An investigation of Transition Metal Oxides in p-Type Dye-Sensitized Solar Cells

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Introduction

In a society increasingly dependent on energy production, the need for alternative energy forms is becoming a priority. Fossil fuels and other traditional means by which the world has been supplying their energy are running out, as well as detrimentally harming the environment. Research in Solar energy has become a priority. Little is known about the use of low cost transition metal oxides, such as Vanadium Oxide, Manganese Oxide, Cobalt Oxide and Iron Oxide in p-type dye sensitized solar cells. The various oxidative states possible with these transition metal oxides makes them viable candidates in the exploration of their use in dye-sensitized solar cells, due to the oxidation reaction that may occur with the illumination of the dye sensitizer.

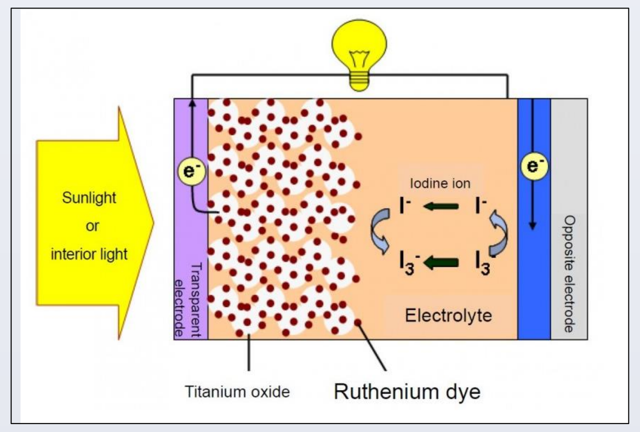


Figure 1: Simple Dye-Sensitized Solar Cell[1]

Hypothesis

- From previous research on NiO DSSC's:
  - Normally NiO is a light colored metal oxide
  - Due to defects from oxidation upon exposure to air, however, it has been observed that the nickel metal oxidizes from 2^+ to 3^+. Thus, it actually appears to be black.
  - Ni's holes are also more localized on individual Ni atoms, due to its 3d orbital structure[2].
- Hypothesized Reaction:
  - Localized electrons in 3D orbital (transition metal row) participate in redox reaction:
  - $M^{n+}_{surf} + Dye^{*} \rightarrow M^{n+1}_{surf} + Dye^{-}$

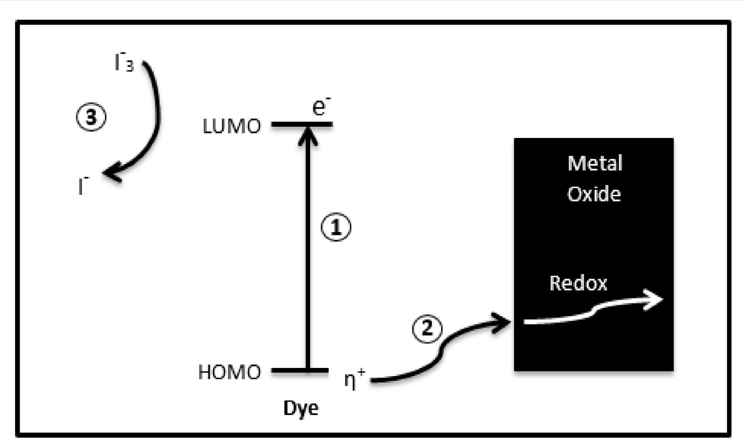
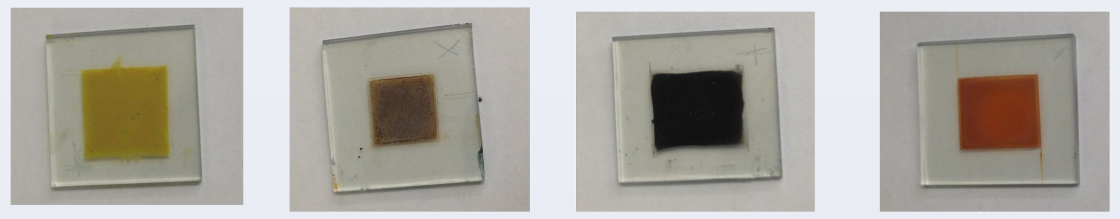


Figure 2: Dye-Sensitized Solar Cell Hypothesized Reaction

Materials & Methods

- The most common oxidative states for the transition metal oxides of Manganese (2+/3+) Oxide, Cobalt (2+/3+) oxide, Iron (3+) oxide, and Vanadium (5+) were synthesized.
- Synthesized via a modification of a research paper that uses a sol-gel method for synthesizing NiO thin films[3].
  - The equivalent amount of 7.72x10-3 moles of a soluble metal salt from each oxide will be combined with 1g of water, 3g of ethanol, and 1g of a F108 polymer.
- Each plate is taped off to form a square area in the middle of an FTO glass plate.
  - 50 micro-milliliters of the metal solution are deposited on each of the glass plates (conducting side).
  - A microscope slide is used to doctor blade the film evenly, and the solution is let to dry.
  - The plates were annealed at 250°C, 350°C and 450°C



