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Architected active metamaterials

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Multifunctional composites have found applications in energy conversion devices, structural health-monitoring systems, actuators, and sensors [1.2]. Electroactive cellular materials such as piezoelectric cellular materials (PCMs) play a key role in advanced multifunctional composites industry by virtue of their unique elastic, dielectric and electromechanical coupling characteristics [3]. The architecture-property relationship of cellular materials (CMs) can be exploited to optimize piezoelectric cellular materials for specific applications. However there is a need to fully understand the role of the geometric cellular features on the dependence of the effective electromechanical properties.

Here, we propose three classes of novel 3-3 piezoelectric metamaterials based on honeycomb like cellular networks. These included conventional hexagonal honeycomb structure, a re-entrant feature which is known to generate auxetic behavior and a semi-re-entrant which is constructed using alternate conventional and auxetic layers. The conventional honeycomb, re-entrant and semi re-entrant show variety of deformation behavior and can produce positive, negative and even zero Poisson's ratio in certain configurations. Passive response of such cellular materials have been extensively studied. Here, three dimensional finite element (FE) models of 3-3 PCMs were developed to study their electromechanical properties. We investigate the effect of orientation of ligament for these three class of cellular materials on the effective electromechanical properties and their suitability in specific engineering applications such as hydrophones. Moreover, we investigated the role of anisotropic properties of cellular material constituents, the sensitivity to the poling direction and its orientation with respect to the porosity of the cellular materials on the electromechanical properties of PCMs. FE results were compared with the analytical solutions available in the literature. Numerical results showed that the excellent piezoelectric properties can be obtained and PCMs exhibit unique combination of properties (low impedance and more sensitivity) couple with auxetic type deformation.

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