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Effect of in-situ grown SiC nanowires on mechanical properties of short carbon fiber-reinforced polymer composites

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ABSTRACT

In order to improve the mechanical properties of the short carbon fiber-reinforced polymer (SCFRP) composites, SiC_{nw} were introduced into the SCFRP composites through an in-situ grown method. It was found that the SiC_{nw} were grown in the matrix and on the surface of carbon fibers. The in-situ grown SiC_{nw} could effectively reinforce the SCFRP composites and lead to an enhanced mechanical properties. The SiC_{nw} not only acted as the secondary reinforcement, but also increased the fiber-matrix interfacial bonding area and bonding strength.

1. Introduction

Short carbon fiber-reinforced polymer composites (SCFRP) have been considered as a new generation of engineering materials due to their simple fabrication process, low cost and excellent chemical stability [1–5]. However, comparing with the traditional materials such as metals, SCFRP composites usually exhibited relatively low mechanical properties, which would limit their applications in a wide field [2,3]. Till now, many researchers have made a great effort to enhance the mechanical properties of SCFRP composites by using different ways [6–12].

Particularly, the introduction of nano-reinforcements, such as carbon nanotubes (CNTs), nanowires and nanoparticles, has becoming one of the main methods to enhance the mechanical properties of SCFRP composites. In the literatures [11,12], CNTs were used to reinforce the phenolic-based composites. It was found that the CNTs could improve the mechanical properties being dependent on their content in matrix. However, in the introduction of nano-reinforcements, one of the challenges is to disperse them homogeneously in the matrix of the composites. Due to the small size and high specific surface energy of nano-reinforcments, they tend to agglomerate during the introduction. Especially, the non-homogeneous distribution of nano-reinforcements in matrix would generate the structural defects, which has a negative effect on the mechanical properties of composites [10]. Considering this issue, it is necessary to develop a new way to introduce the nano-reinforcements into the composites.

In this work, the SiC_{nw} were homogenously introduced into the matrix of SCFRP via an in-situ grown method without the assistance of catalyst. It found that in-situ grown SiC_{nw} could effectively reinforce the SCFRP composites and lead to an enhanced mechanical properties.

2. Experimental

Short carbon fibers (C fiber), phenolic resin (PF), polyethyleneimine (PEI), Silicon (Si) and silicon dioxide (SiO_2) powders were used as the raw materials. Fig. 1 shows the fabrication process for the SCFRP composites with in-situ grown SiC_{nw}.

The green bodies were fabricated by a process similar to that found in the literature [13]. First, the short carbon fibers were dispersed via a novel colloidal processing, where the PF and PEI were used as monomer and cross linker, respectively. The fabricated green bodies were characterized by the homogeneous distribution of short fibers and high open porosity. For the in-situ grown of SiC_{nw}, the green bodies were supported by a graphite mesh and put over the powder mixtures of Si and SiO_2 at 1500 °C for 1 h. The evaporation of Si and reaction between Si and SiO_2 supplied the Si-contained gaseous species, which acted as the gaseous source for the growth of SiC_{nw} as shown in Fig. 1. The detailed growth process and mechanism can be found elsewhere [14]. Following this way, a porous green body with in-situ grown SiC_{nw} can be obtained. The porous green bodies with in-situ grown SiC_{nw}

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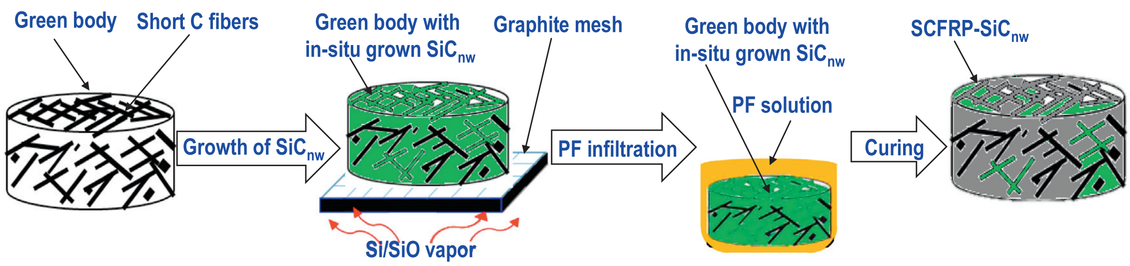

Fig. 1. Schematic illustration for the fabrication process of SCFRP composites with in-situ grown SiC_{nw}.

