transverse cracks on the surface of unfilled polypropylene fibers were observed. It was observed that both carbonyl and hydroperoxide indexes, which are the criteria for the detection of UV degradation of the fibers, were increased due to the increase in the UV irradiation exposure time and the increase in these indexes was smaller for nanocomposite fibers than those of unfilled Polypropylene fibers. It was also observed that crystallinity, crystallite size and total molecular orientation of UV irradiated nanocomposite fibers were increased in comparison with non-irradiated nanocomposite fibers. It was also found that the extent of increase in molecular orientation of the fibers was higher comparing to that for the nanocomposite fibers due to the UV irradiation exposure for the unfilled polypropylene fibers. Tensile properties of both unfilled and nanocomposite fibers were decreased after UV irradiation; this reduction correlated with the extent of the increase in molecular degradation of the fibers, as determined by measuring carbonyl and hydroperoxide indexes.

Keywords: Zinc oxide, Polypropylene, Nanocomposite, Photo-degradation, Fiber

Introduction

Polypropylene (PP) is one of the most commonly used polymers for outdoor environments. PP is applied in many areas such as packaging, textiles, automobile industry, non-durable goods and building materials [1]. PP fibers have numerous advantages in comparison to the other fibers, including high flexibility, low cost, abrasion resistance and light weight. Degradation of PP is a commonly encountered phenomenon that causes some changes in its physical, chemical, and mechanical properties. There are many factors influencing the degradation of polymers such as solar light or other high energy radiations, heating, chemicals attack, stress loading, water absorption, biological sources, etc. Among these factors, ultraviolet (UV) irradiation is a common factor that can induce photo-degradation of polymers under outdoor service environments [2-5]. Therefore, PP degradation due to sunlight exposure is a serious issue that has received considerable research attention [5-12].

It is believed that PP photo-degradation starts with the attack of free radicals on the polymer chains and then the new radicals formed react with oxygen, giving rise to a mixture of products. Wide chain scissions occur, leading to some changes in the physical and chemical properties of PP products. Exposure conditions such as radiation wavelength, radiation intensity, stress, temperature, exposure time and the structure of the polymer have effects on the mechanism and the type of oxidation products [7].

*Corresponding author: youssefi@cc.iut.ac.ir

It was reported that the incorporation of ZnO nanoparticle (NPs) into polymer matrix could have a considerable effect on the reduction of photo-degradation of polymers [5,6,14]. This property was attributed to the superior UV-light absorption effect of zinc oxide NPs [5,6]. ZnO is an n-type semi-conductor and its band gap energy is 3.37 eV [6,13]. In addition to its excellent UV absorption characteristics, zinc oxide has several other advantages: it does not migrate; it is not degraded by the absorbed light; in many cases, it may improve optical, mechanical, and electrical properties of the bulk polymer [14].

Although there are a number of research works on the effects of photo-degradation on the structure and properties of polypropylene and polypropylene/ZnO nanocomposites (NCs), there are few research works on the effects of UV irradiation exposure on the structure and properties of PP/ZnO NCs in the form of textile fibers. In addition, Photo-degradation is known to be more prominent on the surface than in the bulk [15]. Therefore, fibers, due to their noticeably larger specific surface in comparison with moulded materials and films, are more prone to photo-degradation. So, the objective of this research work is to exploit the structural and morphological changes of PP/ZnO NC fibers due to the UV irradiation exposure. This has rarely been considered in the previous publications.

Experimental

Material

Fiber grade polypropylene homopolymer with a melt flow