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Effect of surface functionalization of SiO_2 particles on the interfacial and mechanical properties of PEN composite films

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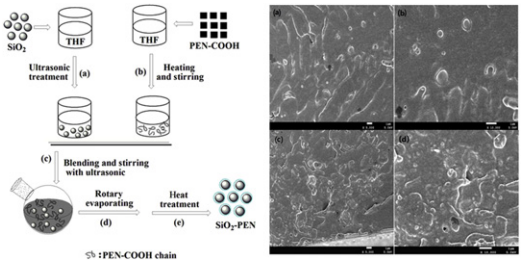
HIGHLIGHTS

- SiO_2 particles were surface functionalized by grafting polyarylene ether nitrile containing carboxyl groups.
- The effect on the morphologies, mechanical and interfacial properties were investigated.
- The interfacial compatibility was characterized using parallel-plate rheometry.
- The inherent mechanism of interfacial compatibility was clarified.

GRAPHICAL ABSTRACT



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ABSTRACT

In this paper, we have introduced a new effective approach to graft polyarylene ether nitrile containing carboxyl groups (PEN-COOH) on the surface of silica (SiO_2) particles which were further confirmed by Fourier transform infrared spectra and transmission electron microscopy analyses. Polyarylene ether nitrile (PEN) composite films with SiO_2-PEN particles were prepared through solution-casting method, which were characterized using parallel-plate rheometry, thermogravimetric and mechanical analysis, aimed at investigating the effect of surface functionalization of SiO_2 particles on the thermal, mechanical and interfacial properties of PEN/SiO_2 composite films. The rheological test indicated that SiO_2-PEN particles presented better dispersibility and interfacial compatibility in the PEN matrix, which was further confirmed from scanning electron microscopy and Cole–Cole plots. The thermogravimetric analysis results revealed that the PEN/SiO_2 composite films showed a slightly increase in 5% weight loss temperature (increased by 1–12 °C) and maximum decomposition rate temperature (increased by 2–5 °C) compared with purified PEN film. DSC curves showed that the glass transition temperatures were in the range of 168–172 °C. In addition, the mechanical properties of composite films were higher than that of pure PEN film even the SiO_2-PEN particles loading reached 6 wt%. In sum, the surface functionalization of SiO_2 particles was confirmed to be an effective method to improve the interfacial and mechanical properties of PEN/SiO_2 composite films.

1. Introduction

In recent years, many laboratories have launched projects on composites containing particles on the nanometer and micron scale with varying success. This is because these composite films exhibit excellent performances such as mechanical [1–3], optical [4–7], optoelectronic [8], magnetic [9] and electrical [3,10] properties. For example, inorganic particles have successively been added to polymers to improve their toughness, thermal and mechanical properties [11]. In polymer composites, surface functionalization of the particles has already been proved to be a wide applicable technique to minimize particle/particle interaction and enhance

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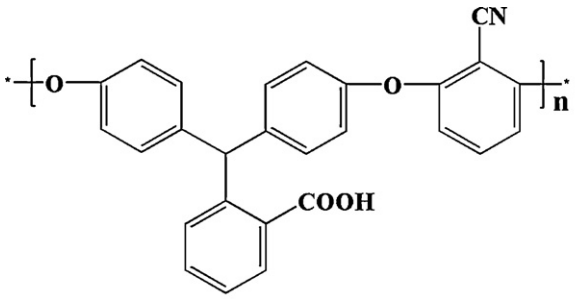
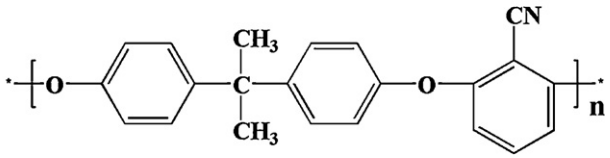
particle/matrix interaction [12]. Therefore, choosing a treatment agent is the key to obtain high-performance composite materials.

