Tuning solar absortance and reflection of high-temperatue solar spectrally selective surfaces

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Abstract

Spectrally-selective solar absorbers are widely used in solar hot water and concentrating solar power (CSP) systems [1,2]. However, the performance at high temperatures (>450 °C) is still not satisfactory due to their high infrared (IR) emittance and long term thermal stability. Recent progress on cermet-based solar absorbers has shown promising temperature thermal stability and wavelength selectivity. Thus, here we explore W-Ni-Al_2O_3, W-Ni-YSZ (yttria-stabilized-zirconia) and W-Ni-SiO_2 cermet based spectrally selective surfaces for high-temperature solar absorber applications [3,4]. The developed multilayer selective surfaces are deposited on a polished stainless steel substrate comprising two sunlight absorbing cermet layers with different W-Ni volume fraction inside the dielectric matrix, one or two anti-reflection coatings (ARCs) and one tungsten IR reflection layer for reduced IR emittance and improved thermal stability.

Regarding the W-Ni-Al_2O_3 cermet based solar absorbers; we observed a detrimental change in the morphology, phase, and optical properties if the cermet layers are deposited on a stainless steel substrate with a thin nickel adhesion layer, which is due to the diffusion of iron atoms from the stainless steel into the cermet layer forming a $FeWO_4$ phase. A 100 nm thick tungsten layer can suppress the degradation of the optical properties at high temperatures and lowers the emittance relative to the stainless steel substrate, which improves the spectral selectivity of the solar absorber. We experimentally demonstrated a solar absorber with a solar absorptance of ~0.9 and total hemispherical emittance of ~0.15 at an operating temperature of 500 °C.

The fabricated W-Ni-YSZ cermet based solar absorbers are tested for their long term thermal stability at 600 °C. A distinct change in surface morphology of the solar absorbers with high oxygen deficiency in their YSZ-ARC layers, suggests to causing the degradation of the optical properties at high temperature. The oxygen deficiency can be effectively overcome through increasing the oxygen partial pressure during sputtering, which leads to a stable solar absorber with an experimentally demonstrated solar absorptance of ~0.91 and a total hemispherical emittance of ~0.13 at 500 °C.

We also developed a new kind of absorber that reflects a certain range of wavelength and absorbs the rest of the whole solar spectra [5]. The absorbed part is used for electrical power generation by steam engine and the reflected part is used for solar photovoltaic conversion. The thermal energy can be easily stored for later conversion to provide electrical power around the clock without worrying the Sun's night time.

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