V_2O_5 450°C Mn_3O_4 450°C Co_3O_4 350°C Fe_2O_3 450°C

Dye Sensitizers

Dye Type	Oxidation Potentials
O18[4]	0.136V
O3[4]	0.106V
MC	1.046
P1	1.126V

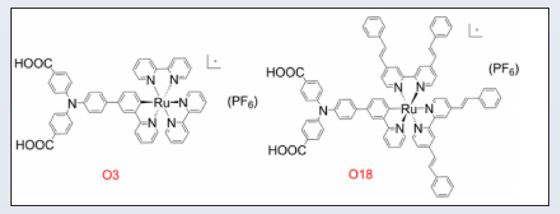


Figure 3: Structure of O3 and O18 Dyes[4]

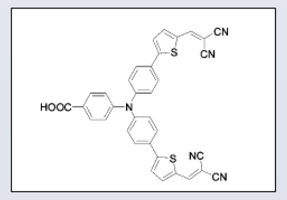


Figure 4: Structure of P1 Dye[5]

Monoxide Syntheses

CoO:

- Cobalt Acetate, ethanol and polyethylene glycols 4000 were combined in an autoclave and put in the oven at 150°C for 24 hours[6].

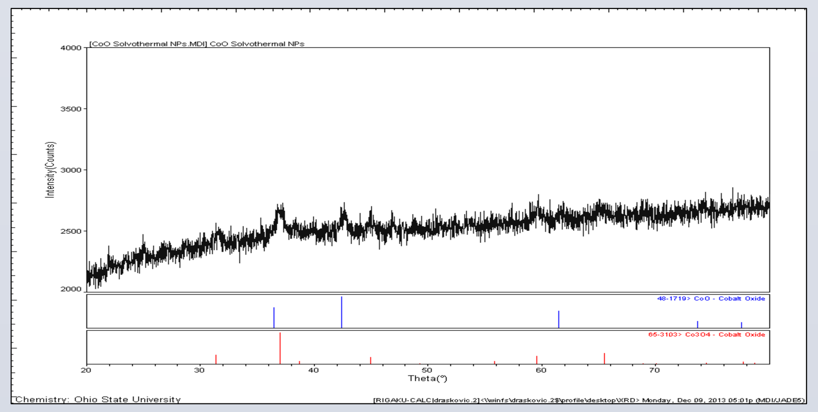


Figure 5: XRD of CoO

MnO:

- Under Nitrogen atmosphere, Manganese acetate and ethanol were combined and transferred to a Teflon-lined stainless steel autoclave. The autoclave was heated at 200°C for 24 hours[7].

