Topic Emerging Materials and Devices

Nanoscale phononic crystal fabrication using colloidal lithography

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Figure

Phononic crystals, as shown in Fig. 1(a), are an important category of metamaterials for various applications where the flow of heat needs to be steered. The phononic metamaterials may be used to scatter phonons such that the thermal conductivity of the engineered material is lowered compared to its pristine state. This can be utilized to make better thermoelectric materials, for bolometric applications and even high-performance thermal insulators for maintaining low temperatures [1, 2, 3].

Colloidal lithography techniques [4] involve the use of nano- or micro-scale spherical beads of silica or plastic, dispersed in a solution. The solution is coated on a crystalline silicon substrate to obtain mono-layer close-packed coverage of the solid beads (dia. 1.1 μm), over unbroken areas ~ 400 μm X 100 μm as shown in Fig. 1(b). The beads can act as a primary mask during further processing. We control the size of the beads by oxygen plasma treatment prior to additional processing. Then a thin layer of Ni is deposited and lifted-off to transfer the pattern to the metal layer. The Ni-layer contains periodic holes at the sites where the beads were located. Finally, using the secondary metal mask the underlying partially bared substrate is etched by reactive ion etching as shown in Fig. 1(c). The metallic mask is removed by standard etchant, thus concluding the creation of a periodic array of holes in the silicon. The initial bead diameter and subsequent control of their size by plasma determine the pitch of the periodic structure, and consequently the degree of phonon scattering. Higher rate of phonon scattering lead to greater suppression of the thermal conductivity. Further details of the fabrication process will be presented.

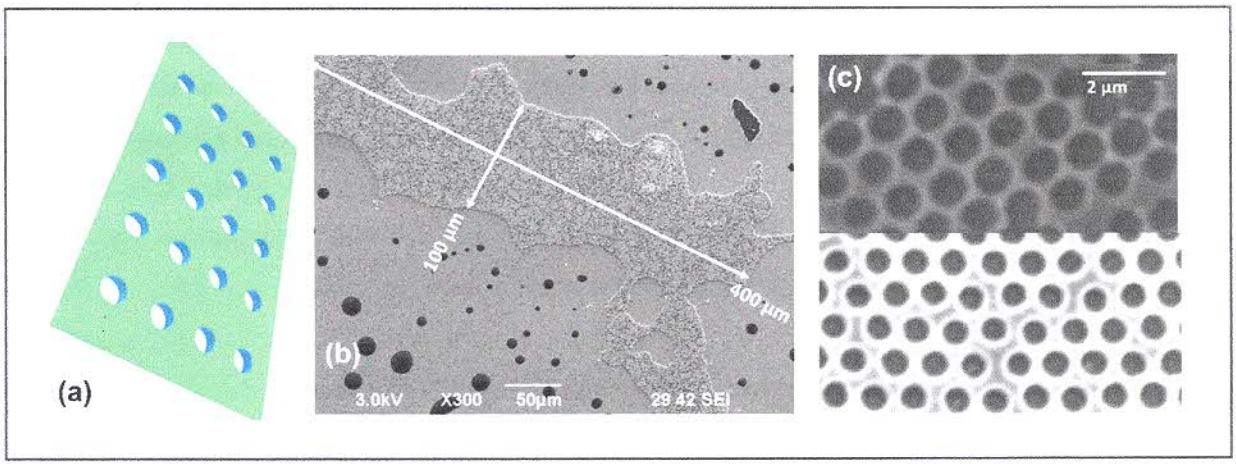

Figure 1: (a) Schematic of a phononic crystal containing 2-dimensional arrangement of holes in a regular periodic fashion; (b) the scanning electron microscope (SEM) image of the monolayer close-packed arrangement of polystyrene beads on silicon substrate by spin coating the colloidal solution of the beads; and (c) the SEM image of the phononic crystal fabricated by dry etching of the nickel secondary mask.

References

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