High-Temperature Solar Selective Coating Development for Power Tower Receivers

Sandia National Labs/NREL

April 26, 2013 | Ghanbari

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

- Co_3O_4 coating were electrodeposited onto polished samples and annealed to study effect on films. Annealed films show increased crystallinity and better durability than rt-deposited coatings. However, optical properties have degraded, possibly due to change in film morphology. (SNL)
- Structural analysis of heated CeO_2 thermal sprayed coatings investigated; increase in absorptance likely due to the intergrowth of secondary phases from the SS304 substrate at T > 700 °C. (SNL)
- Laser treated thermal-sprayed Cr_2O_3 coatings were characterized by XRD and found to retain the Cr_2O_3 crystal structure; therefore the increase in absorption may be due to a change in surface morphology (e.g., “Superblack” effect). Further investigation underway. (SNL)
- Single- and multi-layer films of Ti:Si and Ta:Si were deposited by PVD. Ti:Si 86:14 composition showed η_{sel} > Pyromark at T>500 °C. (NREL)
- Annealing studies of Ti:Si films undertaken. 36:64 composition film stable up to T = 1150 °C.
- Levelized cost of coating (LCOC) was calculated from Solar One data. The LCOC of Pyromark 2500 was estimated to be $1.36/MW$_{th}$, with the largest cost coming from revenue lost due to degradation. (SNL)

NEXT MILESTONES

No Milestones are due for Q3. 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

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