World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:17, No:09, 2023

Effects of Stokes Shift and Purcell Enhancement in Fluorescence Assisted Radiative Cooling

Authors : Xue Ma, Yang Fu, Dangyuan Lei

Abstract : Passive daytime radiative cooling is an emerging technology which has attracted worldwide attention in recent years due to its huge potential in cooling buildings without the use of electricity. Various coating materials with different optical properties have been developed to improve the daytime radiative cooling performance. However, commercial cooling coatings comprising functional fillers with optical bandgaps within the solar spectral range suffers from severe intrinsic absorption, limiting their cooling performance. Fortunately, it has recently been demonstrated that introducing fluorescent materials into polymeric coatings can covert the absorbed sunlight to fluorescent emissions and hence increase the effective solar reflectance and cooling performance. In this paper, we experimentally investigate the key factors for fluorescence-assisted radiative cooling with TiO2-based white coatings. The surrounding TiO2 nanoparticles, which enable spatial and temporal light confinement through multiple Mie scattering, lead to Purcell enhancement of phosphors in the coating. Photoluminescence lifetimes of two phosphors (BaMgAl10O17:Eu2+ and (Sr, Ba)SiO4:Eu2+) exhibit significant reduction of ~61% and ~23%, indicating Purcell factors of 2.6 and 1.3, respectively. Moreover, smaller Stokes shifts of the phosphors are preferred to further diminish solar absorption. Field test of fluorescent cooling coatings demonstrate an improvement of ~4% solar reflectance for the BaMgAl10O17:Eu2+-based fluorescent cooling coating. However, to maximize solar reflectance, a white appearance is introduced based on multiple Mie scattering by the broad size distribution of fillers, which is visually pressurized and aesthetically bored. Besides, most colored pigments absorb visible light significantly and convert it to non-radiative thermal energy, offsetting the cooling effect. Therefore, current colored cooling coatings are facing the compromise between color saturation and cooling effect. To solve this problem, we introduced colored fluorescent materials into white coating based on SiO2 microspheres as a top layer, covering a white cooling coating based on TiO2. Compared with the colored pigments, fluorescent materials could re-emit the absorbed light, reducing the solar absorption introduced by coloration. Our work investigated the scattering properties of SiO2 dielectric spheres with different diameters and detailly discussed their impact on the PL properties of phosphors, paving the way for colored fluorescent-assisted cooling coting to application and industrialization.

Keywords : solar reflection, infrared emissivity, mie scattering, photoluminescent emission, radiative cooling
Conference Title : ICRTSAE 2023 : International Conference on Radiative Transfer, Scattering, Absorption and Emission
Conference Location : Tokyo, Japan
Conference Dates : September 04-05, 2023