Controlling hypersonic phonon propagation in one component polymer nanocomposites

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Phononic hybridization band gaps, originating from the anti-crossing between local resonant and propagating modes, are robust to structural disorder and hence attract particular interest in areas ranging from acoustics to thermo-optic devices. The study of hypersonic phononic crystals imposes substantial demand on fabrication and characterization techniques. Here, we employ polymer chains tethered on silica colloidal particles assuming different polymer density profile which depends on the grafting density and degree of polymerization. We recently pointed out that the brush architecture play a role in dynamical (local and global) and thermomechanical properties of particle-brush both in the individual and assembled (film) state. Through this new approach harnessing local anisotropy of the elastic parameters across the silica/polymer (polystyrene) particle's interface, we tune the phononic band diagram, ω(k), of ordered (also known as "particle brush") films. Theoretical and Brillouin scattering analysis confirm both the robustness to disorder and the tunability of the resulting hybridization gap via variation of length and conformation of tethered polymer chains. Unlike usual hard colloids at nanoscale (e.g. close-packed silica arrays) a flat band of strongly localized rotational modes appears, originating from torsional vibration modes of the isolated particle-brush and, more interestingly, sensitive to the specific polymer chain architecture which controls the interactions between particles. The material crowding reduction in the solid-polymer interface leads to shrinkage of polystyrene chains and chain interpenetration between neighboring particles in the ordered films thus enhancing multiple scattering interactions. Moreover, swelling (which leads to matrix softening thus increasing the band gap width and lowering the frequency of the flat mode) is shown to be an additional stimulus to tune the phonon propagation and the band structure in such particle brush materials. Hence tuning of the band diagram in hypersonic phononic crystals becomes feasible through engineering of polymer chain architecture.