Microstructural Tuning of Piezoelectric Particulate-Polymer-Foam Composites

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Design of conformable piezoelectric composites based on tri-phase PZT-porous polyurethane (PU) with enhanced energy harvesting performance is investigated.

The direct energy harvesting Figure of Merit (FOM) is directly proportional to the piezoelectric charge constant and inversely dependent of the permittivity of the material [1]. Our earlier research has shown that optimization of the electrical as well as mechanical properties of the polymer matrix plays an important role in controlling the piezoelectric charge and output voltage of the diphase composites [2]. The FOM can be further optimized by a combination of dielectrophoretic structuring of piezo ceramic particles and adding a gaseous phase to the polymer matrix in a form of foam. DEP alignment will improve the piezoelectric charge constant of the composite, and foaming will significantly decrease the permittivity of the composite, a combination of both will result in enhanced elecetromechanical behavior.

The effect of the presence of the gaseous component in the polymer matrix in the form of well-distributed spherical inclusions on dielectric and mechanical properties of the composites is investigated. It has been found out that the gaseous component effectively decreases the polymer dielectric permittivity, which increases the piezoelectric voltage constant of the composites significantly. The unique combination of dielectrophoretic structuring of PZT particles and the addition of a gaseous phase to the polymer resin results in the highest performance of the particulate composite sensors reported in the literature so far. The g_{33} values of the newly developed tri-phase composites are twice that of the structured di-phase PZT-bulk PU composites (80 mV.m/N) and more than five times the g_{33} value of bulk PZT ceramics (24-28 mV.m/N). Further optimization of the tri-phase composites by replacing the PZT ceramic with lead free KNN particles results in significant improvement in the piezoelectric output voltage of the structured tri-phase composites. g_{33} values close to that of PVDF polymer sensors (300 mV.m/N) are obtained.

1. Roscow J, Zhang Y, Taylor J and Bowen C R, 2015. Porous ferroelectrics for energy harvesting applications. European Physical Journal - Special Topics, 2015 224 (14-15):2949-2966
2. van Kempen S, Optimisation of Piezoelectric Composite Materials Design through Improved Materials Selection and Property Prediction Methods, MSc thesis, 2012