Preformed Porous Carbon Nanotube Architectures and their composite applications

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1. Introduction

Since single walled carbon nanotubes (SWCNTs) exhibit exceptionally high Young`s modulus (~ 1TPa) and tensile strength (~ 200 GPa), they have been considered an ideal additive for the reinforcement of the polymer composites. However, most polymer composites reinforced with carbon nanotube have shown limited mechanical improvement which is far below the level of the theoretical performance in consideration of the potentials of CNTs. The poor enhancement of mechanical properties of the composites is ascribed to the fact that the SWCNTs are easily bundled by strong van der Waals interactions induced by their small diameter. Here, we report giant enhancement of polymer composites in mechanical properties by using the pre-fabricated, porous three dimensional SWCNT architecture which was built with individually dispersed SWCNTs. The isotropic SWCNT network acts as 3D pre-rebar system in the thermoplastic urethane (TPU). The TPU/SWCNT composites show giant enhancements of 40,000% and 9,700 % in tensile modulus and strength compared to those of the pristine SWCNT aerogel and bare TPU control sample regardless of the tensile direction. Additionally, we observe that the excellent dispersion quality of SWCNT network in the composite allowed the sensitive NIR-fluorescence under various tensile strains

2. Experiments

2.1 Polymer Characteristics.: Thermoplastic polyurethane (TPU) is a commercial grade elastomeric random block copolymer (commercial trade name Texin Sun-3006HF), and was obtained from Bayer Materials.

2.2 Nanotube Characteristics: We used purified CoMoCAT SWCNTs to prepare nanotube hydrogels, aerogels and wetgels. The nanotubes were purchased from SouthWest NanoTechnologies, Inc. (batch CG100) and had diameters ≈1 nm, lengths ≈1 μm resulting in an aspect ratio ≈1000. The SWCNTs were purified and individually suspended in water using sodium dodecylbenzenesulfonate (SDBS) surfactant (Acros Organics. The dispersed nanotubes were shaped into hydrogels and aerogels according to methods previously reported.

2.3 Mechanical Characterization: The tensile stress (σ) was measured as a function of tensile strain (ε) at a rate of 0.15 mm/s at room temperature with a 50 N load cell using an Instron 5940 series tabletop testing system (TA Instruments). The instrument had a position control resolution of <0.1 μmand could measure position with an accuracy of 0.1% of displacement. For the tensile measurements, we followed the ASTM standard ASTM D 882 including the testing of plastic sheets with the thickness less than 0.25 mm.

3. Results and Discussion

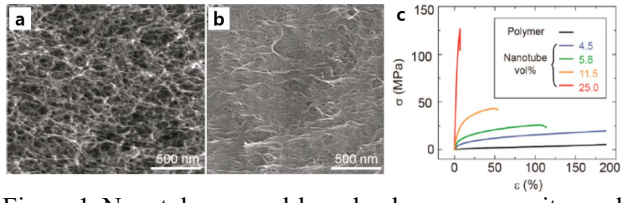

Figure 1. Nanotube aerogel-based polymer composites and mechanical characteristics of composites. SEM image of (a) Nanotube aerogel (b) 25 vol%nanotubes showed that the nanotube networks were unaffected by polymer infiltration, and the composites did not have any voids. (c)The tensile stress (σ) versus tensile strain (ε) curves of polymer and composites with various nanotube concentrations.

The polymer showed linear deformation for ε e 10% with E of 6.63 MPa (Figure 2a), then plastically yielded to a more gradual deformation followed by a steep rise in σ up to a stretchability of ~400% at which point the specimen broke. E of the composites increased dramatically with nanotube addition and reached 2688.5 MPa at 25 vol % nanotube (Figure 2b), which corresponds to >40 000% improvements over that of the polymer.

we integrated preformed hydrogels and aerogels of individually dispersed nanotubes with polymer to increase elastic modulus of composites according to HalpinTsai model up to at least 25 vol % of nanotubes. Our solution-based fabrication method allowed us to create bulk composites with tunable form-factors, and with polymers that were incompatible with nanotubes. Further, in this approach, nanotubes were not covalently linked among themselves and to the polymer, so intrinsic optical, electrical, and thermal properties of nanotubes could be exploited.

References

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