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Nanoscale Phononic Crystal Membranes for Low Temperature Detector Applications

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Nanoscale phononic crystals (PnC) are promising components for several low temperature detector technologies, such as bolometers, transition edge sensors and kinetic inductance detectors (KID). Recent experimental and theoretical studies demonstrate a wide range of tunability for thermal properties of PnCs with correctly chosen geometry. [1-2] Low temperature applications of PnCs often rely on modifications in the phonon band structure, which affects DOS and velocity of heat carrying phonons. For instance, reducing thermal conductance and improving heat capacity is important in optimizing responsivity of bolometric detectors. Furthermore, a PnC can be designed to operate as high frequency notch filter matched to the energy gap of a superconductor. This can effect can improve sensitivity of KIDs by restricting escape of quasiparticle recombination phonons from the KID inductor. [3]

In this work, we discuss theoretical design process of thin film PnCs for low temperature detector applications. We develop a 3D finite element simulation model based on scattering of elastic waves from the PnC, and use it to estimate phonon escape probabilities. Our calculations demonstrate that obtaining a full band gap for Hafnium at ~32 GHz is possible with simple PnC designs that are producible with current nanofabrication techniques. PnC filters can attain extremely high reflection for the recombination phonons, and effectively no restriction for the low frequency thermal phonons, thus preventing excessive heating of the KID inductor. We also demonstrate that a full band gap is in fact not compulsory, and positive effects can be obtained with less extensive modifications to the phonon spectrum.

References:
[1] N. Zen, et al. Nat. Commun. 5, 3435 (2014).
[2] T. A. Puurtinen and I. J. Maasilta, AIP Adv. 6, 121902 (2016).
[3] K. Rostem, P. J. de Visser and E. J. Wollack, Phys. Rev. B 98, 014522 (2018).

Less than 5 years of experience since completion of Ph.D

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