Available online at www.scholarsresearchlibrary.com

Extended Abstract

Archives of Physics Research, 2020, 11 (2)
(https://www.scholarsresearchlibrary.com/journals/archives-of-physics-research/)

ISSN 0976-0970
CODEN (USA): APRRC7

Soft based hypersonic phononics

George Fytas
Max Planck Institute for Polymer Research, Germany
E-mail: fytas@mpip-mainz.mpg.de

Phononic structures (composite materials) in which a periodic distribution of elastic parameters facilitates control of the propagation of phonons, hold the promise to enable transformative material technologies in areas ranging from acoustic and thermal cloaking to thermoelectric devices. This requires strategies to deliberately engineer the phononic band structure of materials in the frequency range of interest. Phononics, the acoustic equivalents of the photonics are controlled by a larger number of material parameters, as phonon cannot propagate in vacuum. The study of hypersonic phononics (hPnC) imposes substantial demand on fabrication and characterization techniques. Colloid and polymer science offer methods to create novel materials that possess periodic variations of density and elastic properties at length scales commensurate with the wave length of hypersonic phonons and hence visible photons. The key quantity is the dispersion ω(q) of high frequency (GHz) acoustic excitations with wave vector q which is measured by the noninvasive high resolution Brillouin light scattering. The approach involves the exploitation of Bragg-type band gaps (BGs) that result from the destructive interference of waves in periodic media. However, the sensitivity of BG formation to structural disorder limits the application of self-assembly methods that are susceptible to defect formation. Hybridization gaps (HG), originating from the anticrossing between local resonant and propagating modes, are robust to structural disorder and occur at wavelengths much larger than the size of the resonant unit. Here, examples based on hierarchical structures will be highlighted: 1D-hPnC to acquire comprehensive understanding, while the incorporation of defects holds a wealth of opportunities to engineer ω(q); in colloid based phononics, ω(q) has revealed both types of band gabs; particle brush materials with controlled architecture of the grafted chains enable a new strategy to realize HG's and; hierarchically nanostructured matter can involve unprecedented phonon phono propagation mechanisms. Phononic crystals, the acoustic equivalents of the photonic crystals, are controlled by a larger number of material parameters. The study of hypersonic crystals imposes substantial demand on fabrication and characterization techniques. Colloid and polymer science offer methods to create novel materials that possess periodic variations of density and elastic properties at mesoscopic length scales commensurate with the wave length of hypersonic phonons and hence photons of the visible light. Polymer- and colloid-based phononics is an emerging new field at the interface of soft materials science and condensed matter physics with rich perspectives ahead. The key quantity is the dispersion of high frequency (GHz) acoustic excitations which is nowadays at best measured by high resolution spontaneous Brillouin light scattering. Depending on the components of the nanostructured composite materials, the resolved vibration eigenmodes of the individual particles sensitively depend on the particle architecture and their thermo-mechanical properties [T. Still et al., Nano Lett. 10, 3194 (2008)]. In periodic structures of polymer based colloids, the dispersion relation ω(k) between the frequency and the phonon wave vector k has revealed hypersonic phononic band gaps of different nature. Colloid and polymer science allows the engineering of acoustic and optical material functionalities of hierarchical structures on various length scales commensurate with and well below the characteristic length scales of phonons and photons. Periodic structures act as both hypersonic phononic and visible light photonic crystals (phoxonics). We recently extended the decade-old field to hypersonic phononics. Many important questions in this young field are just being raised and require new conceptual and technical approaches to address them.

Powerful synthesis and assembly methods are able to create novel structures to host unconventional properties of flexibility and multi-functionality, locally resonant hypersonic soft metamaterials and topological phononic insulators. To complement our best world-wide Brillouin spectroscopy for retrieving the dispersion relations in transparent structures, two new experimental techniques based on laser-induced high frequency phonons and tapered fiber optomechanics will be implemented to engineer strong wave-matter interactions. Band structure calculations will be used as tools to model and predict the acoustic wave propagation in composite structures of varying symmetry, architecture and topology of the building components. Our novel approach, together with intricate methods of processing such materials at a large scale, shows the outline of the emerging field of polymer-and colloid-based phononics.

Promising applications range from tunable responsive filters and one way phonon waveguides to compact acousto-optic devices and sensors and from hypersonic imaging to materials and devices, which allow for directed heat flow and recovery. To access such fundamental concepts a detailed understanding of phonon propagation in nanostructured media is a precondition. This proposal ensures that we will hear much more about currently unknown and unexpected properties and functions of soft phononics and will open up many new lines of research.

Bottom Note: *This work is partly presented at 4th International Conference on Physical and Theoretical Chemistry September 18-19, 2017, Dublin, Ireland*