In general, there is a little chemical affinity between inorganic fillers and polymers, thus without surface treatment of fillers, inorganic particles-filled composites have rather weak interfacial properties and mechanical properties [13]. But, treatment of fillers with a proper chemical(s), commonly referred to as "coupling agent", can significantly improve the interfacial properties of inorganic particle-filled polymers. Hence, surface treatment of fillers is of great practical importance for enhancing the interfacial properties and mechanical properties of inorganic particles-filled composites [14]. There is a variety of coupling agents which were generally used in surface treatment of inorganic particles, but there were more or less difficulties in their practical application [15]. In this paper, we used a new polyarylene ether nitrile containing carboxyl groups (PEN-COOH) which could be anchored to the SiO_2 particles surface more strongly than conventional physical coatings and hard to be desorbed [16]. Eventually, surface functionalized SiO_2 particles (SiO_2-PEN) were obtained, and the FITR and TEM had confirmed that the PEN-COOH was grafted on the particles surface perfectly.

In recent studies, polyarylene ether nitrile (PEN) has been selected as a polymer matrix due to their outstanding chemical properties (radiation resistance, low flammability and toxic gas emission), excellent mechanical properties, high heat resistance, high thermal stability, and good molding workability [17,18]. In this paper, PEN composite films with SiO_2-PEN particles were prepared through solution-casting method. The surface properties and structures of the SiO_2-PEN particles were investigated by Fourier transform infrared spectra, transmission electron microscopy analyses. Furthermore, the effects of surface functionalization on morphologies, thermal and mechanical properties of the composite films were investigated. Besides, the compatibility and dispersion of the SiO_2-PEN particles with polymer matrix were also discussed in detail by rheological test and Cole–Cole plots [19].

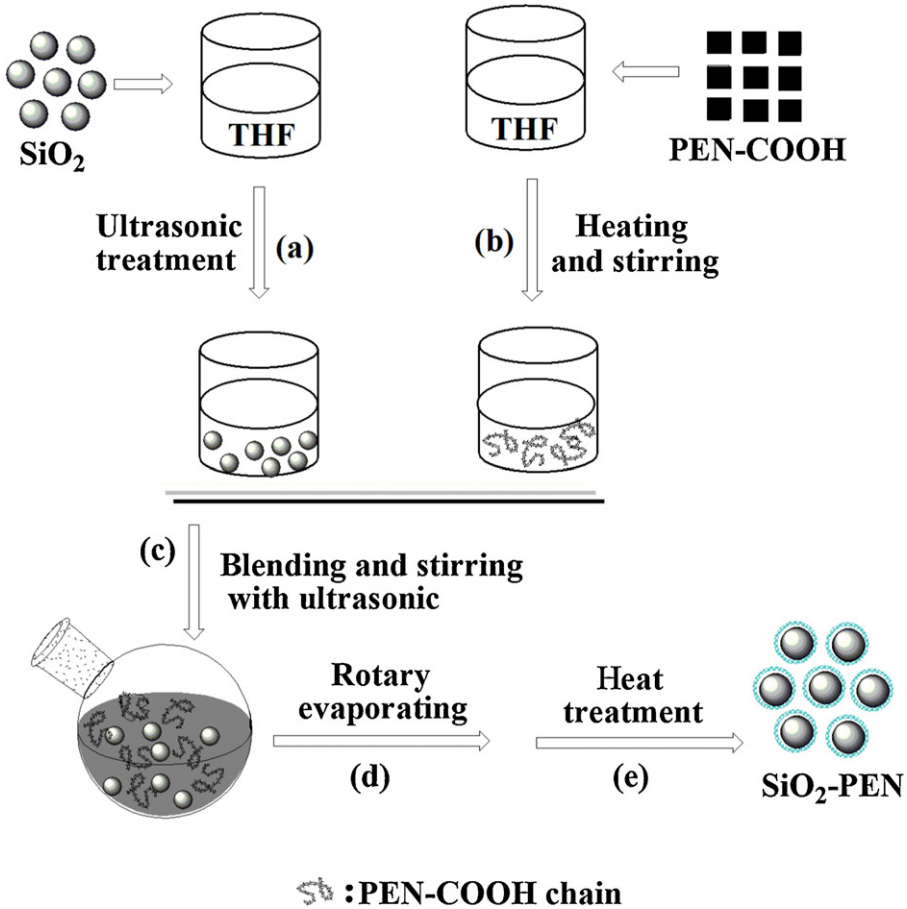


PEN-COOH



PEN

Scheme 1. The structures of PEN and PEN-COOH.



Scheme 2. The schematic diagram of surface functionalized SiO_2 particles.