Purdue University
Purdue e-Pubs

IUTAM Symposium Architectured Materials Mechanics | Symposium Contributions

Sep 17th, 12:00 AM - Sep 19th, 12:00 AM

A Numerical Simulation Capability for Electroelastic Wave Propagation in Dielectric Elastomer Composites: Application to Tunable Soft Phononic Crystals

Michael Jandron
Naval Undersea Warfare Center, michael.jandron@navy.mil

David Henann

IUTAM Symposium Architectured Material Mechanics,
T. Siegmund, F. Barthelat, eds
September 17-19, 2018, Chicago, IL, USA, , Chicago, IL, USA

A numerical simulation capability for electroelastic wave propagation in dielectric elastomer composites: Application to tunable soft phononic crystals

Michael Jandron[1,2], David Henann[1]
(1) School of Engineering, Brown University, Providence, RI
(2) Naval Undersea Warfare Center Division Newport, Newport, RI

KEYWORDS:
Dielectric Elastomers, Phononic Crystals, Wave Propagation, Tunable Materials

Phononic crystals are periodic, composite materials that exhibit phononic band gaps – frequency ranges in which elastic waves are prohibited [1]. For phononic crystals made from soft elastomers, phononic band gaps may be reversibly manipulated through large elastic deformation of the periodic structure [2]. By using soft dielectric elastomers, which undergo large, reversible deformations when acted upon by an external electric field, the frequency ranges of band gaps may be adjusted, and/or new band gaps may be created through electrical stimuli [3].

In this talk, we will discuss our finite-element-based numerical simulation capability for designing electrically-tunable, soft phononic crystals [3,4]. Our finite-element tools address both nonlinear quasi-electrostatic processes and the linearized dynamics of electroelastic wave propagation through a pre-deformed state and may be applied to general composite unit-cell geometries subjected to arbitrary far-field electromechanical preloading. We apply our simulation capability to electrically-tunable, soft phononic crystals consisting of periodic lattices of aligned circular-cross-section fibers embedded in a matrix and demonstrate the shifting of band gaps with electrical preloading parallel to the fibers and the opening, closing, and shifting of band gaps with electrical preloading perpendicular to the fibers. As an example, for a hexagonal lattice of fibers, Figure 1(a) shows the shifting of frequency band gaps with electrical preloading parallel to the fibers, and Figure 1(b) shows the opening, closing, and shifting of band gaps with electrical preloading perpendicular to the fibers. Figure 2 shows the detailed dispersion relations corresponding to Figure 1(b). Finally, we will discuss harnessing electro-mechanical instabilities as a route for enhanced tunability and investigate the roles of large-stretch chain-locking behaviour, material parameter contrasts, and fiber volume fraction.

Acknowledgments

This work is supported through the Naval Undersea Warfare Center In-house Laboratory Independent Research (ILIR) program and funds from the Brown University School of Engineering.

References

[1] Kushwaha, M. S., P. Halevi, and G. Martínez (1994). Theory of acoustic band structure of periodic elastic composites. *Phys. Rev. B* 49, 2313–2322.

[2] Bertoldi, K., and M. Boyce (2008), Wave propagation and instabilities in monolithic and periodically structured elastomeric materials undergoing large deformations. *Phys. Rev. B* 78, 2008.
[3] Jandron, M. and D. Henann (2017), A numerical simulation capability for electroelastic wave propagation in dielectric elastomer composites: Application to tunable soft phononic crystals, *Int. J. Solids. Struct., Submitted.*
[4] Henann, D. L., S. A. Chester, and K. Bertoldi (2013), Modeling of dielectric elastomers: Design
of actuators and energy harvesting devices. *J. Mech. Phys. Solids* 61, p. 2047–2066.

