A WIDE-ANGLE CERMET-BASED SOLAR SELECTIVE ABSORBER FOR HIGH TEMPERATURE APPLICATIONS

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ABSTRACT. The objective of this study is to design a wide-angle cermet-based solar selective absorber for high temperature applications by using a characteristic matrix method and a genetic algorithm. The present study investigates a solar selective absorber with tungsten-silica (W-SiO_2) cermet. The predicted radiative properties show good solar performance, i.e., thermal emittances, especially beyond 2 μm, are quite low, in contrast, solar absorptance levels are successfully high with wide angular range.

INTRODUTION

Solar selective absorbers can play an important role for improving power generation efficiency [1]. A solar selective absorber is an artificial material that has ability to absorb sun light efficiently with low levels of thermal emission. Therefore, an ideal solar selective absorber should have high solar absorptance and low thermal emittance. Previous research on cermet-based absorbers has focused on mid-temperature applications [2], but high-temperature applications beyond 1000K have not been well-explored. The present study investigates a solar selective absorber with tungsten-silica (W-SiO_2) cermet. We consider the oblique solar light irradiates absorbers.

The objective of this study is to optimize wide-angle cermet-based solar selective absorbers for and high temperature applications. We employ a characteristic matrix method [3] for solving the electromagnetics and a genetic algorithm for optimization. Effects of operating temperature, metal volume fraction and thickness of layers are investigated in order to show a valuable guidance for understanding and designing of solar selective absorbers.

PROBLEM STATEMENT

Figure 1 shows a schematic of the solar selective absorber with cermet. The structure consists of an anti-reflection (AR) coating, wavelength selective cermet layers, and a highly reflective back layer. The silica (SiO2) is chosen for the AR coating due to the low refractive index. The first layer of cermet from the top is called "Cermet 1", and the second layer is called "Cermet 2". One of the test cases for double-layer solar selective absorber is shown in Table 1.

Table 1: Recipe of double-layer solar selective absorber

Layer	Material	Volume fraction	Thickness (nm)
AR coating	SiO_2	0.0	54.97
Cermet 1	W-SiO_2	0.1845	49.15
Cermet 2	W-SiO_2	0.4926	52.23
Reflective Layer	W	1.0	300

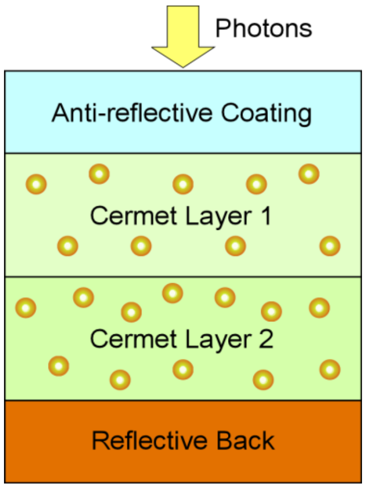

Figure 1. Schematic of solar selective absorber

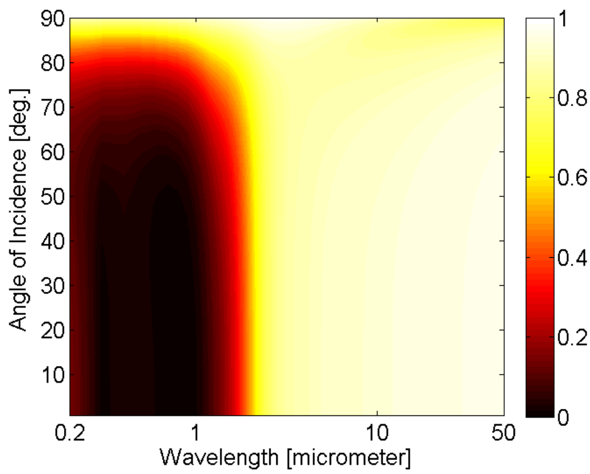

Figure 2. Directional dependence of reflectance

We assume that metal particles are distributed randomly inside ceramic. There are many possibilities for evaluating the volume fractions of the metal-ceramic composites, layer thicknesses, and number of layers. Therefore, the genetic algorithm is employed for considering the optimum design of a selective solar absorber.

COMPUTATIONAL METHOD

The radiative properties of nano/micro-scale materials depend not only on the properties of the materials but also on their electromagnetic behavior. To consider the electromagnetic effect, the amplitude and the phase of the electric field must be calculated, i.e., the Maxwell equation should be solved. Since a 1D multilayer structure is relatively simple, this study employs the characteristic matrix method. If the refractive indices of the cermet, metal, and ceramic are known, one can calculate the reflectance, and then solar absorptance and thermal emittance. The refractive indices of dielectrics can be modeled by a constant refractive index over the full spectrum. Metals can be modeled by the Lorentz–Drude model. The refractive indices of cermet materials can be modeled by the effective medium theory. The Bruggeman model is suitable over a wide range of metal volume fractions.

RESULTS AND DISCUSSION

In Fig. 2, the directional dependence of the reflectance for 2-layer W-SiO2 cermet-based solar selective absorber is shown at 1000K. Since the largely oblique incident light cannot be absorbed effectively for a visible light in the cermet layers, the hemispherical reflectance for visible range is slightly higher than the normal reflectance. Even though there is a limitation for a solar absorption, the optimized structure show good spectral selectivity over a wide angular range, and would therefore be good candidate for solar thermal applications. The solar absorptance is successfully high, and thus, the solar photons are effectively absorbed by the cermet and by phase interference. For more detailed results, which including the effects of operating temperature, metal volume fraction and thickness of layers, will be presented in our poster

REFERENCES

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