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Giant Flexoelectric Effect of Polymeric Porous Composite and Its Applications

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ABSTRACT

Non-uniform strains produce a localized break in the microscopic inverse symmetry of materials, which leads to the electromechanical coupling phenomenon known as flexoelectricity in all dielectric materials. However, the size-dependent flexoelectric effect typically only manifests at small scales. Creating a considerable flexoelectric output at the macroscopic scale remains a bottleneck. Micro- and nano-porous materials own a significant number of randomly distributed microscopic pores and ligamentous structures, which can deform non-uniformly under arbitrary forms of macroscopic loading. Moreover, since the small size effect of flexoelectricity, the entire flexoelectricity of the micro- and nano-porous materials will be much more significant than that of the solid counterpart. Here, a theoretical framework of porous structures to predict the flexoelectric electric output is presented, and a quantitatively analysis to reveal the major governing parameters is performed [1]. Porous polydimethylsiloxane (PDMS) and polyvinylidene fluoride (PVDF) are fabricated to verify the theoretical models. Based on the theory, a stacked-and-twisted porous composite is fabricated with PDMS and nano-copper-calcium-titanate (CCTO) particles to improve the flexoelectric coefficient of ligaments, combining with the optimized aspect ratio, compression-torsion coupling deformation mode and multiple induction electrodes to increase the flexoelectric output [2]. Its mass- and deformability-specific flexoelectricity is four orders of magnitude more than that of the matrix material, and the density-specific equivalent piezoelectric coefficient reaches 100 times greater than that of the piezoelectric ceramic lead-zirconate-titanate. Its stress-strain relations and electrical output remain stable under 1,000,000 times of cyclic loads. Finally, we demonstrate that the porous composite exhibits an efficient omnidirectional electromechanical coupling ability for applications as sensor and strain gradient electric generator (SGG) – a portable sample can charge mobile phones and blue tooth headsets.

KEYWORDS

Flexoelectricity; porous composite; equivalent piezoelectric coefficient; strain gradient electric generator; energy harvesting

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