FABRICATION OF 3D PHONONIC CRYSTALS FOR THERMAL TRANSPORT MANAGEMENT

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Thermal transport is an important physical phenomenon, and it has recently become even more relevant for the reduction of energy losses and the increase of efficiency in novel devices based on thermoelectricity [1]. Significant reduction of thermal conduction was recently achieved by coherent modification of phonon modes [2], with the help of periodic phononic crystal structures. However, currently the experimental studies have only been performed for two-dimensional (2-D) nanostructures. Theoretically, the magnitude of control of thermal transport should be even stronger in three-dimensional (3-D) phononic crystal structures. For that reason, the question arises how to fabricate the desired 3-D phononic crystal nanostructures.

We have already used 260 nm diameter polystyrene colloidal crystals in the fabrication of 3-D phononic crystals [3]. Unfortunately, this material is typically not stable enough under harsh chemical compounds required in e-beam lithography. For that reason, here we introduce the non-organic material, silicon dioxide (SiO_2), in the form of spherical 170 nm sized colloidal crystals. Low-concentration deionized water solution of SiO_2 spheres was used for single-step vertical deposition in order to receive self-assembled close packing crystal 3-D nanostructure (Fig. 1) [4]. The colloidal crystals are deposited on silicon nitride chip coated by thin titanium oxide layer to make the surface hydrophilic. The most challenging step in fabrication this structure is to make superconducting tunnel junctions on top of this rough nanosphere surface for thermometry. Different methods were tested, out of which the deposition of thin aluminum oxide layer (up to 100 nm) using atomic layer deposition (ALD) on top of thick (few microns) SiO_2 3-D structure at low temperature (50-80 ˚C) gives promising results. However, it does not solve the problem of coating wider cracks, which are created due to the domain structure of self-assembled colloidal crystals [3]. The coating with the material initially in liquid phase might be the proper solution to this problem. That is why negative photoresist (SU-8) was found to be the most promising material to make rough nanosphere surface smooth, giving us the possibility to fabricate tunnel junctions on top of it, with initial steps already in progress.

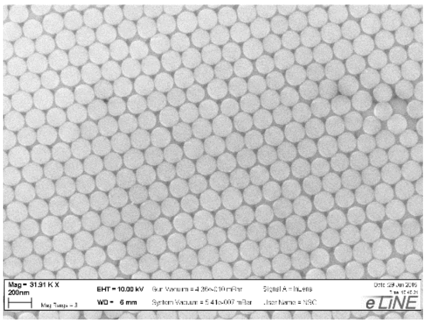

Figure 1. Top view of self-assembled silicon dioxide colloidal crystal structure.

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