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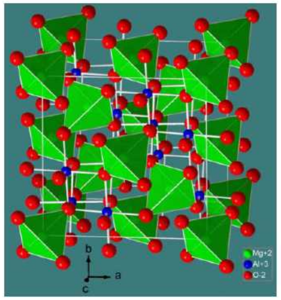

ESI: Solar Selective Coatings for Concentrating Solar Power Applications

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Overview

- CSP Towers
- Solar Selective Coatings
- Methods
- Analysis
- Results
- Energy Surety

CSP Towers

- Concentrated Solar Power Tower
  - Heliostats reflect sunlight
  - Receiver absorbs light to heat a working fluid
    - Receiver is coated with a selective absorber to maximize heat absorption
  - Uses heat from working fluid to make steam and power a turbine

Next Generation CSP

- Higher temperatures (>600 °C) needed to increase efficiencies
  - Increased power cycle efficiency
  - Decreased energy storage cost
- Issues that develop at higher temperatures
  - Increased heat loss from receiver
  - Degradation of materials

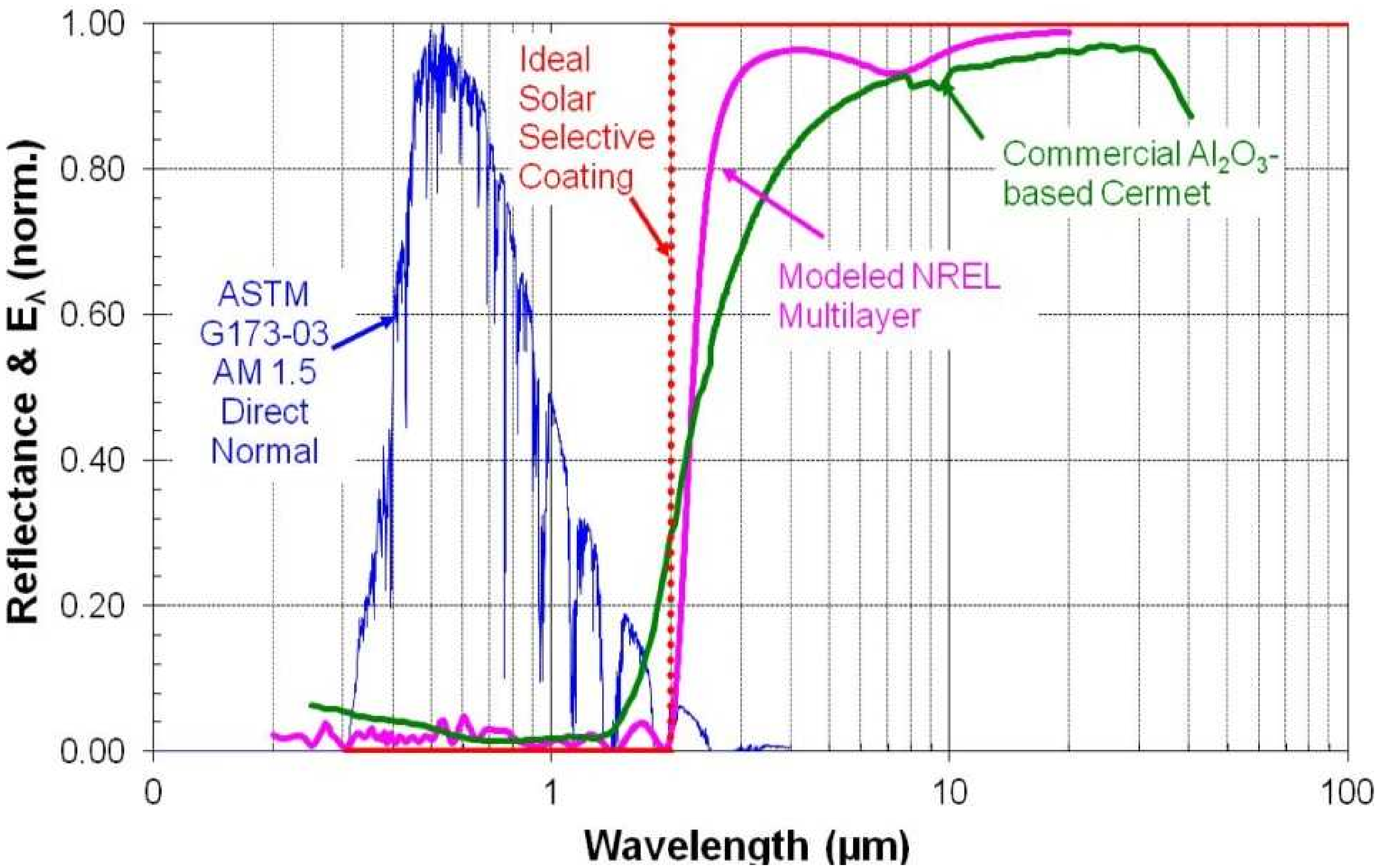
Solar Selective Coatings

- Selective coatings
  - Attempt to mitigate the heat loss at higher temperatures
- Other coatings are available, but not suitable for these conditions
  - Pyromark^{TM} 2500 is industry standard for CSP towers
    - Very high absorptivity (~0.96), but also high emissivity (~0.87)
  - Coatings are available for other CSP technologies but are unstable at desired temperatures

