Abstract

The high energy demand and increasing environmental contaminants compel to explore alternative sources of energy. Solar energy is one such clean energy source, which is widely explored to fulfill energy requirements with no or say minimum pollution. Solar thermal technology is the direct way to harness solar energy into thermal energy using spectrally selective coated receiver tubes. For efficient conversion of solar energy to thermal energy, the spectrally selective absorber coating (SSAC) should exhibit high absorptance (ideally 100%) in UV-Vis-NIR range (0.3- 2.5 μm) and low thermal emittance (ideally 0%) in infrared red region (2.5-25 μm). So far, various SSAC structures are reported using different physical vapor deposition (PVD) as well as solution routes. These are generally cermet (metal in a ceramic host) based structures, which are stable up to mid-temperature range (≤ 300 °C). In contrast, very few structures are reported for high-temperature applications, and these structures are usually synthesized using PVD routes.

There are numerous SSACs based on different materials, but only limited coatings are commercially available, and for high-temperature, commercial coatings are even smaller in number. These structures are mainly fabricated using PVD routes, relying on complex fabrication systems and associated high costs. Thus, there is a need to develop new SSAC structures, having high absorptance and low thermal emittance using easy and low-cost fabrication techniques, which are stable in mid as well high-temperature range. The current work is primarily focused on optimization of black chrome (BC), one of the oldest cermet based structure, for large scale coatings on radiation calorimeter device for solar irradiance measurement. The absorptance and emittance of the optimized structure are 0.95 and 0.05, respectively. The fabricated structures are investigated in terms of their structural/microstructural and optical properties. The impact of deposition time duration, thickness, and current are investigated and optimized to achieve the desired optical properties. The coated structure shows thermal stability in mid-temperature range. Further nickel (Ni) and cobalt (Co) co-pigmented anodized nanoporous alumina structures are investigated and optimized for their solar thermal performance. The optimized absorptance and emittance values are ~ 95% and ~ 0.14, respectively. These structures are thermal stability up to 300 °C in open environmental conditions and showed high corrosive resistive as compared to only nickel anodized alumina structures.

We also investigated tungsten as an infrared reflector layer for high-temperature SSAC applications. Tungsten thin films are fabricated on stainless substrates (i.e. W/SS) as an IR reflector layer using a sputtering technique. The observed minimum emittance is ~ 0.13 for the optimized W/SS infrared reflecting layer. The impact of residual oxygen, as well as intrinsic property of tungsten on thermal emittance, are investigated. The intrinsic interband transitions in tungsten lie around 1.75 eV i.e. in visible range, may exhibit absorption, and thus limiting the emittance values. Further, the formation of oxide i.e., WO_X may also limit the emittance near ~ 0.1, showing relatively higher values. We also focused on the development of SSACs structure using low-cost sol-gel based dip coating, scalable for large area coatings to realize any practical solar thermal application. A small semi-automated dip coating system is developed in the laboratory with variable speed options to control the processing speed. This system is used to deposit $SiO_2/ZnO/(Sn\text{-}In_2O_3)_{n=4}/SS$ multilayer structures, consisting of semiconducting and dielectric layers, alternatively on SS substrate. Here, SiO_2 is used as the anti-reflecting layer on top of the SSAC structure. The structures are robust against thermal and environmental cyclability. The optimized structures showed absorptance ≥ 0.85 and emittance ~ 0.14, with no significant degradation in solar thermal properties after thermal cycling. This process is further extended to achieve the coating on 25 mm diameter 0.3 m long SS tube to demonstrate the scalability of the process for coating on practical structures. These coatings show strong corrosion resistance and highly stable under ambient conditions.