Manufacturing and characterisation of a piezoresistive strain sensor based on the rGO@PDMS composite for skin and prosthetic support systems

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Abstract Due to an ever-increasing amount of population focusing more on their personal health, thanks to rising living standards, there is a pressing need to improve personal healthcare devices. These devices presently require laborious, time-consuming, and convoluted procedures that heavily rely on cumbersome equipment, causing discomfort and pain for the patients during invasive methods such as sample-gathering, blood sampling, and other traditional bench-top techniques [1]. The solution lies in the development of new flexible sensors with temperature, humidity, strain, pressure, and sweat detection and monitoring capabilities, mimicking some of the sensory capabilities of the skin [2]. Along these lines, carbon-based composite materials, which include graphene and other allotropes, have also garnered significant interest due to their electromechanical stability, extraordinary electrical conductivity, high specific surface area, variety, and relatively low cost [3].

Thus, in this work, a piezoresistive strain sensor based on a polydimethylsiloxane (PDMS) composite nano reinforced with reduced graphene oxide (rGO) was manufactured, characterised, and tested for possible applications which include joint movement and breathing pattern monitoring, exhibiting the physical and electromechanical characteristics required for the effective detection of physiological signals. The samples were prepared via solution casting, followed by characterisation of the piezoresistive effect of the material, mechanical (3-point bending and tensile), morphological (SEM), structural (FTIR), and thermal (TGA) properties, along with performance testing in live-human's body parts.

Regarding results, it was observed the influence of the used PDMS elastomer-crosslinker ratio, cure temperature and time, dispersant and rGO content in the final performance of the sensor, with the possibility to tune certain characteristics to be better adjusted to specific applications. For this kind of application, the indicated elastomer-crosslinker is 15:1 cured at 120 °C for 20 minutes, with isopropyl alcohol as the dispersant and a rGO content between 3-5 wt.%. The obtained average gauge factors ranged from 7.49-14.85 for 3 wt.%, 9.84-30.8 for 4 wt.%, and 0.56-9.16 for 5 wt.% rGO, establishing these samples as effective piezoresistive sensors for bioengineering applications. It was also concluded that the manufactured composites exhibited good linearity and piezoresistive performance in the 1.54-2.87% strain range, some stability in the 100 cycle 3-point bending tests, the tensile strength varied from 1.05 MPa to 3.084 MPa, the degradation temperature ranged from 380 °C to 410 °C, as well as composites reversibly losing their electrical component before the structure integrity was lost, when tensile tested. Lastly, two proofs of concept were developed, where real-time acquisition and monitoring of data related to joint movements and breathing patterns was successfully performed in volunteers.

Keywords: Bioengineering; Polymer Composites; Piezoresistivity; Flexible Sensors; Nanomaterials.

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