Solar Selective Coatings

- Ideal Absorber Properties
  - High solar absorptivity ($\alpha > 0.95$)
  - Low thermal emissivity ($\varepsilon < 0.40$)
    - Emissivity is a measure of the heat loss from a material
  - Long term stability in air at high temperatures (oxidation resistant)
  - Ability to survive many heating and cooling cycles
  - Low cost manufacturing

Ideal Selective Coating



aa4

Depicted here is the solar spectrum (blue) as well as an ideal selective absorber (red).

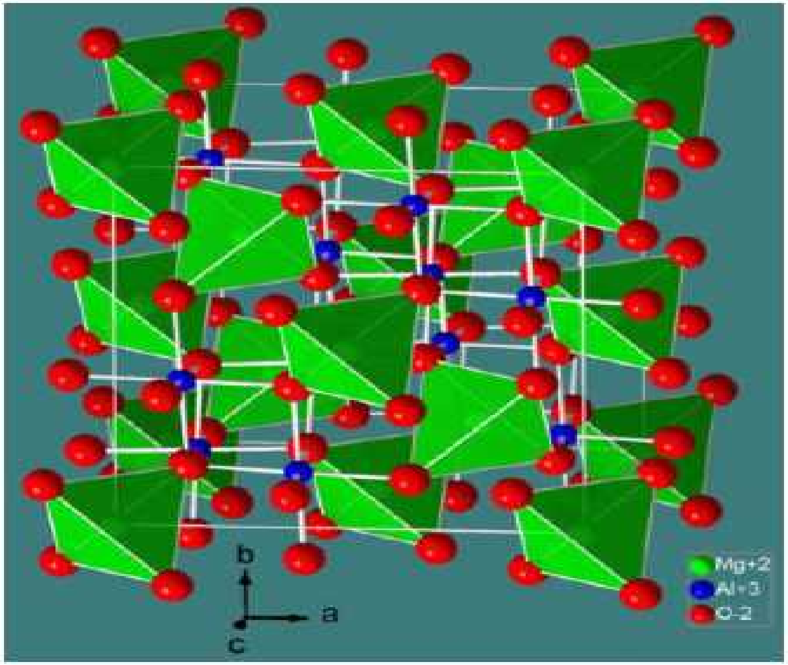
Slide 7

aa4 You don't have to write it out, but don't forget to mention the ideal absorber absorbs 100% of visible wavelength, but does not emit in the IR range. (And if anyone asks, at high T, emittance = absorbance according to Kirchoff's law).

Andrea Ambrosini, 8/1/2013

Method

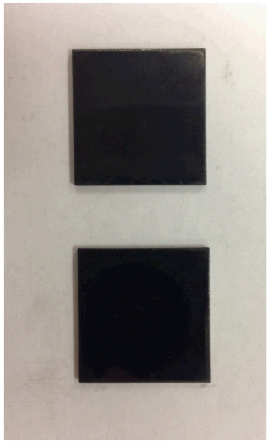
- Metal Oxide Spinels
  - Chosen for inherent high temperature stability and oxidation resistance
  - Optical properties can be tailored by doping with transition metals
  - Co_3O_4 showed initial promise, used as base for experiments



To the left is the spinel oxide unit cell. The red atoms are oxygen, while the green atoms occupy the tetrahedral sites and the blue atoms occupy the octahedral sites.

