Multifunctional porous conductive TPU/carbon-based system 3D printed for piezoresistive sensors

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During the last forty years, which increased significantly with the advent of nanostructured carbon-based conductive materials, light, highly conductive and easy-to-obtain fillers have broadened the spectrum of materials that had been used up to that time, opening up the possibility of greater development of multifunctional materials. In particular, the carbonaceous fillers, homogeneously dispersed within a polymer matrix, immediately represented a valid alternative to the metals used in the field of piezoresistive systems. A significant challenge for the scientific community is represented the by the achievement of an effective percolation pathway, which allows the passage of an electric current at the lowest percentage of filler (percolation threshold). Generally, a conductive composite can be obtained by exploiting the concept of segregation of filler in the polymeric matrix.

Selective Laser Sintering (SLS) 3D printing is one of the most interesting technology, able to build up easily the segregated filler network, starting from polymeric powder adequately prepared. It is focused on the sintering of polymeric particles by a laser in the classic layer-by-layer mode. In this work it was investigated the possibility of obtaining piezoresistive materials printed with 3D SLS using thermoplastic polyurethane (TPU) as a polymer matrix and graphene nanoparticles (GE) and multiwalled carbon nanotubes (MWCNTs) as conductive filler, evaluating the effect of different geometries and porosities (from 20% to 80%) and different shape of the conductive filler (i.e. 1D filler and 2D filler). Porous systems were printed using TPU modified with 1wt% of GE and starting from Diamond (D), Gyroid (G) and Schwarz (S) geometries for the building up of systems with regular porosity.

3D printed TPU products with MWCNTs and a mixture of the two fillers, again at 1wt% but with a proportion of 70/30 wt/wt MWCNTs/GE with geometries D and G, in order to investigate a possible synergistic effect of the two conductive fillers. The results showed that the porous structures based on TPU with 1wt% MWCNTs/GE exhibit excellent electrical conductivity and mechanical strength. In particular, all the porous structures show a robust negative piezoresistive behavior, with a GF values of about -13 at 8% deformation. Moreover, the G20 porous structures (20% porosity) show microwave absorption coefficients ranging from 0.70 to 0.91 in the 12-18 GHz region and close 1 in the THz (300 GHz - 1 THz) frequency region. The results show that the simultaneous presence of MWCNT and GE brings about a significant improvement in the multifunctional properties of porous structures, which are piezoresistive actuators for potential application in the field of prostetic devices.

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