

TiO₂–SiO₂ composite nanoparticles containing hindered amine light stabilizers encapsulated by MMA–PMPM copolymers

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Received: 19 June 2017 / Accepted: 26 September 2017 / Published online: 5 October 2017
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Abstract TiO₂–SiO₂ composite nanoparticles containing hindered amine light stabilizers (HALSs) were prepared by encapsulation of commercially available TiO₂–SiO₂ nanoparticles using methyl methacrylate (MMA) and 1,2,2,6,6-pentamethyl-4-piperidyl methacrylate (PMPM) copolymers through mini-emulsion polymerization. The Fourier transform infrared spectral analysis (FTIR) showed that the hindered amine light stabilizer PMPM was incorporated into the TiO₂–SiO₂/P(MMA-co-PMPM) composite nanoparticles. The X-ray photoelectron spectroscopy analysis (XPS) showed that the surface of TiO₂–SiO₂ nanoparticles was enriched with HALS moieties. The formation of P(MMA-co-PMPM) random copolymers on the surface of TiO₂–SiO₂ nanoparticles was determined by differential scanning calorimetry (DSC), and the percentage of the chemically grafted P(MMA-co-PMPM) coverage on the TiO₂–SiO₂ nanoparticles surface was 40.9 wt% determined by thermogravimetric analysis (TGA), which revealed that the TiO₂–SiO₂ nanoparticles were successfully encapsulated by MMA–PMPM copolymers. Scanning electron microscopy analysis indicated that the TiO₂–SiO₂/P(MMA-co-PMPM) composite nanoparticles were mainly homogeneous spherical shape particles, with an average size of about 90 nm. Rhodamine B (Rh.B) photocatalytic degradation study revealed UV-shielding characteristics for TiO₂–SiO₂/P(MMA-co-PMPM) composite nanoparticles and showed a remarkable decrease in photocatalytic activity of TiO₂–SiO₂ nanoparticles. These results indicated that TiO₂–SiO₂/P(MMA-co-PMPM) composite nanoparticles may be

promising light stabilizers with covalent functionalization of polymeric HALS, which has little photocatalytic activity, and can be introduced into the weathering-resistant polymer materials to improve their application properties.

Keywords Hindered amine light stabilizers · Titanium dioxide · Composite nanoparticles · Photocatalysis · Miniemulsion polymerization

Introduction

Polymer materials may be degraded by various environmental factors such as light, oxygen, temperature, water, microorganisms and pollutants, causing distinct discoloration, surface cracking, chalking, and weaker mechanical properties [1–3]. It is generally acknowledged that ultraviolet in sunlight and oxygen are the main factors in aging degradation of polymer materials, especially for those in outdoor applications [4–6]. To protect the polymer materials from UV destroy and delay the aging degradation processes, one common approach is to incorporate an UV absorber as additive into a polymer matrix [7–9]. Nanoscale titanium dioxide (TiO₂), with rutile crystal structure, which is a well-known inorganic UV absorber, is often added to the polymer materials to extend their service life because of its excellent UV light absorption properties, superior physicochemical stability, nontoxicity and optical property [10–12]. However, the interaction between UV radiation and the TiO₂ surface would generate free radicals that might cause the degradation due to the photocatalytic activity of TiO₂ [13]. Hence, it is necessary to suppress the photocatalytic activity by TiO₂ coated with appropriate materials. Silica (SiO₂) and alumina (Al₂O₃) are widely used as coating materials to suppress TiO₂ photocatalytic activity [14, 15]. Many studies have

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