Studying an Economical Solar Selective Coating for Practical Solar Thermal Technologies

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Abstract

In solar power applications, sunlight is reflected and focused about seventy to eighty times while being directed towards collector plates or tubes. Under these conditions, the collectors can heat up to about 400 C. In order to ensure high absorptance, low emissivity and good thermal selectivity, these collector plates or tubes should be coated with a solar selective coating.

- **First, the recent trends in the field of solar selective coatings is reviewed with a special focus on coatings having records of application in industrial settings.**
- **Second, black chrome is selected based on a compelling comparison of cost versus performance for small to medium sized industries.**
- **Third, the behaviour of this coating is studied by experimentally simulating actual service conditions using infrared lamps that radiate heat waves to black chrome coated test tubes.**

This poster summarizes the design and details of an experimental set-up required to perform these tests. In addition, it reports, compares and discusses the experimental data measured for the black chrome coating.

Discussion

In solar power applications, collector tubes are often used to store the heat reflected by parabolic mirrors. These consist of a stainless steel metal tube coated with a solar selective coating and enclosed in a clear glass vacuum tube. Through this metal tube, a heat transfer fluid flows from the solar panel arrays to the power generation plant where it is used to turn water into steam.

The solar selective coating applied on the stainless steel tube is a specifically engineered material designed to optimise the amount of energy transferred into the metal pipe. This solar selective coating should have high absorptivity, low emissivity and very good thermal stability.

Black chrome is an economical solar selective coating due to the deposition method being electro-deposition and not physical vapor deposition. Black chrome was heavily used in the solar power industries in the 1970s. Although the solar power industry has moved on to better performing PVD coatings, black chrome is a far less expensive alternative for small plants. The characteristic of black chrome coating is given in table 2.

The average price of using matt black chrome electro-deposited on solar collector tubes is about 100 times less expensive than multi-layer complex-material PVD-deposited coatings that are feasible for big companies and large budgets. The solar performance of matt black chrome is well accepted since it was frequently employed by NASA and suggested by Lawrence Berkeley National Lab in 1970s, and it was fostered to several other application. The solar performance of this coating is slightly below that of the advanced coatings while the price is significantly lower. This becomes more attractive for small budgets.

The characteristics of black chrome coating

Type	Coating Material	Substrate	Deposition Method	Absorptance, a	Emissivity, e	a/e	Temperature, C	Stability in Vacuum, C
Single Layer	Matt Cr-Cr_2O_3	Stainless Steel 316	Electro Deposition	0.97	0.09	10.8	350	400

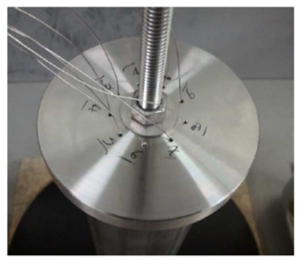
Conclusion

The collector tube with black chrome coating can reach about 40 °C higher temperature inside the collector versus the collector tube with no coating, and also reaches maximum temperature about 48 % faster. The mean dispersion from the expected value of measured temperature is statistically examined for IR test set-up as +/- 3.6 °C. The thicker coating might slightly improve the performance. Although a free-from-scratch coating operates more effectively, a scratched surface condition is still much more effective than a non-coating. Many literature and references confirm that black chrome coating does not degrade below a threshold of 350 °C in air and 400 °C in vacuum. Thermal stability and long term performance has not been studied, however, change in color of the coating (with no effect on thermal record) was observed during tests around the threshold in air. This suggests staying below 350 °C in air and 400 °C in evacuated glass.