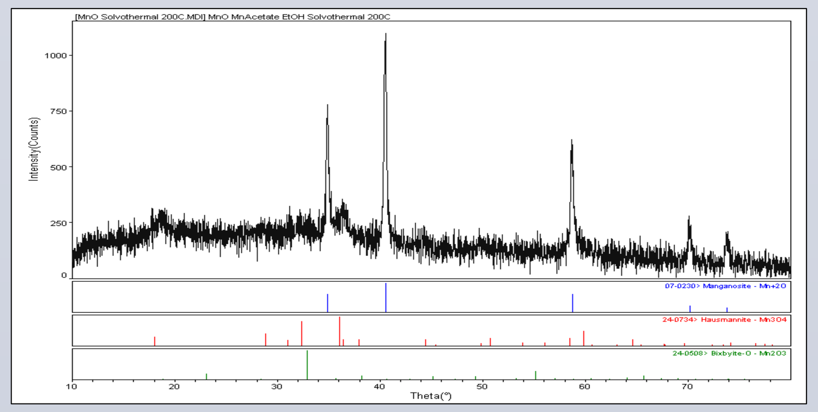


Figure 6: XRD of MnO

Results

Common Oxide Results

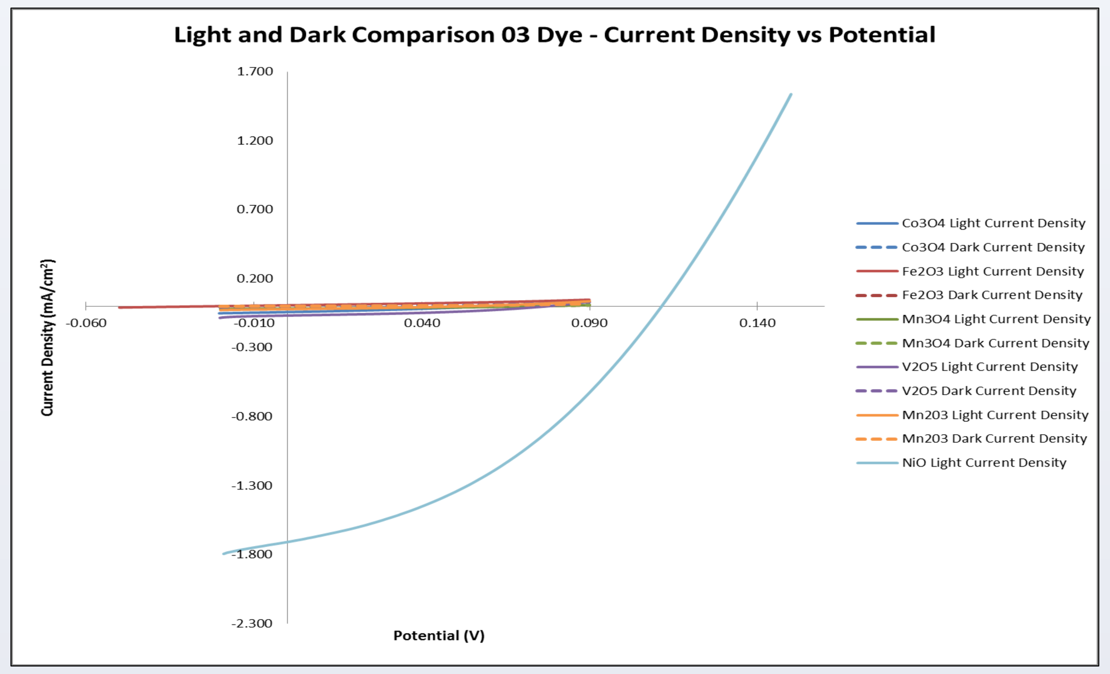


Figure 7: Metal Oxide Solar Cells in O3 Dye

Monoxide Results

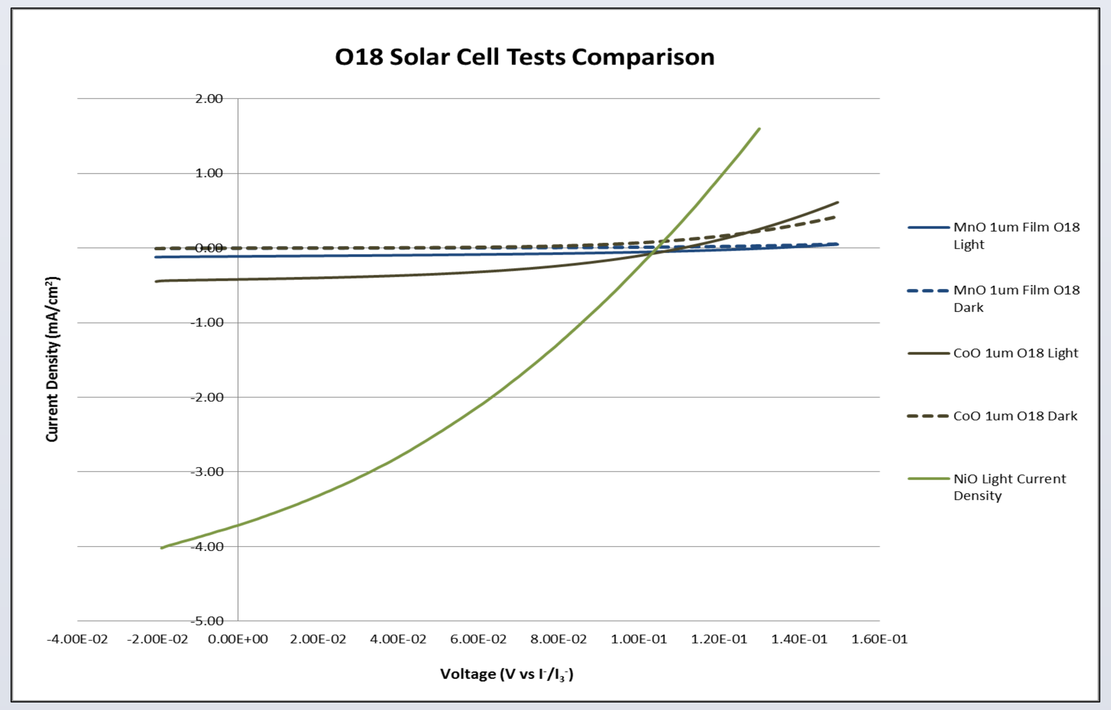


Figure 8: Metal Monoxide Solar Cells in O18 Dye

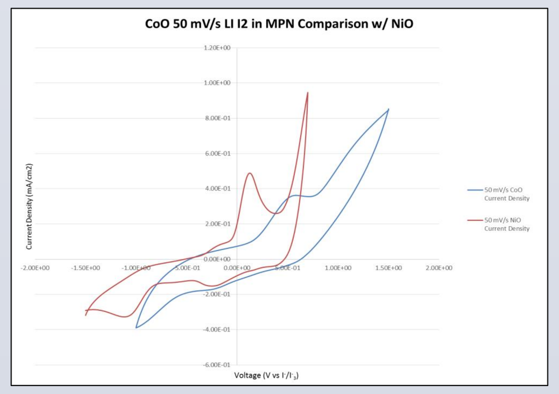


Figure 9: CoO CV

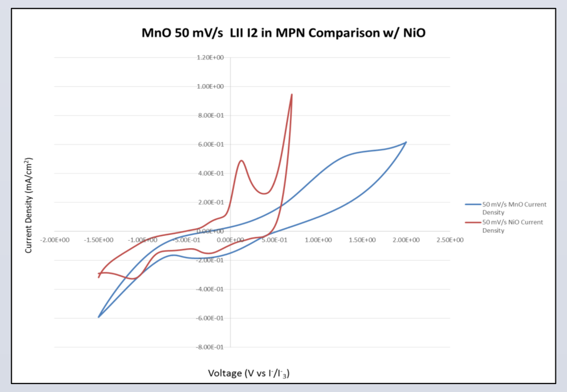


Figure 10: MnO CV

Continuation: Tungsten and ITO Results

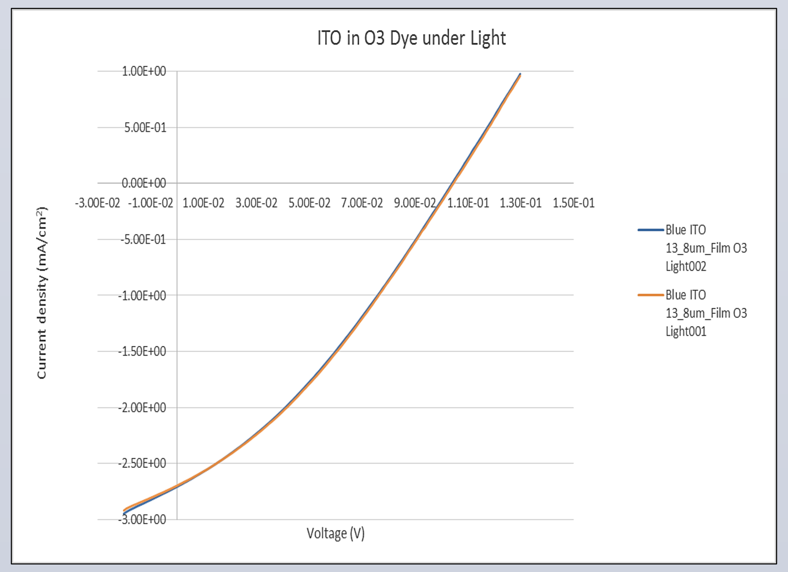


Figure 12: ITO Solar Cell Test in O3 Dye

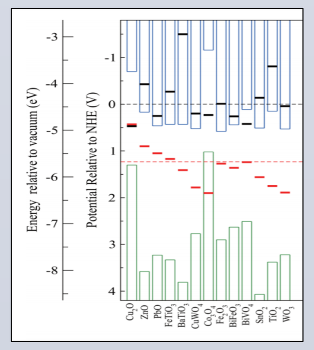


Figure 11: Band Gap Positions

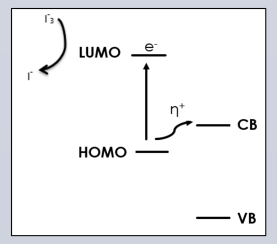


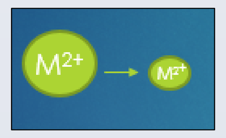
Figure 13: Mechanism

Figure 14: Tungsten Oxide Solar Cell Tests

Metal Oxide	Efficiency (%)
NiO in O18 dye	0.104
ITO in O3 dye	0.090
NiO in O3 dye	0.074
WO3 in O3 dye	0.0310
CoO in O18 dye	0.0198
MnO in O18 dye	0.0059

Conclusions

Why are the currents significantly smaller than NiO?



- Mn → Ni
  - Super-exchange mechanism stronger
  - Spin Changes
  - Jahn Teller Distortions

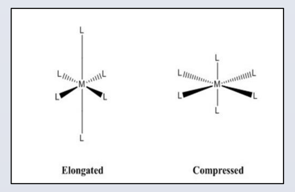


Figure 15: Jahn Teller Distortion

Future Work

- Optimize uniformity of films
- Test cells using new high performing dyes
- Synthesize and Test FeO solar cells
- Tungsten Oxide Doping

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