ICCES, 2024, vol.29, no.1
DOI: 10.32604/icces.2024.011671

PROCEEDINGS

Multiscale Modeling and Application of Strain-Dependent Piezoresistive Behavior in Porous MWCNT/Polymer Nanocomposites

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ABSTRACT

For composite materials incorporating porous structures with multi-walled carbon nanotubes (MWCNTs), the effects of pores and MWCNT agglomeration significantly impact electrical conductivity. Theoretical modeling of the piezoresistive behavior is crucial for understanding the electromechanical response of porous MWCNT/polymer nanocomposites. Currently, there is limited theoretical modeling that considers the combined effects of porosity and MWCNT agglomeration on the electrical conductivity and piezoresistive performance of porous MWCNT/polymer composites. Addressing this gap, this paper presents a multiscale modeling approach for the strain-dependent piezoresistive behavior of porous MWCNT/polymer nanocomposites. The model considers the influence of porosity and MWCNT agglomeration, predicting the effective conductivity and the effect of compression strain on electrical conductivity. In accordance with this theoretical framework, we have developed a mechanically resilient and flexible hybrid tactile sensor featuring microstructured, sensitive MWCNT/polymer nanocomposites, tailored for integration into human-cyber-physical systems (HCPS). These sensors serve as pivotal elements for the real-time monitoring of stress in 3D printing manufacturing processes, structural assembly stress, and human physiological signals within HCPS contexts. The sensor characteristics revealed by this theoretical framework can offer guidance for the design of high-performance porous MWCNT/polymer nanocomposites strain sensors based on microstructure considerations.

KEYWORDS

MWCNT/polymer; agglomeration; porous structure; hybrid response

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.