Piezo-Resistive Sensing in Carbon Nanofiller-Reinforced Epoxy Nanocomposites: The Effect of Morphological Characteristics

Yubao Deng, Ozan Can Zehni, Tayyab Khan, Mark A. Bissett, William W. Sampson, Robert J. Young, Ian A. Kinloch

National Graphene Institute, Henry Royce Institute and Department of Materials, School of Natural Sciences, The University of Manchester, Oxford Road, Manchester, M13 9PL, UK

Yubao.deng@manchester.ac.uk

This study presents a comparative investigation into the piezo-resistive behaviour of epoxy-based nanocomposites reinforced with three distinct carbon nanofillers—carbon black (CB), multi-walled carbon nanotubes (MWCNTs), and graphene nanoplatelets (GNPs)—each with unique morphological characteristics. Experimental testing under tensile strain, combined with Monte Carlo simulations, reveals how filler shape and network formation influences electrical conductivity under deformation and hence strain sensitivity. Spherical CB particles, rod-like MWCNTs, and polygonal GNPs formed distinct conductive networks, leading to markedly different piezo-resistive responses. Amongst them, GNPs showed the highest gauge factors (GF > 60) under tension, which was attributed to significant disruptions in their conductive networks. MWCNTs offered moderate but stable responses, whereas CB composites showed only moderate sensitivity with greater variability. Simulation results closely mirrored experimental trends, particularly in the strain-dependent behaviour of different filler shapes. This strong agreement between simulation and experiment demonstrates the potential of morphology-informed design strategies and highlights these nanocomposite systems as promising candidates for real-world piezo-resistive sensing applications in structural health monitoring.

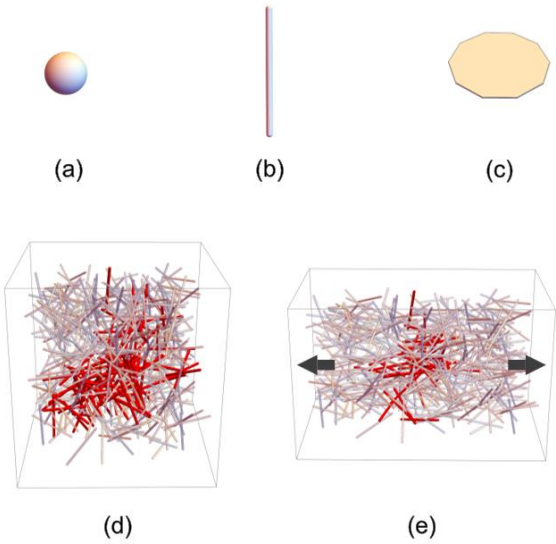

Figure 1. (a–c) Schematic representations of the three filler geometries studied: sphere (0D), rod (1D), and polygon (2D). (d) The undeformed configuration of a simulated, rod-filled network at the percolation threshold. Red rods highlight the percolating network. (e) The same network under an applied +50% tensile strain, where the large deformation is used to demonstrate the simulated structural response.

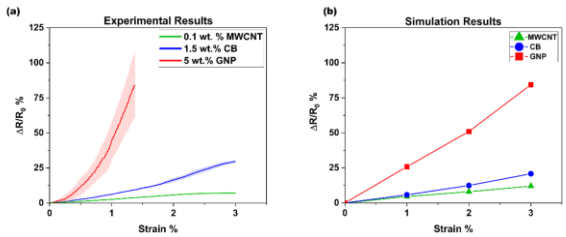

Figure2 . (a) Comparison of mechanical and piezo-resistive properties for nanocomposites containing MWCNT (0.1 wt.%), CB (1.5 wt.%), and GNP (5 wt.%) (b) Experimental resistance change response of these nanocomposites under tensile and compressive loading (c) Simulation results for rod-, sphere-, and polygon-shaped filler 70% percolated networks.