Polymer Sensors for Shape Sensing of Adaptive Structures

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Abstract

Advances in layered manufacturing technologies and materials science are making the manufacture of complex structures with adaptive mechanical characteristics easier to achieve. Additionally, the ability to print soft and flexible polymers such as Thermoplastic Elastomers (TPE) in consumer-grade Fusion Deposition Modeling (FDM) 3D printers is reducing the barriers to producing mechanically adaptive structures. Conductive Polymer Composite (CPC) piezoresistive sensors based on a Carbon Black (CB) and TPE have been produced [1] in order to measure the deformation of textile bands applied in wearable computing applications. By modifying the stiffness regions of the band with liquid rubber materials, the sensing function of the band sensor can be tuned. Mechanical testing has shown that the band sensor shows some relaxation during loading to different strain levels, but has very low signal drift over time for strain monitoring. Mechanical characterization of the piezoresistive sensor (in 0.3 mm diameter monofilaments) has shown a decoupling between the non-linear force and a linear electrical resistance response during tensile loading. The CB/TPE sensor material can achieve ultimate strains of over 150%, with a safe working range up to 100% [2]. Pre-straining of the material is required in order to improve the sensor performance. Initial tests included the bonding of a U shaped sensor onto elastic bands for monitoring the hand motion of a person or to detect the pulse wave of a person. Subsequent tests included sensor integration into a 3D printed TPE compliant structure with an unfolding nature in the sensor region. The 3D printed band with an expanding structural design unfolds along the direction of longitudinal strain to monitor structural deformation. Future research will focus on integrating the sensor material directly in the printing process, lending to use in smart skins for soft robotics or wearable computing applications.

[1] Clemens, F.J.; Koll, B.; Graule, T.; Watras, T.; Binkowski, M.; Mattmann, C.; Silveira, I. Development of piezoresistive fiber sensors, based on carbon black filled thermoplastic elastomer compounds, for textile application. Adv. Sci. Technol. 2013, 80, 7–13.

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