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Carbon fibers modified with silicone peroxide containing vinyl groups for silicone rubber reinforcement

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ABSTRACT

A silicone peroxide, tris(tert-butyldioxy)-vinyl-silane (VTPS), was adopted for carbon fibers (CFs) surface modification to improve the mechanical properties of CFs reinforced polydimethylsiloxanes (PDMS) composites. FT-IR and XPS confirmed that the Si-CH$=$CH$_2$ groups, which could generate covalent bonds between CFs and PDMS, were chemically bonded to CFs surface. And the method gave no obvious damage to CFs as shown by SEM and tensile strength analysis. After VTPS modification, the interfacial shear strength (IFSS) between CFs and PDMS was increased, and then the mechanical properties of CFs/PDMS composites were greatly improved (tensile strength from 0.59 to 0.90 MPa, tear strength from 0.83 to 3.65 kN/m).

1. Introduction

Carbon fibers (CFs) is widely used for reinforcement of polymeric matrix, due to its excellent mechanical properties, low density and high corrosion resistance [1,2]. However, the non-polar and inert surface of CFs usually results poor interfacial interactions with polymeric matrix, which negatively affects the mechanical properties of CFs/polymer composites [3–5]. In order to overcome this disadvantage many methods have been developed, such as electrochemical method [6], plasma spray [7], physical coating and chemical grafting treatment. These methods can yield high reactiveness of CFs, but usually sacrifice its strength [8].

PDMS is usually used as high performance materials. However it needs to be reinforced with relatively large amounts of fillers, due to the weak bonding in the molecular chains [9]. Based on its excellent mechanical properties, CFs would be an ideal reinforce fillers for PDMS. However due to the chemical inertia of CFs [1], their composites do not exhibit those properties. To improve the interfacial interaction between PDMS and CFs, this research introduced vinyl groups to the surface of CFs via free radical coupling reaction of CH$_2$$=$CH-Si-O$\cdot$ from thermal decomposition of VTPS. The vinyl groups bonded to the CFs surface could form chemical bonds during crosslinking process of PDMS [10] (via hydrosilylation reaction) as shown in Fig.1. The modification process was relatively moderate, and would not sacrifice the modulus of CFs.

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2. Experimental

2.1. Modification of CFs

Polyacrylonitrile-based CFs (diameter about 3 μm, purchased from Toray, Japan) was first cleaned using anhydrous ethanol, then rinsed in deionized water and dried at 80 °C to give CFs-CH$_3$CH$_2$OH. CFs-CH$_3$CH$_2$OH was immersed in the solution of VTPS (5.0 wt% in anhydrous ethanol) at room temperature for 2 h, followed by drying in hot air oven at 120 °C for three hours to give CFs-VTPS, the VTPS modified CFs.

2.2. Preparation of composites

5.0 g CFs-VTPS, 100.0 g PDMS, platinum catalyst(20 ppm) and cross-linking agent (silicone oil containing Si-H, 4.0 wt% of PDMS) were milled in three-roller miller several times until a homogenous fluid was obtained to give CFs-VTPS reinforced composites (CFs-VTPS/PDMS). Composites reinforced with CFs-CH$_3$CH$_2$OH (CFs-CH$_3$CH$_2$OH/PDMS) were also obtained with the same procedure as a control. The two composites were cured under 120 °C for mechanical test.

3. Results and discussions

3.1. Chemical composition variation of CFs surface

The surface composition analysis was performed on a FT-IR spectrometer. As shown in Fig. 2(a), CFs-CH$_3$CH$_2$OH presented no

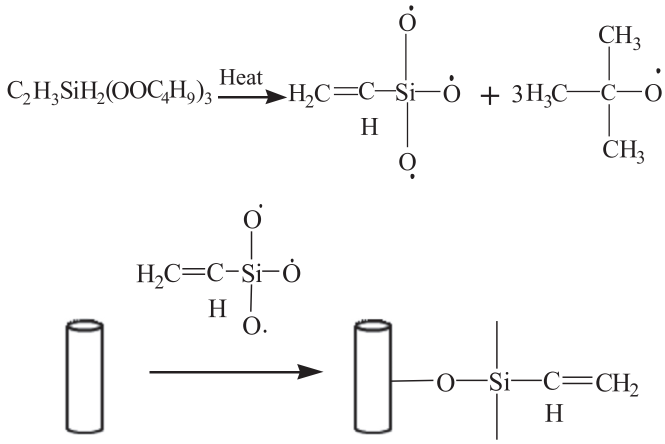

Fig. 1. Surface modification of CFs with VTPS.

obvious absorption. While for that of CFs-VTPS, many peaks assigned to silicone components could be observed, including those at 3433 cm^{-1} (stretching vibration of Si-OH), 1067 cm^{-1} and 929 cm^{-1} (assigned to Si-O-C and Si-O) [11]. Further analysis confirmed the existence of Si-CH=CH$_2$ from absorption at 3021 cm^{-1} and 1635 cm^{-1} (stretching and bending vibration of Si-CH=CH$_2$). In order to prove that VTPS can generate reactive