Method

- Spin Coating
  - Provides a facile and inexpensive method of coating stainless steel coupons
  - Easily screened for stability and optical properties
  - Solution was deposited onto a coupon, spun at 5000 rpm for 30 seconds, and dried on a hot plate
  - After 10 layers, coupon was sintered in a box furnace at 600 °C
  - Process was repeated to form coatings of 40-50 total layers



Analysis

- Absorptance measurements taken using a 410 solar reflectometer from Surface Optics Corporation and a solar spectrum reflectometer from Devices & Services Co.
- Emittance measurements taken using a ET100 emissometer from Surface Optics Corporation as well as a Temp 2000A from AZ Technology
- Diffuse reflectance performed using a Shimadzu UV-3600 UV-Vis-NIR spectrophotometer

Figure of Merit

- A figure of merit is used to compare the selectiveness of different materials
- Incorporates absorptance, emittance, temperature (923 K) and solar flux
- In an ideal material, η_{sel}= 1 meaning the material has 100% solar absorptance and 0% thermal emittance

$$\eta_{sel} = \frac{\alpha_s Q - \varepsilon \sigma T^4}{Q}$$

- α_s = solar absorptance
- Q = irradiance on the receiver (W/m^2)
- ε = thermal emittance
- σ = Stefan-Boltzmann constant ($5.67x10^{-8}$ $W/m^2/K^4$
- T = surface temperature (K)

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Photos placed in horizontal position with even amount of white space between photos and header

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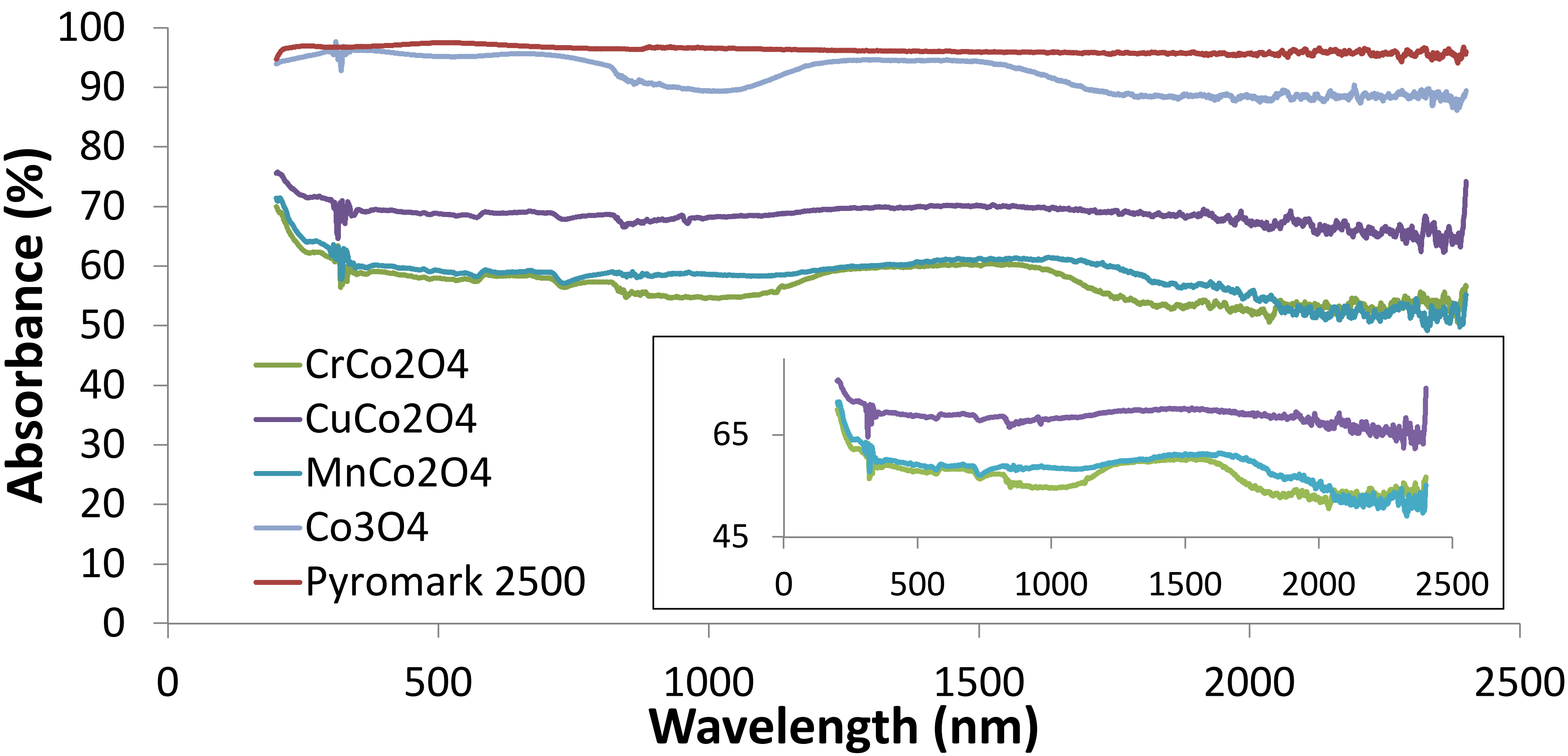
Diffuse Reflectance



