

Abstract

Mechanochemical Approach to Carbon Nanotubes-Based Piezoresistive Sensors' Fabrication [†]

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Abstract: The development of 3D porous nanocarbon composites has improved the performance of piezoresistive sensors. However, the functionalization and surface distribution of nanocarbon may limit conductivity and mechanical stability. In this study, a mechanochemical approach was developed to create an elastomeric/CNTs 3D porous nanocomposite. By changing parameters such as CNT length and polymer amount, different composites with improved piezoresistive properties can be produced for wearables or fluidic devices. The material can withstand compressive stress up to 150 Kpa and has a sensitivity of up to 330 Kpa^{−1} and a limit of detection of 0.2 Pa and 50 nm for pressure and extension, respectively.

Keywords: piezoresistive sensor; carbon nanotubes; nanocomposite; conductive flexible materials



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1. Introduction

Flexible electronics have potential applications in various fields, but creating highly conductive components with excellent mechanical stability remains a challenge. The use of carbon conductive nanomaterials, such as carbon nanotubes (CNTs) and graphene, has shown promise, but their fabrication requires chemical functionalization of the carbon nanomaterial, which presents issues. A new, scalable, and user-friendly strategy based on mechanochemical functionalization of CNTs was developed to produce porous CNT-based piezoresistive composites.

2. Materials and Methods

Fructose microparticles and 3% pristine multiwalled carbon nanotubes (MWCNTs) were mixed overnight with a tube rotator shaker and subsequently immersed in a solution containing PDMS prepolymer diluted in hexane at varying ratios. The resulting mixtures were filtered and packed into Teflon molds, sealed, and cured in an oven at 80 °C for 3 h. The sugar particles were then removed by immersing the composites in hot water.

Characterization

Morphological characterization was carried out with SEM and TEM. Resistance variation was recorded with a Keithley 2400 source meter. Pressure control was maintained using a LLOYD LR50K Plus dynamometer (Ametek Srl, Peschiera Borromeo (MI Italy)).

3. Discussion

Porous PDMS/MWCNTs foams were produced by mechanochemical disruption of π - π stacking in MWCNT bundles, followed by non-covalent adsorption of MWCNTs onto fructose particles, adsorption of diluted PDMS onto the composite surface, polymerization, and removal of the fructose (Figure 1a). The resulting conductive material had well-dispersed, pristine MWCNTs acting as efficient reinforcing fillers [1]. The foam's conductivity varied with different sensitivities at different strain ranges due to different mechanisms causing a change in material resistance. The sensitivity and pressure range of the sensor can be easily adjusted by changing the polymer dilution and carbon nanotube length. Longer CNTs resulted in better mechanical stability, conductivity, and mechanical properties with a lower limit of detection (0.2 Pa) [2]. Higher polymer dilution enabled nanocomposites with an incredible limit of detection for displacement (~ 50 nm). However, lower dilutions produced sensors capable of monitoring larger pressure ranges (up to ~ 150 kPa). The material demonstrated improved performance compared to other materials reported in the literature [3]. The nanocomposites could be assembled into finger ring devices to monitor vigorous or small signals (Figure 1b,c). Recent results have shown the possibility of integrating the system into lab-on-chip devices to monitor microfluidic devices.

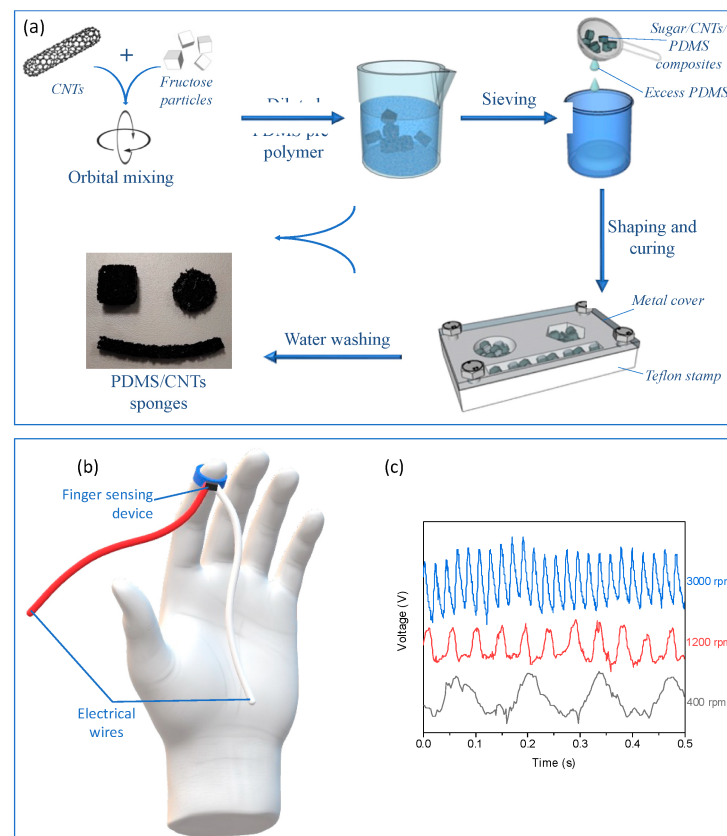


Figure 1. (a) Fabrication scheme of the PDMS/CNTs foams. (b) Scheme of the finger sensing device; (c) signals recorded during vortex movement.

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