Supporting information

Cooling performance of TiO_2 based radiative cooling coating in tropical conditions

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S1 Design of paint coating

The design of a paint coating involves optimizing several parameters, including the particle's radius, volume fraction, and coating thickness. To model the radiative properties of the coating, we rely on the Kubelka-Munk (KM) theory [1–3] and a semi-analytical technique [4]. The design process proceeds in two stages:

- The KM theory [1–3] is first employed to determine the optimal radius for the spherical TiO_2 pigment particles.
- With the optimized pigment particle size as a given input, the pigment volume fraction is fine-tuned using our proprietary semi-analytical technique [4].

The complex refractive indices of TiO_2 and PDMS used in the simulation are given in Fig. S1. In the first stage the pigment volume fraction and coating thickness are kept constant at 5% and 1 mm, respectively. This low volume fraction avoids any dependent scattering, and the larger thickness ensures that reflective performance isn't affected by variations in its depth. Since TiO_2 absorbs in the ultraviolet range up to 0.39 μm, all weighted reflectivity ($R = \int I_{\mathrm{AM1.5}}(\lambda)R(\lambda)d\lambda / \int I_{\mathrm{AM1.5}}(\lambda)\, d\lambda$, where $I_{\mathrm{AM1.5}}(\lambda)$ is the spectral solar irradiance [5]) calculations aimed at optimizing design parameters are carried out over the 0.39–3 μm spectrum. The weighted reflectivity values for different radii are shown in Fig. S2a. The weighted reflectivity of TiO_2/PDMS coating for pigment radius 0.25 μm is maximum and thus this value is considered for the optimization of volume fraction.

In the subsequent stage, we employ the semi-analytical methodology detailed in [4] to determine the optimal volume fraction f of the scattering pigment. The results are presented in Fig. S2b, which shows the calculated reflectivity of the coating for varying f. Coatings with $f = 15$ % and 20 % show similar performance with $R_{\mathrm{solar}} = 96.5$ % and 97.0 %, respectively. Thus, 15 % pigment volume fraction is considered for the development of paint. Moreover, when examining the 15 % volume fraction coating across different thicknesses, it becomes evident that beyond the 250-300 μm mark, any increment in reflectivity is marginal.

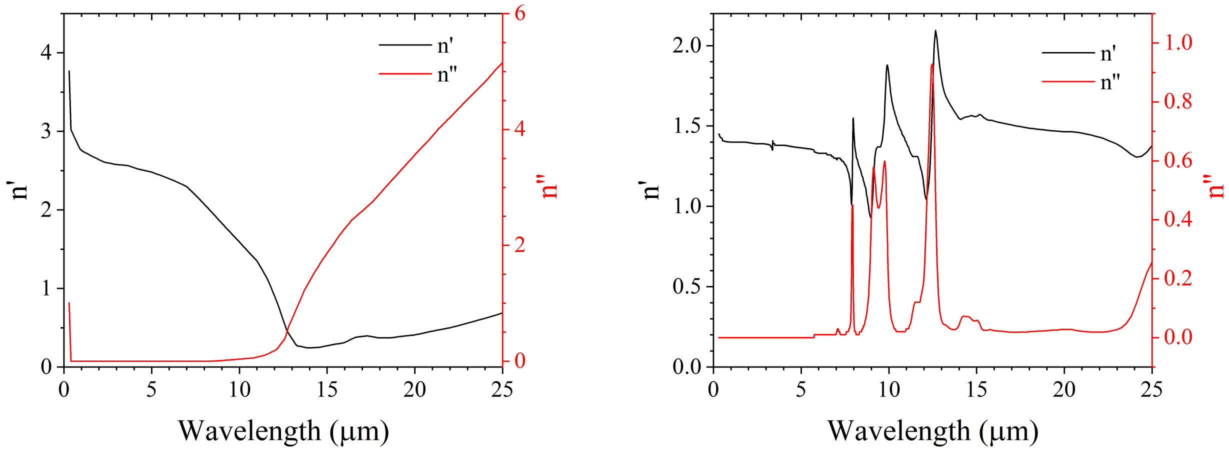
S2 Calculation of atmospheric transmittance using MODTRAN

