Radiative cooling by tailoring surfaces with microstructures

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Lots of structures, such as multi-layer or photonic structures, have been proposed for applications of radiative cooling : total reflection in the solar spectrum and total emission in the atmospheric transparency window (8-13 μ m). In this study, we optimize a structure combining a multi-layer and a grating. It is the first time that simple gratings are used for radiative cooling applications.

We use optimized BN, SiC and SiO_2 gratings, which have emissivity peaks in the transparency window. We place under these gratings a metal/dielectric multi-layer structure to obtain a near perfect reflectivity in the solar spectrum and to enhance the emissivity in the transparency window. This design, combining grating and multi-layer, allows engineering adaptive thermal emission to radiative cooling requirements. Multi-layer structures create resonant radiative modes that help a heated structure to radiate thermal energy in the far-field. Gratings diffract non radiative modes like surface waves, such as surface phonon-polaritons. Thus, a structure combining a multi-layer and a grating allows to couple and radiate both radiative and non-radiative modes. It constitutes an advantage compared to other structures.

We used the Rigourous Coupled Wave Analysis (RCWA) method coupled to a particle swarm optimization (PSO) algorithm to optimize our structure. The optimized structures produce a good radiative cooling power density up to 80 $W.m^{-2}$ at night and a mean daytime radiative cooling power density of 55 $W.m^{-2}$, with local atmospherical and solar conditions in Poitiers.
2D gratings of our theoretical structure and experimental prototypes are also considered in order to converge to practical applications.

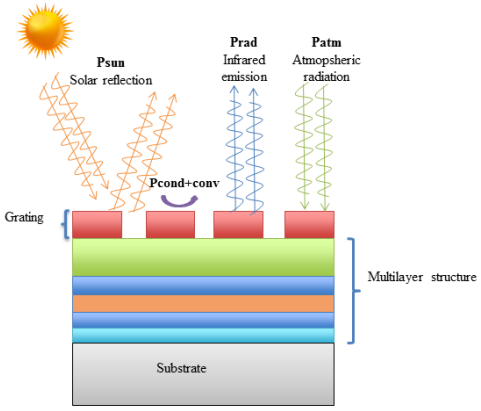

Figure 1 : Schematics of a radiative cooler composed of a multi-layer structure and a grating overhead with the radiative and non-radiative processes taking place