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Electromagnetic scattering by fine ceramic spheres and scattering-induced suppression of insolation heating

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1.INTRODUCTION

After the earthquake and the nuclear power plant accident happened in 2011 in Japan, there has been a fatal electric power shortage problem in summer due to the great demand for energy, especially for air-conditioning. It is of key importance to cut the demand and to save energy. In fact, 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. Coating buildings' walls and roofs with such paint, the temperature in rooms could be kept lower without using air-conditioner. This phenomenon is well known and has even been utilized in the past, but has hardly been analyzed theoretically yet. Theoretical analysis would greatly enhance its effect of the suppression of insolation heating.

We focus on the light scattering by fine spheres assuming that the scattering causes the phenomena. Mie scattering theory might be dominant for the scattering of infrared radiation by the spheres used in the paint. We calculate the intensity of total waves which pass through the paint layer using Mie theory and investigate how the structure of the paint attributes to the intensity.

2. METHOD

In this study, we considered three layers: air, paint (fine silica spheres are randomly distributed in this layer), and iron. We assumed a plane electromagnetic wave whose amplitude was unity and evaluated the total intensity of the transmitted waves, which were supposed to be the transmitted incident wave and scattered wave from each sphere. We used Fresnel equations for reflection and transmission of a plane wave which incidented on a boundary between two layers, and Mie theory for the scattering of a plane wave by fine spheres.

We used four models. The size of the spheres for each model was as follows: (a)0.5, (b)0.4, (c)0.3 and (d)0.2~0.6 (in line with the Gaussian distribution) micrometer. The wavelength of the incident wave was assumed to be largely near infrared band (0.5~2.5 micrometer).

3. Result

We calculated the total intensity of the transmitted waves for every wavelength. The total intensity of the transmitted waves turned out to get minimum when the wavelength of the incident wave was near the spheres' diameters. This suggests that specific wavelength could be selectively weakened by specific size of spheres. Moreover, there was little difference of the intensity distributions between model (c) and (d). This implies that scattering characteristic of the average size of spheres could be obtained even in case of various sizes of spheres.

4.Summary

Our goal is to analyze light scattering to find most efficient structure of the scatterer. We supposed fine silica spheres randomly distributed in a paint layer and calculated the total intensity of transmitted waves.

We found that specific wavelength could be selectively weakened by specific size of spheres and that scattering characteristic of the average size of spheres could be obtained even in case of various sizes of spheres. These facts would be useful to carry this study on to apply the results of this study to the practical paint.

Keywords: scattering, electromagnetic wave, ceramic sphere, Mie scattering, energy saving, insolation heating