Key References;

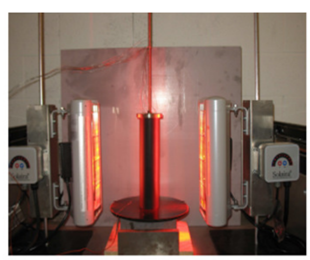
[1] H. Price, "Parabolic trough technology overview", Trough Technology - Algeria. National Renewable Energy Laboratory (NREL), p. 9, 2002.
[2] J. Jones, "Reducing the Cost of Energy from Parabolic Trough Solar Power Plants", National Renewable Energy Laboratory (NREL), 2003.
[3] A. Powell, "Thermal Storage For Solar Thermal Power", Material Seminar Series, the University of Ottawa, Presented by Cubit Power Systems Inc 2012.
[4] N. Selvakumar, H. C. Bershilia, "Review of physical vapor deposited (PVD) spectrally selective coatings for mid- and high temperature solar thermal applications", the National Aerospace Laboratories in Bangalore, doi:10.1016/j.solmat.2011.10.028, India, 2012.
[5] C. E. Kennedy, "Review of Mid to High Temperature Solar Selective Absorber Materials", the National Renewable Energy Laboratories in Golden, NREL/TP-520-31267, Colorado, 2002.
[6] C. M. Lampert, "Microstructure on a Black Chrome Solar Selective Absorber", Lawrence Berkeley National Laboratory, Local Identifier: LBNL Paper LBL-8022, first 1978 republished 2011.

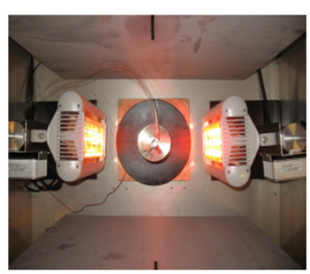
Three Segments



Thermocouples' Numbering

Several Hours of IR Radiation Changes the Color

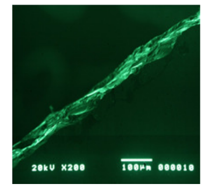


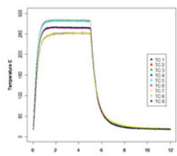


Experimental Setup that Simulates the Heating Light of the Sun i.e. IR on collector Tube

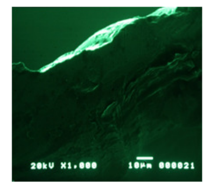
Thermocouples' Numbering and Position

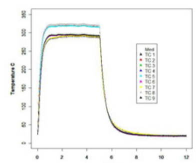
Thermocouple's Number	Segment	Location (Degree)
1	Bottom	0
2	Middle	20
3	Top	40
4	Bottom	60
5	Middle	80
6	Top	100
7	Bottom	120
8	Middle	140
9	Top	160



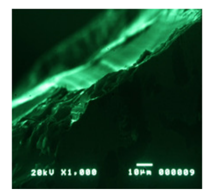


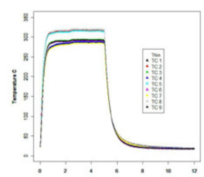
Reference Tube – No Coating



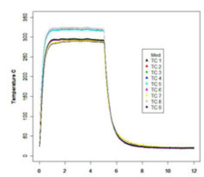


Medium Thickness Coating





Thin Thickness Coating



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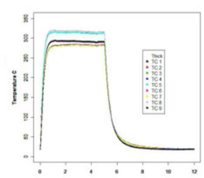
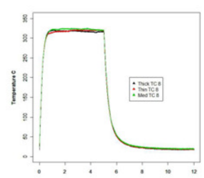
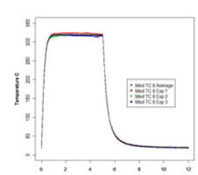


Thick Thickness Coating

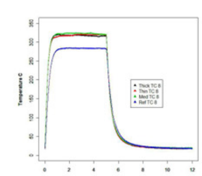


Thickness Effect

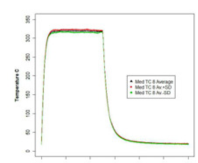
Studying the Effect of Thickness



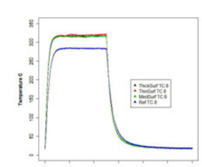
Randomness from Repetition



As Electro-Deposited



Statistical Analysis of Randomness



Scratched Surface

Studying the Effect of Surface Condition