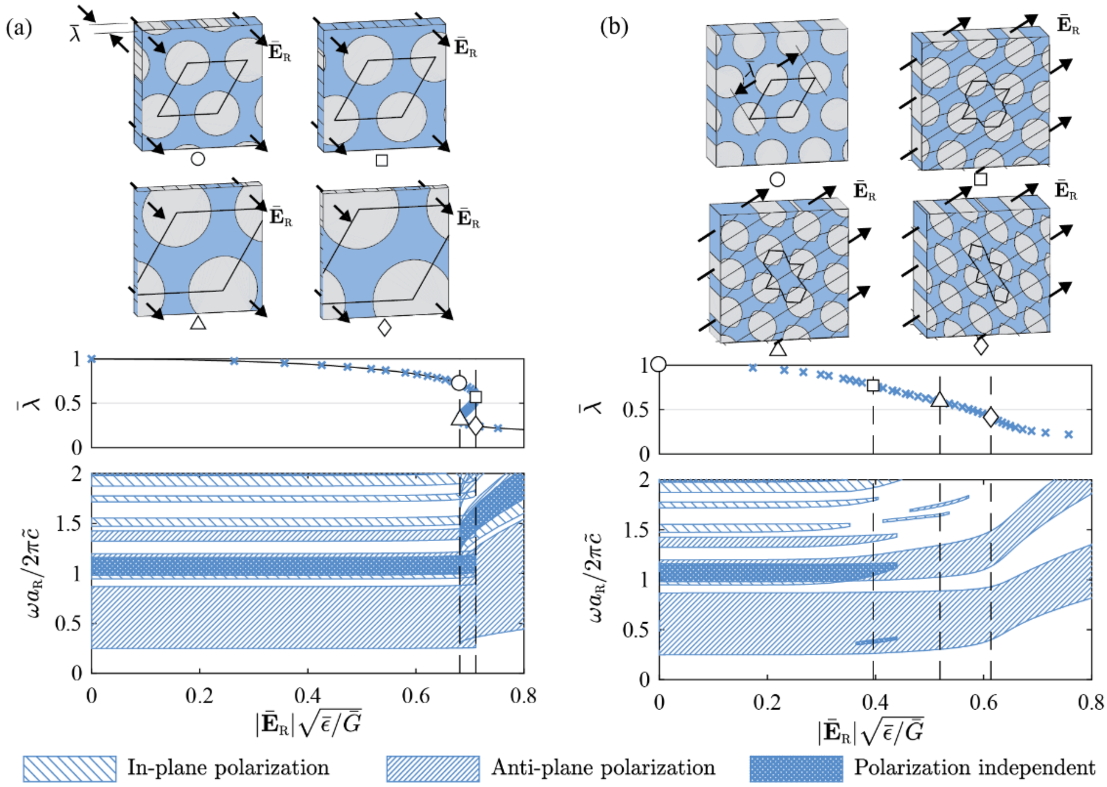

Figure 1. Electrical tunability of dielectric elastomer composites made from Gent materials, arranged in a hexagonal lattice and preloaded (a) parallel to the fibers, and (b) perpendicular to the fibers along the least-packed direction. The plots represent the dependence of frequency band gaps on the electric field (normalized frequency on the vertical axis with normalized electric field on the horizontal axis). The corresponding macroscopic stretch is also shown along with several states of deformation.

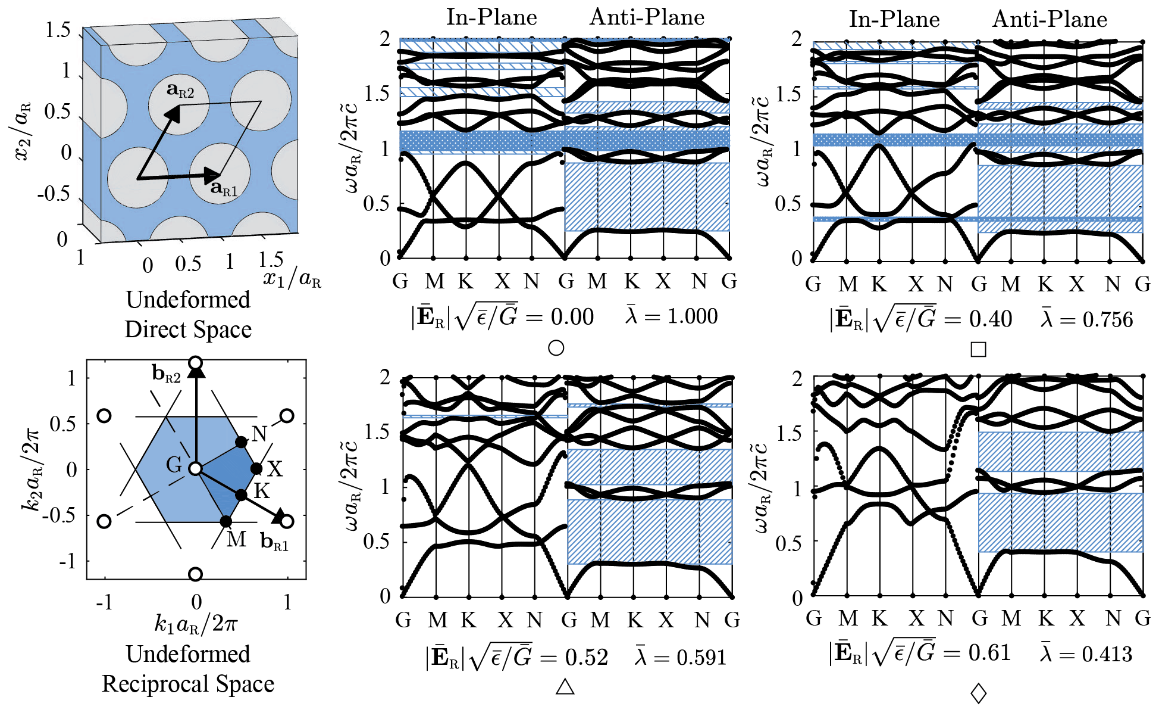

Figure 2. Dispersion relations corresponding to the markers in Figure 1(b). The direct lattice and reciprocal lattice are shown on the left.