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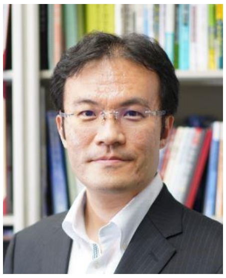
Invited Talk



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Heat transfer in nanostructured Si and heat flux control technique

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<Abstract>

Heat transfer in Si nanostructure is not only an interesting topic in fundamental physics, but also an important practical study for efficient heat dissipation in electronic devices. In this talk, fundamentals of thermal phonon transport in nanostructured Si will be explained and some technique to control heat flux in Si membrane by nanostructuring will be introduced.

Heat dissipation is described by Fourier law in bulk material and the phonon transport is completely diffusive in this system. However, in micro/nano structures, where thermal phonon mean free paths are shorter than typical dimension of the structures, phonon transport will be semi-ballistic. In semi-ballistic phonon transport regime, thermal conductivity is no more intensive variable. Boundary or surface scattering processes determine the thermal conductivity of the system. In other words, nanostructuring can control the thermal conductivity of the material. For effective control of the thermal conductivity, the dimension of nanostructure should be designed by taking into account of thermal phonon spectrum of the material. Thermal phonons distribute to very broad frequency range, which corresponds to broad mean free path range. Therefore, it is essential to clarify the phonon mean free path spectrum and prepare nano/micro structures to impede the phonons in the volume zone. Thermal conduction reduction in well-designed poly-Si membranes with phononic crystal patterning will be introduced [1].

It is also interesting to develop heat flux control technique in Si by nanostructuring. We experimentally demonstrate formation of directional fluxes of ballistic phonons in one- and two-dimensional silicon phononic nanostructures, in which periodic arrays of nano-holes or corrugations formed directionality of the thermal phonons. This effect makes guiding and even focusing of heat fluxes possible in Si by nanostructuring [2, 3].

[1] M. Nomura, et al., Phys. Rev. B 91, 205422 (2015).
[2] R. Anufrief, et al., Nat. Commun. 8, 15505 (2017).
[3] R. Anufrief, et al., ACS Nano 12, 11928 (2018).

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Masahiro Nomura is Associate Professor in Institute of Industrial Science, The University of Tokyo. He received Ph.D. degree in Applied Physics in 2005, respectively, from The University of Tokyo. His research interests include hybrid quantum science, phonon/heat transport in semiconductor nanostructures, and energy harvesting by thermoelectrics. The concept of his current research is “from photonics to phononics” using phononic crystals, which have some physical analogy with photonic crystals. He is a recipient of The Young Scientists’ Prize by the Minister of Education, Culture, Sports, Science and Technology (2012), ISCS Young Scientist Award (2017), German Innovation Award – Gottfried Wagener Prize (2018), and ten other awards.