The atmospheric transmittance calculation is done using MODTRAN which takes precipitable water vapour (PWV) as an input. The PWV (or total water column) is related to the relative humidity (RH) and ambient temperature. We adopt a method developed by Dong et al. [6] to calculate PWV from RH and ambient temperature. First, absolute humidity (AH) is evaluated in terms of RH and ambient temperature using the following expression

$$\mathrm{AH} = k\ \mathrm{RH}\ T^{a-1}10^{c+b/T}, \quad (1)$$

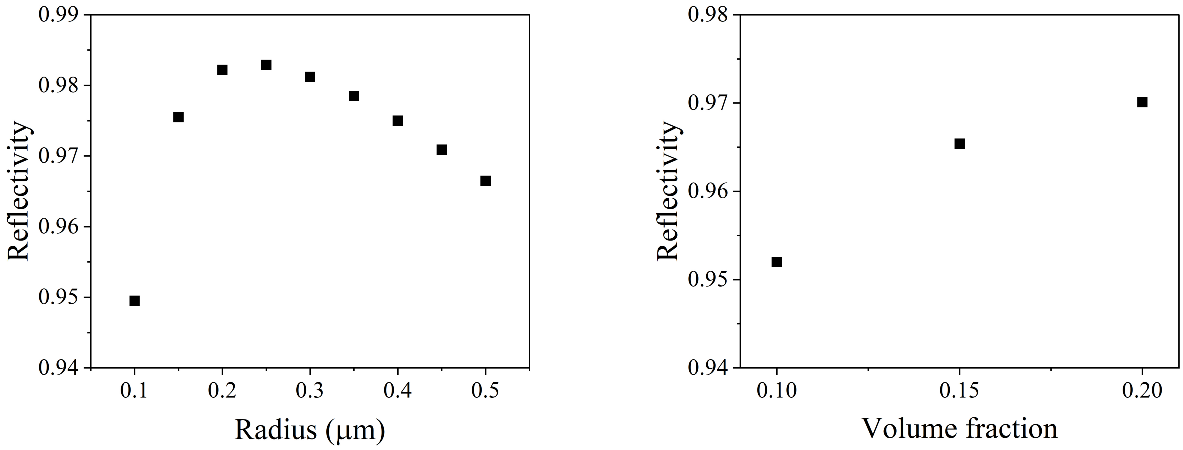
where, AH has units 10^{-3}g cm^{-3}, T has units of Kelvin and the coefficients $a = -4.9283, b = -2937.4$, $c = 23.5518$ and $k = 0.21668$ g K bar^{-1} cm^{-3}. Mumbai being a tropical region, the water column profile of the tropical atmosphere used in MODTRAN is selected to calculate

PWV from AH. As mentioned by Dong et al.[6], the specific density of precipitable water vapour (= AH $\times 10^5$) is calculated having its units as [g cm^{-2} km^{-1}]. It is then scaled for the entire atmospheric layer using the default distribution of the tropical atmosphere. The sum of the density of precipitable water vapour of all the layers will give the total PWV of the atmosphere.



(a) (b)

Figure S1: (a) Complex refractive index ($n' + in''$) of TiO_2[7]. (b) Complex refractive index ($n' + in''$) of PDMS[8,9].



(a) (b)

Figure S2: Reflectivity of TiO_2/PDMS coating for (a) various radius (r) of particles calculated using Kubelka Munk theory[1–3], keeping f (=5%) and L (=1 mm) constant, and (b) various volume fractions calculated using semi-analytical technique[4] keeping r (=0.25 μm) and L (=300 μm) constant.

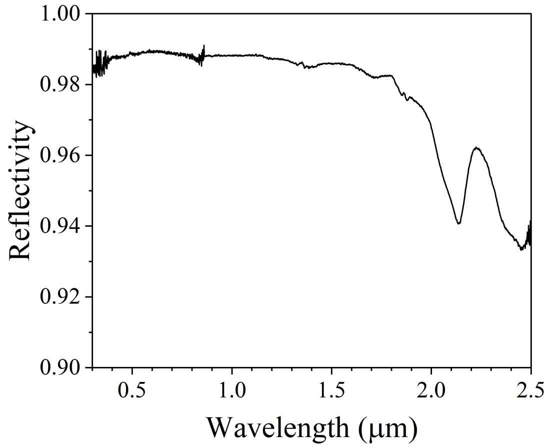


Figure S3: Reflectivity of the spectralon reflectance standard. Spectralon reflectance standard is used as a baseline correction to measure the reflectivity of the coating using UV-vis-NIR spectrometer. The obtained relative reflectivity is then multiplied by the reflectivity spectrum of spectralon reflectance standard to obtain the absolute reflectivity of the coating.

References

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