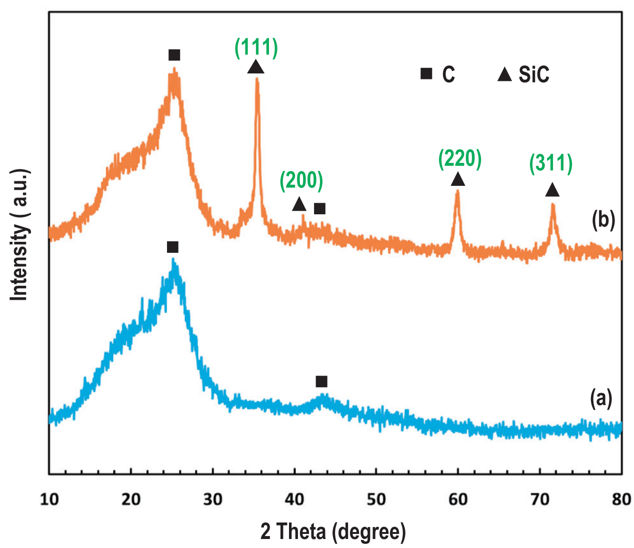

Fig. 2. X-ray diffraction patterns for: (a) SCFRP; (b) SCFRP-SiC_{nw}.

were infiltrated by PF solution. After three cycles, a dense SCFRP composite with in-situ grown SiC_{nw} was fabricated (hereafter, referred as SCFRP-SiC_{nw}) as shown in Fig. 1. Meanwhile, the SCFRP composites without in-situ grown SiC_{nw} were also fabricated being used as a reference (hereafter, referred as SCFRP).

3. Results and discussion

Fig. 2 shows XRD patterns of SCFRP and SCFRP-SiC_{nw}. The broadening of carbon peaks in two composites might be caused by the low graphitization of carbon fiber and vitreous carbon derived from the pyrolysis of phenolic resin [15]. For the SCFRP, there is no presence of SiC peaks as shown in Fig. 2(a), but three sharp diffraction peaks of SiC in SCFRP-SiC_{nw} were clearly observed as shown in Fig. 2(b). These peaks are well matched with (111), (220) and (311) diffraction planes of β-SiC [14]. The presence of SiC peaks could be attributed to the in-situ grown SiC_{nw}.

Fig. 3 shows the SEM micrographs of the porous green body with in-situ grown SiC_{nw}. It was clear that large amount of SiC_{nw} were homogeneously distributed in the pores as shown in Fig. 3 (a). By comparing the mass change before and after the growth

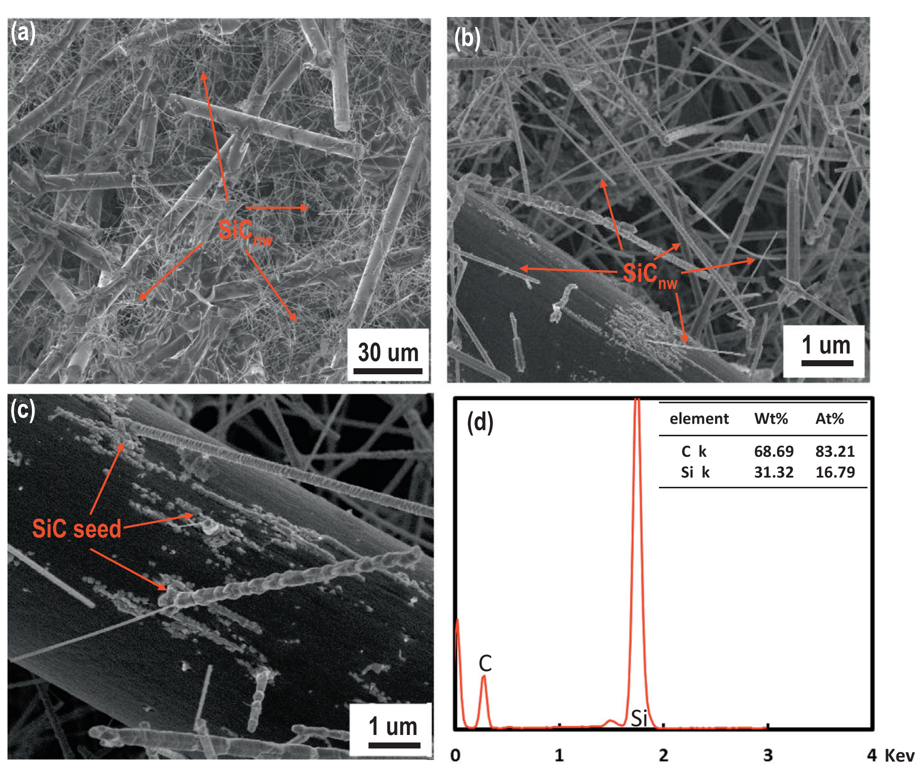

Fig. 3. SEM micrographs of the porous green body with in-situ grown SiC_{nw}: (a) the distribution of SiC_{nw} in the pores; (b) SiC_{nw} grown on the pyrolysis carbon particles; (c) high magnification image showing the SiC_{nw} grown on the surface of carbon fiber with the induction of SiC seeds; (d) EDS result of SiC_{nw}.