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Flexible, Hydrophobic and Mechanical Strong Poly(Vinylidene Fluoride): Carbon Nanotube Composite Films for Strain-Sensing Applications

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Abstract : Carbon nanotube (CNT) – polymer composites have been extensively studied due to their exceptional electrical and mechanical properties. In the present study, poly(vinylidene fluoride) (PVDF) – multi-walled CNT composites were prepared by melt-blending technique using pristine (ufCNT) and a modified dilute nitric acid-treated CNTs (fCNT). Due to this dilute acid-treatment, the fCNTs were found to show significantly improved dispersion and retained their electrical property. The fCNT showed an electrical percolation threshold (PT) of 0.15 wt% in the PVDF matrix as against 0.35 wt% for ufCNT. The composites were made into films of thickness ~0.3 mm by compression-molding and the resulting composite films were subjected to various property evaluations. It was found that the water contact angle (WCA) of the films increased with CNT weight content in composites and the composite film surface became hydrophobic (e.g., WCA ~104° for 4 wt% ufCNT and 111.5° for 0.5 wt% fCNT composites) in nature; while the neat PVDF film showed hydrophilic behavior (WCA ~68°). Significant enhancements in the mechanical properties were observed upon CNT incorporation and there is a progressive increase in the tensile strength and modulus with increase in CNT weight fraction in composites. The composite films were tested for strain-sensing applications. For this, a simple and non-destructive method was developed to demonstrate the strain-sensing properties of the composites films. In this method, the change in electrical resistance was measured using a digital multimeter by applying bending strain by oscillation. It was found that by applying dynamic bending strain, there is a systematic change in resistance and the films showed piezo-resistive behavior. Due to the high flexibility of these composite films, the change in resistance was reversible and found to be marginally affected, when large number of tests were performed using a single specimen. It is interesting to note that the composites with CNT content notwithstanding their type near the percolation threshold (PT) showed better strain-sensing properties as compared to the composites with CNT contents well-above the PT. On account of the excellent combination of the various properties, the composite films offer a great promise as strain-sensors for structural health-monitoring.

Keywords : carbon nanotubes, electrical percolation threshold, mechanical properties, poly(vinylidene fluoride), strain-sensor, water contact angle
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