Proceedings of the Canadian Society for Mechanical Engineering International Congress 2021
CSME Congress 2021
June 27-30, 2021, Charlottetown, PE, Canada

Hierarchical Cellular Ferroelectric Metamaterials

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ABSTRACT

The engineering of microstructures has been adopted as an effective approach to tune the overall performance of advanced materials. In this article, inspired by hierarchical porous biomaterials, the multiphysical properties of hierarchical cellular ferroelectric metamaterials constructed of six commonly used primitive cubic unit cells are elicited. Both multiscale asymptotic homogenization and scaling relationship methods are proposed to predict the effective ferroelectric properties of hierarchical cellular metamaterials. Analysis on the influence of design parameters, e.g. hierarchical order, cell topology, and relative density on their effective ferroelectric figures of merit is conducted. The 2nd-order hierarchical cellular ferroelectric metamaterial exhibits remarkable improvement compared to the corresponding 1st-order unit cell. For example, the normalized FOM_{33} of hybrid 2nd-order T3-2/L3-1 (ρ_1 = 0.2, ρ_2 = 0.25) is 117.49, while it is 19.95 for 1st-order L3-1 (ρ = 0.05). Increasing the structural hierarchical order can further improve the effective ferroelectric properties of hierarchical cellular ferroelectric metamaterials. This work highlights the potential of ultralight hierarchical ferroelectric metamaterials as the next generation of hydrophone, IR detector, flexible self-powered sensors, and thermal energy harvesting devices.

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