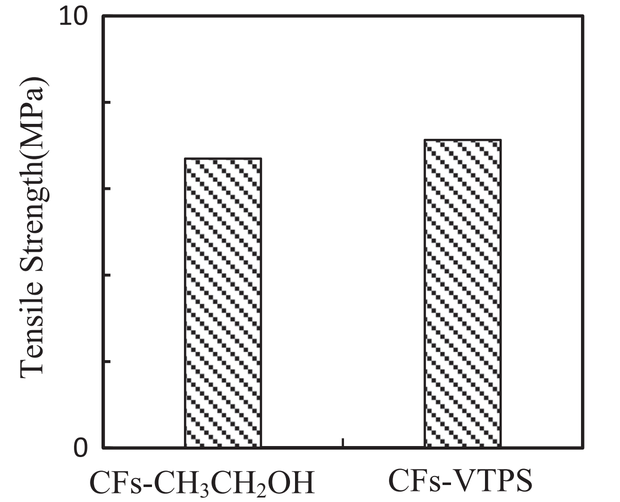

Fig. 4. Tensile strength of CFs-CH$_3$CH$_2$OH and CFs-VTPS.

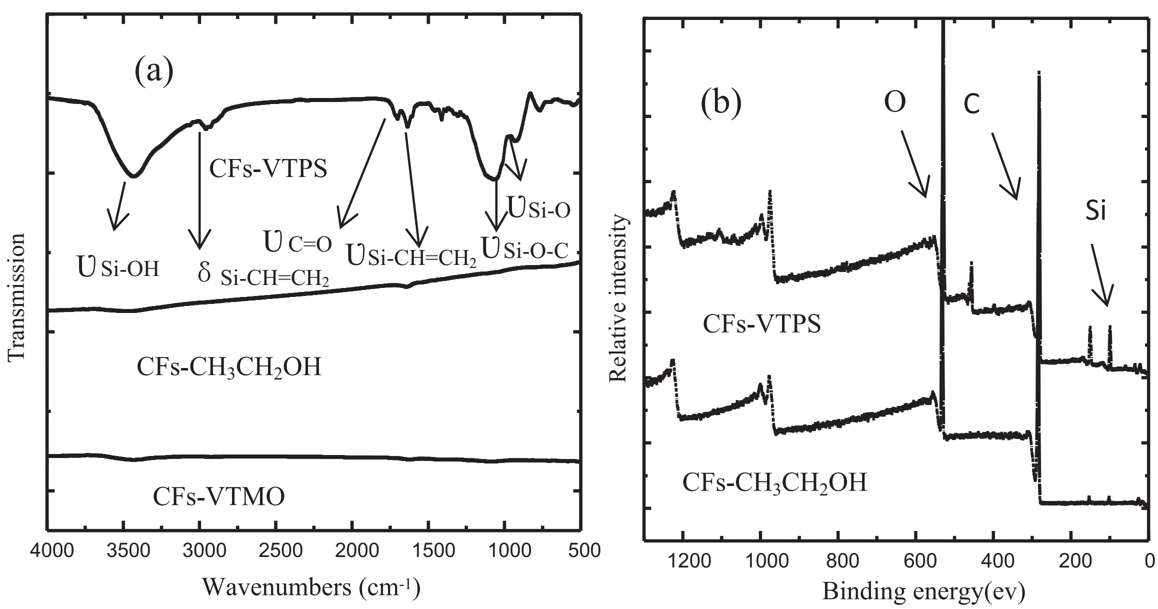

Fig. 2. Chemical composition of the CFs surface: (a) FT-IR spectra of CFs and (b) XPS wide scan spectra of CFs-CH$_3$CH$_2$OH (77.13% C and 21.2% O) and CFs-VTPS (65.44% carbon, 26.5% O and 8.06% Si).

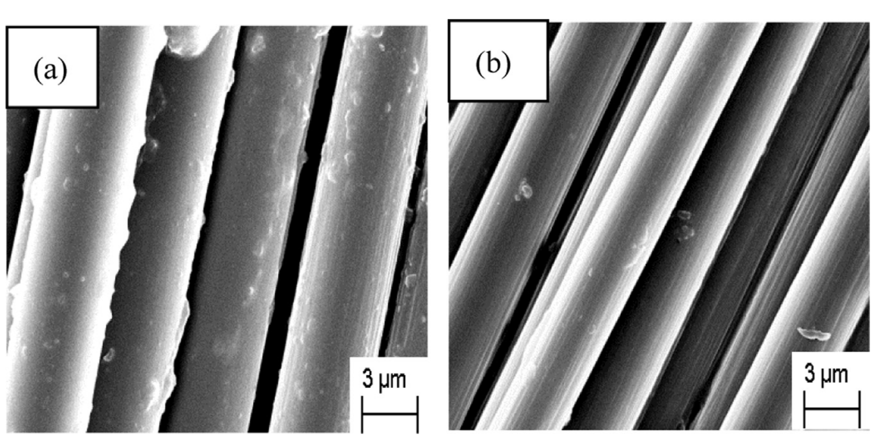

Fig. 3. SEM images of the carbon fibers: (a) CFs-CH$_3$CH$_2$OH, (b) CFs-VTPS.