Title: Solar Selectivity of Cermets with Large Particles
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ABSTRACT

Solar selective absorber materials are important for improving the efficiency of solar thermal energy conversion systems. Among these materials, the metal-dielectric composites known as cermets are of special interest due to their very good selectivity and high thermal stability. We study the solar selectivity of cermets with large particles. In particular, we evaluate theoretically the solar absorptance and thermal emittance of these materials. These quantities are calculated from the spectral reflectance by standard expressions, and are in turn used to calculate the figure of merit for the materials. In particular an AM1.5 solar spectrum is used to evaluate the solar absorptance. The cermets for solar applications consist of one or more layers of metal particles embedded in a dielectric (ceramic) binder, deposited over a metallic substrate. The optical properties of cermets with particles which are small as compared to the wavelength of radiation (usually of the order of several nanometers) are well understood from the theoretical point of view. In this work, we consider metal inclusions with diameters between 0.01 to 0.25 micron. The size of these particles is not small as compared to the wavelength of visible light, and it becomes necessary to take into account the effects of multiple scattering in the optical response of the material. In order to obtain the spectral reflectance we have to resort to an hybrid method. On the one hand, the scattering is strong in the visible and near infrared. In this range the single scattering effects are described with the help of the Lorenz-Mie theory of scattering. The information provided by this theory is used together with a four-flux radiative transfer model to include the multiple scattering effects. On the other hand, in the infrared, for wavelengths above 5 microns, the absorption of the dielectric binders forbids the use of the Lorenz-Mie theory. There we use an effective medium model to describe the response of the composite medium. This is possible due to the very weak scattering in that spectral region, for the particle sizes considered. The transition point between these two calculation methods is given by an empirical rule as the wavelength which is 10 times the particle diameter. We consider in particular cermets of Cobalt in Alumina, and Nickel in Silica, in both cases with Nickel substrates. In general we obtain moderately high values for the figure of merit, which are in some cases comparable with those of small particle cermets. It is found that, because of fundamental reasons, particles larger than those considered here are not adequate to have good a selectivity. This is due to a displacement of the cutoff of the absorption by the particles to longer wavelengths with increased size, as predicted by Lorenz-Mie theory. In addition, the particle size has a direct influence in the thickness of the cermets. This is a critical consideration because the selectivity is lowered as the thickness increases due to infrared absorption by the binders.