High-Temperature Solar Selective Coating Development for Power Tower Receivers

SunShot U.S. Department of Energy

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PROJECT OBJECTIVES

Goal: Develop solar selective coatings for next- generation concentrated solar power towers that exhibit high absorptance with low thermal emittance, that can operate in air at temperatures ≥ 650 °C without degradation for ≥10,000 cycles. Develop a metric , similar to the levelized cost of electricity (LCOE), that accounts for performance, costs, and reliability/durability for coating materials.

Innovation: Current coatings are not suitable for the high temperatures and oxidative environments for power towers. Our novelty lies in an integrated approach to develop new materials with optimized optical properties and stability. 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, thereby controlling the resulting optical and thermal properties. Novel multi-layered coatings predicted by models developed at NREL will be investigated.

Milestones: No Milestones required FY13Q1; All FY13 milestones due 9/30/2013.

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

- High-temperature electrodeposition used to deposit Co_3O_4 coatings directly onto stainless steel coupons. Coatings show a figure of merit competitive with Pyromark©. (SNL)
- Optical and thermal properties of Haynes alloys were examined, as part of effort to characterize next-generation building materials for CSP towers. (SNL)
- Thermal durability examination (600-800 °C) of coatings underway. Spin-coated and thermal-sprayed coatings remain robust, but most materials show a decline in optical properties. (SNL)
- Thermal-sprayed Cr_2O_3 coatings were laser-treated to change surface morphology. Initial results show an increase in absorptance after treatment. (SNL)
- Films of TiO_2 and SiO_2 were sputtered by PVD. Individual layers of TiSi with a wide range of Ti:Si compositions were also co-sputtered and characterized. (NREL)
- The multilayer model was optimized for Power Tower temperatures (700 °C). The 550 °C and 700 °C multilayer stacks were deposited with the optimized single layer deposition conditions. (NREL, FY12 work, report to DOE 1/31/2013)
- Levelized cost of coating (LCOC) (a LCOE-like metric) defined as the ratio of the total annualized coating costs ($) to the annual thermal energy absorbed (kWh_{th}). (SNL)

NEXT MILESTONES

No Milestones are due for Q2. Year-end Milestones follow.

Milestone (Task 1.1) Sandia: Quantify parameters (doping concentrations, thickness, deposition methods, substrate choice, and synthesis conditions) which yield optimized solar selective properties for spinels and thermally sprayed coating and meet or exceed the selective absorber efficiency of best formulations from FY12 AOP (e.g., Co_3O_4-based spinels,η_{sel}=0.916) and present to DOE statistical method used and results.

Milestone (Task 1.2) NREL: Downselect 5 candidate binary materials for deposition of a full-stack whose modeled properties have a selective absorber efficiency that meet or exceed that of the best material identified in the FY12 AOP task (e.g., sputtered multilayer, η_{sel}=0.916).

Milestone (Task 1.3) Sandia: Complete SAND report documenting the system-level metric for candidate selective surface coating and Pyromark which incorporates initial and reoccurring costs (materials, labor, and equipment) along with performance.

All Milestones due 9/30/2013; all milestones are low risk