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Metal-Dielectric Antireflection Coating on Metallic Substrate for Solar Selective Absorbers of Concentrating Solar Power Systems

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***Abstract*—**We design and discuss metal-dielectric antireflection coating on metallic substrates for Solar Selective Absorbers of Concentrating Solar Power Systems. The average reflectance is 8.5% at 400-3000nm and 84.4% at 3000nm-10000nm of the metal-dielectric structure.

***Keywords*—**Concentrating solar power systems, solar thermal, solar selective absorber, absorptance, emittance.

I. Introduction

CONCENTRATING solar power (CSP) systems use solar selective absorbers to convert sunlight to transfer solar thermal energy. Solar thermal is an efficient and simple processes, conversion efficiency can reach 50% and low cost. Solar energy selective absorber is a key component. It must have a good absorptance of the sun radiation, and at the same time only a small thermal emittance. The temperature of concentrating solar collectors of CSP must be more than 400 °C. The challenge not only maintains good high absorption and low-radiation characteristics at high temperature, but also has structural stability under high temperature environment required. To accomplish this, new more efficient selective coatings are needed that have both high solar absorptance(α)and low thermal emittance(ε) more than 500°C. Current solar selective absorbers didn't have the stability and performance desired for moving to higher operating temperatures. For CSP applications, the ideal selective coatings would be low-cost and easy to manufacture, chemically and thermally stable in air at elevated temperatures [1] ($T \geq 500$ºC), and have a high solar absorptance ≥ 0.95 at wavelengths (λ) ≤ 3μm and a low thermal emittance ≤ 0.05 at $\lambda \geq$ 3μm. The classical way to decrease the reflectance of a metallic film is to use black paint to insure high absorption. For example, Giovannini and Amra [2] deposited a dielectric layer over a black painted layer. There was significant improvement to meet higher absorption requirements but the black painted layer was too thick and the edges not sharp enough to pattern.

The antireflection coating (ARC) enhances the transmittance of light by decreasing reflected light, but it does not remove the reflectance from the metallic substrate. In recent years, black electrodes [3]-{4] and ARCs [5]-[9] on metallic substrates have seen wide development. We will design the high-temperature solar selective absorber using metal-dielectric stack multilayer structure to reduce reflection of metallic substrates.

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II. Design

Design of an ARC for a dielectric substrate is quite different from that for a metallic substrate. ARC on metallic substrate needs both metallic and dielectric layers. The thickness of the bottom dielectric layer must compensate for the phase shift induced by the metallic substrate and the metal layer is not to absorb the light but to benefit from its complex admittance n-ik in order to more efficiently reach to AR condition [10]. This kind of metal layer needs large k and a constant nk/λ for all the wavelengths. Chromium and Inconel (an alloy of Cr-Ni-Fe) are often used for metal-dielectric black absorbers, because of the linear property of nk/λ [11]-[12].

The optical constant of the material is very important in optical thin film design. We deposited single layer SiO_2 and Nb and analyzed the optical constants. The metal layer is Nb, which is less absorbing and n value is near k value. Table I shows that the optical constant of SiO_2 and Nb at 550 nm.

TABLE I
OPTICAL CONSTANTS OF SiO_2 AND NB AT 550NM

Material	Refractive index	Extinction coefficient
SiO_2	1.46	0
Nb	3.03	3.09

There are four metal-dielectric structures:
Sub/Al/SiO_2/Nb/SiO_2/Air (3layers),
Sub/Al/ SiO_2/Nb/SiO_2/Nb/SiO_2/Air (5 layers),
Sub/Al/ SiO_2/Nb/SiO_2/Nb/SiO_2/Nb/SiO_2/Air (7 layers),
Sub/Al/SiO_2/Nb/SiO_2/Nb/SiO_2/Nb/SiO_2/Nb/SiO_2/Air(9 layers).

Where sub is metallic substrate and Al is Aluminum film which thickness is 200nm. The simulation thickness of every layer of structures shows in Table II. Fig. 1 is simulation spectra of four different metal-dielectric structures. Simulation spectra of four structures at 400nm to 3000nm shows in Fig. 2.When the layer numbers increase, the average reflectance at 400nm~3000nm increase and the average reflectance at 3000nm~10000nm decrease. Table II is simulation average reflectance of structures.

TABLE II
THE SIMULATION THICKNESS (NM) OF EVERY LAYER OF STRUCTURES

structure	3layers	5layers	7layers	9layers
layer1(SiO_2)	86.1	98.9	18.1	37.4
layer2(Nb)	8.2	12.8	10	8.5
layer3(SiO_2)	89.9	98.3	111	106.5
layer4(Nb)		4.9	10.2	14.8
layer5(SiO_2)		97.4	106.3	105.8
layer6(Nb)			5.1	7.4
layer7(SiO_2)			103.3	103.5
layer8(Nb)				3.7
layer9(SiO_2)				104.4

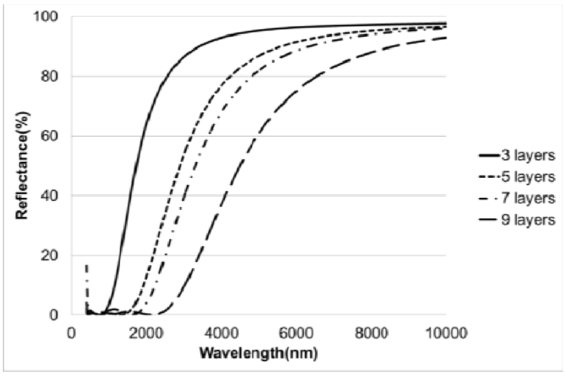

Fig. 1 Simulation spectra of four didferent metal-dielectric structures

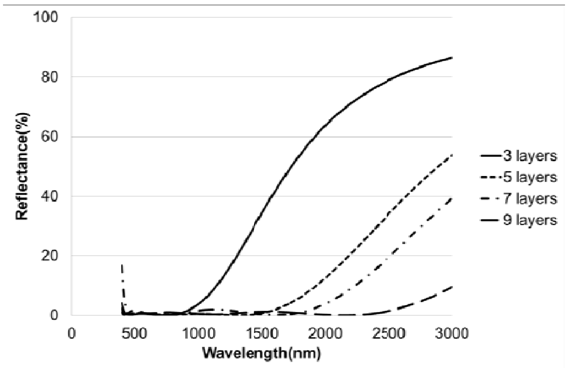

Fig. 2 Simulation spectra of four structures in 400nm to 3000nm

TABLE III
SIMULATION AVERAGE REFLECTANCE OF STRUCTURES

structure	Average reflectance 400nm~3000nm(%)	Average reflectance 3000nm~10000nm(%)
3layers	43.0	95.6
5layers	14.1	88.3
7layers	8.5	84.4
9layers	1.5	69.8

III. CONCLUSION

In this study, we design and discuss metal-dielectric antireflection coating on metallic substrates. The average reflectance is 8.5% at 400-3000nm and 84.4% at 3000nm-10000nm of the 7 layers structure :

Sub/Al/SiO_2/Nb/SiO_2/Nb/SiO_2/Nb/SiO_2/Air shows in Table III. It have good result to solar selective absorber and is much thinner than the typical printed absorber. After design we will manufacture the metal-dielectric antireflection coating on Copper(Cu) substrates, then measure the solar absorptance(α) and thermal emittance(ε) in high temperature.

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