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Spectral Emissivity Evolution of Radiative Cooling Materials during Water Condensation

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Meta-materials radiative properties engineering for radiative cooling applications has drawn increasing attention in the micro and nano-scale heat transfer community during the past decade [1–3]. For this purpose, the primary adopted strategy is to design materials with high emissivity in the atmospheric transparency window [8-13] μm , for instance, and high reflectivity (low emissivity) elsewhere. When used in real conditions, i.e., outdoors, the materials' radiative properties can be affected by various external factors such as dust, mechanical damage, or water vapor condensation when the cooling temperature goes below the dew point temperature. In some applications, such as dew water harvesting, the external processes (condensation in this case) are desired [4,5]. However, they can modify the radiative properties in an undesired manner, reducing emissivity in the atmospheric window and the resulting radiative cooling power. In this work [6], we report for the first time on the evolution of the spectral emissivity of a radiative cooling material during water condensation. We designed and used an ad hoc experimental setup to monitor the spectral emissivity dynamics in situ during condensation, combining FTIR spectroscopy and microscopy under controlled environmental conditions (temperature, relative humidity, surrounding gas, etc.). We show that the emissivity at saturation is that of water for the film case and weighted by the drop surface coverage for the drop case. Theoretical calculations and numerical simulations support the experimental data. We also assess the localized contribution of droplets on emissivity through spectral images with a micron-scale resolution down to 6.25 μm . The obtained results are of interest to the development of passive radiative coolers for atmospheric vapor harvesting and, more generally, to understanding the influence of water on the spectral emissivity of any surface.

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