European Polymer Journal 153 (2021) 110493

Contents lists available at ScienceDirect

European Polymer Journal

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

Accelerated photodegradation of polystyrene by TiO_2-polyaniline photocatalyst under UV radiation

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ARTICLE INFO

Keywords:
Nano TiO_2-PANI composites
Polystyrene
Photodegradation
Break down voltage
Dielectric permittivity
Mechanical properties

ABSTRACT

Photodegradation of polystyrene (PS) was studied under ultraviolet (UV) radiation, using nano TiO_2, surface modified with polyaniline (PANI). X-Ray diffractogram reveals that the crystalline structure of TiO_2 remained intact in TiO_2-PANI composites. The existence of strong molecular interaction between TiO_2 and PANI lead to a decrease in the optical bang gap energy of TiO_2 in the composites. PS loaded with TiO_2-PANI composites underwent better chain scission and photo-oxidation compared to PS and PS-TiO_2 composites, upon UV irradiation. TiO_2-PANI composites enhanced the mechanical properties (tensile and flexural) of PS appreciably. Tensile and flexural strengths however decreased with respect to UV exposure time, proving mechanical deterioration of the polymer composites as an outcome of photodegradation. Thermal stability of the composites too decreased upon UV exposure. A decrease in the values of break down voltage as well as increase in dielectric permittivity of the composites upon UV irradiation suggests the formation of charge centers and polarisable species in the polymer matrix. All the polymer composites underwent considerable weight loss due to the formation and evolution of volatile gases, during the course of photodegradation. Suitable mechanism of degradation of PS composites was proposed based on the observed results.

1. Introduction

20th century witnessed rapid growth in plastic production worldwide [1]. The global production of plastics was estimated to be around 2 metric tons in 1950 [2]. The total quantity of plastic produced between the years 1950 and 2018 was around 6 billion tons. Out of these only 21% has been incinerated or recycled, while the remaining 79% were left untreated [3]. Disposable plastic commodities comprises 50% of the total plastics ever produced [4]. Increase in the global plastic production, lead to an increase in the concentration of plastic debris spread across the world, threatening the ecosystem seriously [5]. Even though most of the commodity plastics like polystyrene, polypropylene, polyethylene, polyvinyl alcohol, polymethyl methacrylate etc are non-biodegradable, they could be degraded photochemically. The so called photodegradation, even though a slow process, could be considered a safe method for the demolition of polymer debris. The process neither requires additional expensive energy nor does produce any hazardous side products during the course. Photodegradation causes chain dissociation in polymers along with oxidation. The physical, chemical, mechanical, electrical and optical properties of the polymer are severely affected after photodegradation [6,7]. Macromolecular residue left behind after the process could undergo biodegradation much easily. Photodegradation could be implemented as a common system of plastic waste treatment only if the entire process proceeds in a stipulated time. Introducing photocatalysts/ photosensitizers could efficiently accelerate the rate of photodegradation. This work mainly studies the accelerated photodegradation of polystyrene (PS) under ultraviolet (UV) radiation in the presence of surface modified nano TiO_2 as photocatalyst. Surface modification of TiO_2 has been done by coupling it with polyaniline (PANI).

TiO_2 is an extensively studied versatile photocatalyst used in various applications including environmental remedial measures [8,9]. Satisfactory results were obtained when TiO_2 was used as photocatalyst for polymer degradation [10–12]. TiO_2 absorbs UV radiation of solar spectra, owing to its optical band gap energy ranging between 3.2 and 3.5 eV, resulting in electron-hole pair separation between valence band

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https://doi.org/10.1016/j.eurpolymj.2021.110493
Received 19 March 2021; Received in revised form 18 April 2021; Accepted 26 April 2021
Available online 11 May 2021