Voltage Controlled Topologically Protected Wave Propagation in Dielectric Membrane-type Acoustic Metamaterials

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Abstract

Topological acoustic metamaterials have attracted enormous research attention in recent years. A significant hallmark of these structures is that they can support interface modes that are robust to structural disturbance and protected by topology. However, most of the studies are often limited to the passive structures that manifest wave propagation at fixed frequency ranges. In view of the shortage of non-passive topological acoustic metamaterials, this work has a primary motive to study the active control of topologically protected wave propagation in soft dielectric membrane-type metamaterials (MAM) based on quantum spin Hall effect (QSHE). The unit cell of the periodic structure is designed with C_{6v} symmetry. Then, the plane wave expansion method is adopted to analytically capture the system dispersion properties. A finite element model is further developed and excellent convergence with the analytical result is presented. By adjusting locations of spraying discs in the honeycomb unit cell, mode shape inversion is observed, separating the topologically trivial state from the nontrivial counterpart. Consequently, the topologically protected interface modes (TPIMs) are observed. Additionally, an electrical voltage that lies within the locking-up limit is applied to MAM to actively control the working frequency of the TPIM. Further, several waveguide paths are designed to control the robust wave propagation in the structure. Conclusively, a voltage-controlled topological metamaterial is designed to actively tune the working frequency range of the device.

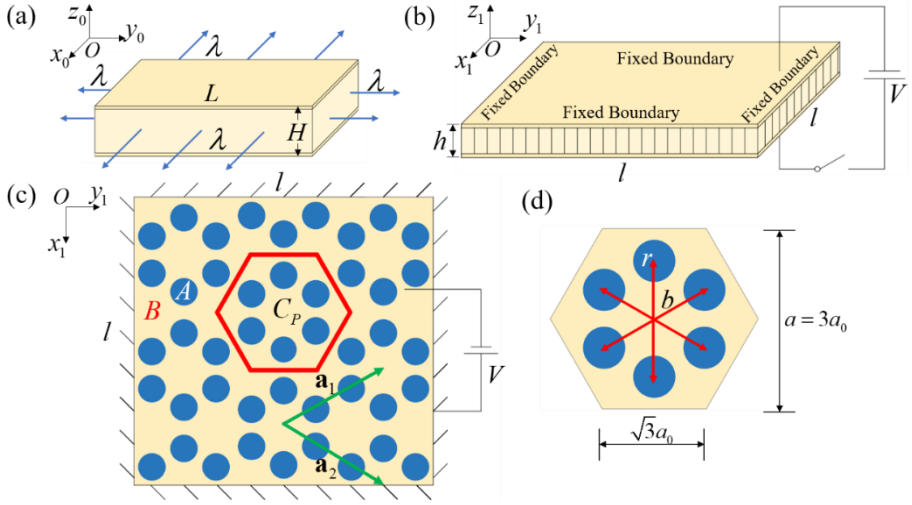

Fig 1. (a) Initial state of MAM applied with equi-biaxial pre-stretch in an XOY plane; (b) fixed boundary is applied to the deformed MAM controlled by an applied voltage; (c) top view of MAM after spraying heavy metallic particles on both sides; (d) unit cell of MAM.

References

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