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The insulation effects caused by the scattering of electromagnetic waves by fine spheres against insolation heating

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The temperature of materials rises when they are exposed to the sunlight (insolation heating). Insolation heating could be suppressed when the materials are coated with paint admixed with fine silica spheres (insulating paint). By coating buildings' walls and roofs with such paint, the temperature in the subjacent rooms could be kept lower thanby coating with regular one. The temperature of the former could be enough low so that no air-conditioning becomes necessary even in the mid summer. These phenomena are well known in a practical manner and have been widely utilized. However,the cause of the phenomena has hardly been analyzed theoretically yet. Moreover, micron-scale ceramic spheres have been known as the best commixture than the other metallic commixture of the same size. Theoretical analysis would greatly enhance the effects of the suppression of insolation heating. We focus on the light scattering by fine spheres under the assumption that the scattering of lights, i.e., electromagnetic waves, attributes to suppression of insolation heating and that the imaginary part of scattering coefficients of the spheres is a key to explain the observed phenomena. In this study, we therefore consider commixture sphere materials to be (i)silica, (ii)aluminum and (iii)copper, distributed in a paint layer coating an iron material, and calculate transmission, reflection and absorption coefficient using the Monte Carlo ray tracing method based on the Mie theory. Using these coefficients, the rise in temperature of surface of the iron layer would be estimated. We finally investigate how the structure of the paint attributes to the insulating effects.

We assume three layers: air, paint, and iron, and commixed fine spheres in the paint layer using Distinct Element method (DEM). A number of photons vertically incident to the paint at random position from the air. We then count the number of photons that reaches the iron to estimate the intensity of the transmitted wave, and count the number of photons that are absorbed by spheres to estimate the intensity of the absorbed wave energy. Fresnel Equations are used to identify photons' behavior stochastically using a random number. Moreover, Mie theory is used to calculate the radiation pattern of scattering at each sphere when a photon incident to the sphere. As a result, it is estimated that the transmission coefficient would be less than 0.1 forthe commixture material of silica whose radius is smaller than ca. 0.7 micrometers. On the other hand, the transmission coefficient could be much less than 0.1 if we use conductive spheres. However, in the latter case, the absorption coefficient would be approximately 0.5, which could cause the rise in temperature of the spheres and the paint.

We estimate the rise in temperature of iron layer using coefficients calculated above. Near-infrared radiation of the sunlight is assumed to be the incident wave. As a result, whereas the temperature would be 63 degrees Celsius if no paint is coated. On the other hand, the temperature would be suppressed to 39, 59 or 56 degrees Celsius, respectively, if we use silica, aluminum or copper spheres of the same radii of 0.5 micrometers. The metallic commixture could lower the temperature rise but the absorption of the energy seems deteriorate the efficiency of the insulation.

In conclusion, silica is one of ideal material for insulating paint in contrast with conductive ones such as aluminum and copper, mainly due to the absorption phenomena of electromagnetic waves by spheres.

Keywords: mie scattering, monte Carlo Ray-tracing, insulating paint, sphere, electromagnetic scattering