Experimental Investigation of a Photonic Radiative Cooler under Sub-tropical Climate

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Keywords: *Photonic Radiative Cooler, Passive Radiative Cooling, Thermal Radiation.*

Abstract

More than 30% of electricity consumption in the residential and commercial sectors is for space conditioning in Hong Kong. Reducing the energy consumption for space conditioning is essential to develop energy-efficient buildings. There are various techniques for space conditioning, but radiative cooling is a very attractive one, since it requires no electricity and is environmentally friendly. By using a photonic structure to selectively reflect and emit photons in different wavelength regimes, net cooling can be achieved if the emission of infrared to outer space, (where the radiation background temperature is 2.7 K) exceeds the absorption of sunlight and environmental thermal radiation. In other words, to realize net passive radiative cooling below ambient air temperature, strong reflection of sunlight and strong emission of thermal radiation with a wavelength within the atmospheric infrared window (8-13 microns) must be achieved simultaneously. In this study, an integrated photonic solar reflector and thermal emitter, also named a passive radiative cooler, has been developed. The cooler consists of seven alternating layers of HfO_2 and SiO_2 with different thicknesses, on top of 200 nm of silver, and all are deposited on a 200 mm diameter silicon wafer. The cooler has been tested under the Hong Kong hot and humid climate. Three different thermal designs of the cooler have been studied. The three designs include non-vacuum, and vacuum with seven potassium chloride (KCl) IR-Pass windows as well as one system with a single KCl IR-Pass window. The coolers have been examined during daytime and night time operation as well as under different sky conditions. Investigation is mainly based on the temperature difference between the radiative cooler and ambient air. The experimental results show that the passive radiative cooler with seven KCl windows and the cooler with non-vacuum design provide a satisfactory cooling effect at night (i.e. the ambient air temperature is reduced by about 7 ^{o}C), but the coolers cannot produce a cooling effect during daytime under any of Hong Kong's weather conditions. The same results are obtained for the passive radiative cooler with the single KCl window design during daytime operation. However, the cooling capacity of the passive radiative cooler with non-vacuum design under a clear sky night achieves 38 W/m^2. Overall, this study indicates that cooling by using night radiation technique seems to be feasible in Hong Kong, but there remains much work to successfully produce the cooling effect under direct sunlight in Hong Kong's climate.