High Refractive Index Photonic Crystals for Simultaneous Enhancement and Redistribution of the Spectral and Directional Thermal Radiation

Dong Liu [C, S], Hai-Tong Yu, Zhen Yang and Yuan-Yuan Duan
Department of Thermal Engineering, Tsinghua University, Beijing, China
liu-d10@mails.tsinghua.edu.cn

Outstanding control of thermal radiation properties is significant in many energy conversion processes including solar-thermal, solar-photovoltaics, solar-thermochemical and solar-thermophotovoltaics. The radiance, E, at a wavelength , λ, in a direction, ϑ, is the most fundamental quantity in thermal radiation. The blackbody hemispherical radiance over the entire spectrum obeys the well-known Stefan-Boltzmann law along with the Planck spectral distribution and the Lambertian directional distribution. Many studies have sought to enhance the thermal radiation in the far-field regime and the near-field regime or to tailor the spectral and directional radiance distributions. Here, we present general guidelines to design photonic crystals using transparent materials with high refractive index. Such photonic crystals are used to simultaneously enhance the thermal emissions and redistribute the spectral and directional radiation distributions. We observed an $n^{0.80}$-fold enhancement (n is the refractive index) of the blackbody hemispherical radiance and an $n^{1.04}$-fold enhancement of the blackbody normal radiance to the far-field vacuum at the selected wavelength where the vertical mode of the photonic crystal matches the destructive mode. In this case, the blackbody is modified to a wavelength selective thermal emitter with enhanced hemispherical and normal radiation fluxes. Our results shed light on applications of high refractive index materials in harvesting solar energy.