Architecture Controls Phonon Propagation in All-Solid Brush Colloid Metamaterials

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To understand and control the propagation of phonons in materials has emerged as an important requisite to advance innovations in materials that are relevant to a wide range of technology areas such as high-frequency filters, telecommunication, optomechanics and thermal transport. In this contribution, the formation of phononic band gaps in self-assembled colloidal brush materials is investigated using Brillouin light scattering. The results demonstrate that brush architecture exerts a profound impact on the phonon dispersion characteristics of brush particle assembly structures. In sparse brush systems, the phonon dispersion displays similarity to regular two-component colloidal structures such as polymer-embedded colloidal crystal assemblies. The phonon dispersion relation is well represented by elastodynamic theory under the assumption of perfect boundary conditions, indicating an isotropic distribution of stiffness across the particle/polymer interface. In contrast, dense colloidal brush assemblies feature more complex dispersion characteristics. The full elastodynamic theory reveals that the different dispersion characteristics are well described by application of imperfect boundary conditions. The latter are consistent with stiffness anisotropy across the particle/polymer interface which is consistent with the orientation of chains due to crowding across a region adjacent to the interface.