16th International Workshop on Advances in Experimental Mechanics 2012
August 19-25 2012, Portoroz, Slovenia

Simultaneous measurement of mechanical and electrical properties of conductive elastomers for strain sensor applications

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Abstract

Conductive elastomers are highly deformable rubber-like materials that exhibit a moderate and easily measurable electrical resistance during at least some of their deformation. They are set to play an increasingly important role in flexible polymer electronics and kinaesthetic systems. Their resistance changes with deformation as well as deformation history, similarly to the way in which the mechanical response of elastomers exhibits the well known Mullins effect.

This paper begins by outlining the requirements on conductive elastomers for strain sensing applications. This is followed by presentation of simultaneous experimental measurements of stress, strain and electrical resistivity carried out by exposing one commercial conductive silicone elastomer (Elastosil), one carbon-black filled EPDM rubber, and two nanocomposites of thermoplastic polyurethane and multi-walled carbon nanotubes to a series of cyclic strain histories. It was found that the resistivity-strain relationships of the materials exhibited different hysteresis and dependence on pre-strain. The resistivity of the nanotube-filled elastomers changed dramatically with pre-strain, making them more suitable to memory sensor applications. A region of strain at constant resistance was identified in the nanotube filled elastomers (possibly arising from bending and buckling modes of the nanotubes), making them unsuitable for real-time sensing.

During cyclic loading, the carbon-black filled elastomers exhibit a lower resistivity during the loading part of the cycles than during the unloading part, while the opposite effect was seen in the nanotube-filled elastomers. A possible explanation of the phenomena will be described in terms of hysteretic plastic flow processes in the thermoplastics, and of hysteretic cohesive interactions between carbon-black particles in the cross-linked elastomers. The paper will conclude by summarising the new perspectives on the microstructure of these materials *during* deformation that can be obtained by the simultaneous measurement of electrical and mechanical properties.