Diffuse reflectance spectrum of select materials

Slide 13

aa8 Verbally explain diffuse reflectance. Caption this with something like "Diffuse reflectance spectrum of select materials" and then descirbe what you are showing, e.g. "these show high absorpatnce , but the emissivity drop should be sharper and more pronounced"

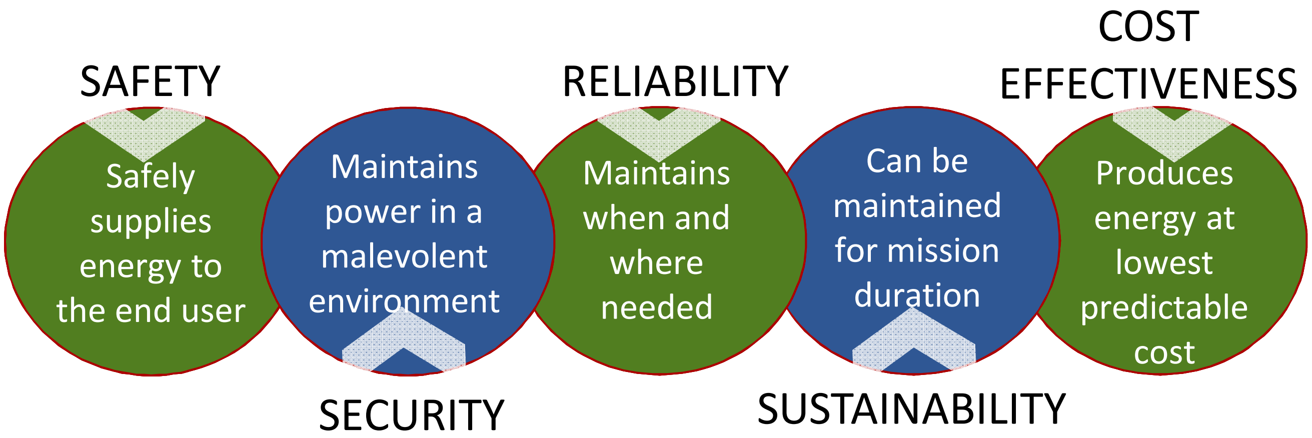
Andrea Ambrosini, 8/1/2013

Summary and Future Work

- Summary
  - Several materials show promise
  - $MnCo_2O_4$ has a figure of merit close to that of Pyromark^{TM} 2500
    - Had one of the highest absorptivites and the lowest emissivity of materials tested
  - Cr-doped samples showed lower selectivity than Cu-doped and Mn-doped materials
  - Higher dopant concentrations produced more selective materials

- Future Work
  - Structural characterization of materials using SEM and XRD
  - High temperature durability tests (600-800°C)
  - On sun tests at National Solar Thermal Test Facility
  - Testing of different transition metal series as well as combinations of multiple transition metals

Energy Surety



- Cost Effectiveness
  - Increases overall efficiency, decreasing cost
- Sustainability
  - Ideally, coating lasts as long as tower deployment or can easily be reapplied
- Reliability
  - Maintains selectivity longer than current materials, keeping tower efficient

Thank you for your attention

Questions?