Enhenced flexoelectricity in polymer elastomers with asymmetric structure

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Abstract

Flexoelectricity is an electro-mechanical coupling effect between electric polarization and mechanical strain gradient. Dielectric materials, such as ceramics, rubber, plastics, etc., have a flexoelectric effect, and bending or twisting to them will generate electricity, but not when applying pressure or tension, which greatly limits its application, because in fact tension and pressure loads are the easiest to obtain. In this work, we establish a theoretical model and asymmetric structure in polymer elatomers, in which complex asymmetric structures can exhibit flexoelectric effects under any load due to their local structural asymmetry compared to traditional structures. By comparing a series of parameters of the asymmetric structure, we design a structure in elastomer, as a result, its equivalent piezoelectric coefficient is much larger than the material flexoelectric coefficient. The results show that the polymer elastomers with asymmetric structure can be widely used in the energy harvesting, sensing and mechanical actuating with high flexoelectric effect.

Key words: flexoelectricity, polymer elastomer, asymmetric structure

1 Introduction

Flexoelectricity is a type of electro-mechanical coupling effect in dialectric materials. In recent years, flexoelectricity attracts more and more researchers because of its properties like dimension dependence and independence of Curie temperature. Plenty of studys have been done on flexoelectricity including theoritical deduction and computational method, and flexoelectric effects are observed in ferroelastrics, liquid crystals, biomembranes, polymers and semiconductors. The vast application prospect of flexoelectric effect are reported in areas like sensing, energy harvesting, data storage and mechanical actuating. The bending of polymer long chains and the uneven distribution of dipole moments in polymers cause eletro-mechanical coupling effect.In particular, since polymer elastomers can achieve large bending or stretching over the elastic range, their flexoelectric effects are very strong by applying a large strain gradient. As a result, the flexelectric effect of polymer elastomers is investigated by many researchers such as polydimethylsiloxane(PDMS), polyvinylidene fluoride(PVDF), polyethylene terephthalate(PET). Based on the microscopic complexity of porous structures and the scale effect of flexoelectricity, Zhang et al. design an interconnected porous polymer with ultra high flexoelectric effect. Although polymers are benefited by its advantages like biocompatibility and low-cost manifacturing, the applications of flexoelectricity of polymer elastomers are restricted by the flexoelectric coefficients which is averagely two orders smaller than those of ferroelectric ceramics. Enhancement of fexoelectricity in polymer elastomers is reached by methods like dimension shrinkage, pre-strain gradient and strcture design.

In this work, we design an asymmetric structure. Because any form of loading will cause strain gradient at the asymmetric point of the structure, the flexoelectric effect of the asymmetric structure under any direction or any form of loading is obtained. Then we fabricated PDMS blocks with this asymmetric structure, and measured the flexoelectric response. The experimental results are in good agreement with the theory, and the tensile rate can reach more than 15% in the elastic range, simultaneously, the sensitive flexoelectric induction is obtained.

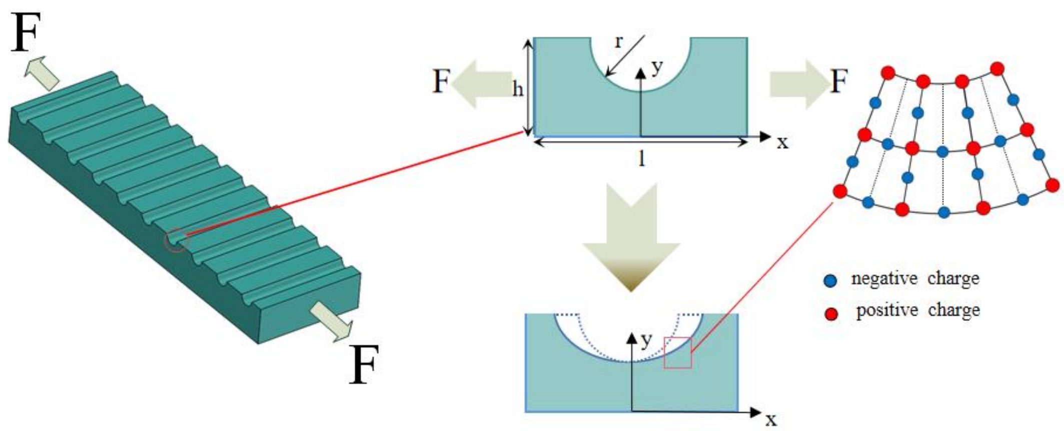

Fig.1. Schematic illustration of polymer elastomers with asymmetric structure and flexoelectrcity induced by force.