Thermal tuning on band gaps of the coupled extensional, thickness-stretch, and thickness-twist waves in a periodic AT-cut quartz crystal nanoplate with consideration of the surface and nonlocal effects

Wenjun Wang[1], Peng Li[1,2], and †*Feng Jin[1]

[1]State Key Laboratory for Strength and Vibration of Mechanical Structures, School of Aerospace, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China

[2]School of Human Settlements and Civil Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China,

*Presenting author: jinfengzhao@263.net

†Corresponding author: jinfengzhao@263.net

Abstract

Based on the size-dependent two-dimensional (2D) theory of piezoelectric plates considering surface and nonlocal effects, a theoretical model of one-dimensional (1D) phononic crystals (PCs) nanoplate with consideration of surface and nonlocal effects is developed successfully and used to investigate theoretically the size-dependent characteristic and thermal field-dependent active modulation of the band structures of the coupled extensional (E), thickness-stretch (TSt), and thickness-twist (TT) waves in a periodic AT-cut quartz crystal nanoplate, which can completely describe the band gap behavior of the PCs plates from views of microscopic and macroscopic. The analytical results indicate that the influence of the surface and nonlocal effects is more remarkable for the higher-order band gaps despite the slight change for the lower-order band gap, which have a significant impact on the band gap characteristic in high frequency region. Besides, the thermal field-dependent active modulation of the band structures for nanoscale PCs has been achieved theoretically by applying the external stimuli temperature fields. To some extent, the open and close, location and width, as well as number of the band gaps in the considered frequency region can be actively tuned by applying the different temperature fields, which mainly due to the strongly temperature-dependent elastic properties of PC materials. Totally speaking, the current work is essential and crucial for the thermal field-dependent active modulation of the nanoscale PCs. Meanwhile, these results provide an efficient guidance for active controllability of the coupled elastic waves propagation and intelligent regulation of phononic nanodevices.

Keywords: PCs nanoplate, surface and nonlocal effects, band gaps, thermal field, active tunability