High-Temperature Solar Selective Coating Development for Power Tower Receivers

Sandia National Labs/ NREL

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PROJECT OBJECTIVES

Goal: Develop solar selective coatings for next- generation CSP towers that exhibit high absorptance with low thermal emittance, that can operate in air at temperatures ≥ 650 °C without degradation for ≥10,000 cycles.

Innovation: Current coatings are not suitable for the high temperatures and oxidative environments for power towers. At SNL, solution-based deposition methods allow rapid deposition and screening of coatings with intrinsic optical properties. A thermal spray process is under development to deposit promising materials on a large-scale, including receivers in service, enabling rapid resurfacing receivers in the field. The LCOE-like metric will capture the cost and lifetime performance of coatings. NREL will focus on physical vapor deposition (PVD) methods which allow extremely fine control of the morphology, stoichiometry, and crystal structure. Novel multi-layered coatings predicted by models developed at NREL will be investigated.

Milestones: Quantify parameters which yield optimized solar selective properties for spinels and thermally sprayed coating which meet efficiency of η_{sel}=0.916; Downselect 5 candidate binary materials for PVD of a full-stack whose modeled properties have a selective absorber efficiency that meet or exceed that of η_{sel}=0.916; Develop a metric, similar to the levelized cost of electricity (LCOE), that accounts for performance, costs, and reliability/durability for coating materials.

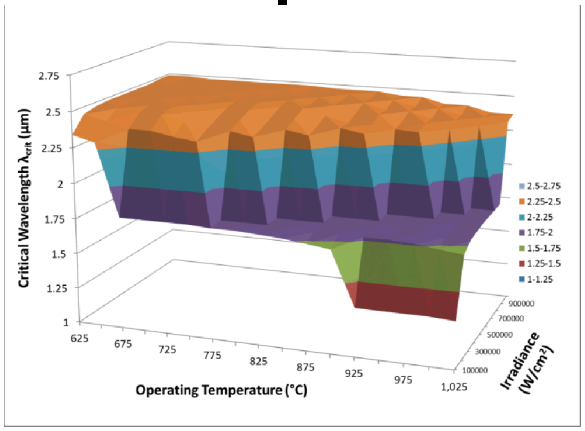
APPROACH

Technical Approaches

- Utilize solution-based spin coating and electrodeposition methods to enable the facile synthesis of coatings with varying formulations and dopant concentrations. Such methods allow for rapid deposition and optical screening f a composition space. (SNL)
- Focus on materials that are intrinsically (i.e. inherently) solar-selective, are stable in an air environment at temperatures in excess of 650 °C, and can be applied to the receiver surface in an manufacturing environment or in the field (SNL)
- Physical vapor deposition (PVD) methods that allow extremely fine control of the morphology, stoichiometry, and crystal structure, thereby controlling the resulting optical and thermal properties (NREL)
- Explore modifying surface morphology by introducing pore formers in thermally sprayed coatings and deposition geometry of refractory metals to tailor the optical properties (SNL & NREL)
- Levelized cost of coating (LCOC), is defined as the ratio of the total annualized coating costs ($) to the annual thermal energy absorbed (kWh_{th}) (SNL)

KEY RESULTS AND OUTCOMES

- Developed surface modification of thermal-sprayed coatings which increases η_{sel} (0.89) of LSM and Cr_2O_3 coatings compared to as-deposited (SNL)
- Identified Mn- and Cu- doped Co_3O_4 spinels with η_{sel} > 0.86 (SNL)
- High-temperature electrodeposition of Co_3O_4 films heated to 300 C display η_{sel} > 0.90 (SNL)
- $TaSi_2$ based design that repeatedly demonstrated η_{abs} > 0.910 in annealed samples and is stable up to 1000 C. (NREL)
- "Localized Cost of Coating" metric developed which shows that initial solar absorptance was the most significant parameter impacting the LCOC, followed by thermal emittance, degradation rate, reapplication interval, and downtime during reapplication.



Optimum critical wavelength for an ideal solar selective absorber as a function of both T and irradiance.

NEXT MILESTONES

FY14 Milestones

- Identify alloy substrates suitable for high-T tower operation
- Develop microstructured coatings
- Determine a full ranking of materials and deposition methods for refractory metal compounds based on their ability to enhance the selective surface efficiency compared to Pyromark 2500
- Isothermal (furnace) testing of promising coatings to measure durability and performance at high-T
- Design testing rig for on-sun testing of coating materials

Go/No Go Decision Point 2:

At least one promising selective surface coating has been developed which has been shown to have selective absorber efficiency (ηsel) degradation rate of less than 1%/yr under high temperature (>700°C) and on-sun conditions.

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