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Investigation of the damage sensing abilities of additively manufactured conductive polymer composites

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Self-sensing is a functionality of great interest for the development of smart materials. Mechanical self-sensing is intended as both in situ strain monitoring and damage sensing: the first refers to the material's ability to monitor small and/or reversible deformation; instead, damage sensing is the material's intrinsic ability to monitor its mechanical integrity through the detection of damage. Among damage sensing techniques, resistance based measurements enable real time in situ health monitoring by detecting variation in the electrical current flow caused by disruptions in conductive pathways. Conductive polymer composites have been widely studied focusing on strain sensing applications; instead damage sensing, has been less explored for this material class. In this work, the mechanical and electromechanical properties of a piezoresistive 3D printed composite material are characterised to investigate its potential for damage sensing applications. Specifically, polylactic acid (PLA)/carbon black (CB) composite constructs are characterised using electromechanical tests to failure, measuring samples'electrical resistance change during loading. Due to the viscoelastic nature of the material, strain recovery tests are performed to identify the onset of permanent deformation. Cyclic electromechanical tests are also carried out to further investigate the correlation between mechanical damage and electrical resistance evolution, and assess the stability of the electrical network. The results show a strong link between the onset of permanent deformation and transition points observed in the measured electrical signal. Additionally, results of cyclic tests showed no resistance stabilization, and are in agreement with the yield hypothesis. Cyclic tests results also reveal a high sensitivity of the conductive network which is capable to detect and distinguish previously occurred deformation (both reversible and irreversible). Overall, this work demonstrates the damage sensing capabilities of additively manufactured PLA/CB samples. It also presents a novel and readily reproducible characterization framework, with the potential to be extended to a multitude of polymeric materials and types of damage.

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