Perovskite Solar Cells Constructed With High School Lab Equipment

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INTRODUCTION

Solar energy has been noted as a pure and renewable energy source. Electricity is caused by the movement of electrons, so the goal of a solar cell is to move electrons based on the photonic rays of the sun. Photons, or energy in the form of light rays, react with the electrons in the N-junction of a solar cell. This energizes the electrons into moving through the P-junction. The N-junction is achieved by using an electrically negative material/chemical, while the P-junction is done by using a material that is electrically positive. This in turn creates both a negatively and positively charged ends of the solar cell, and allows for a voltage differential to form. (Dhar, M.) Our goal was to create a perovskite solar cell using the limited lab equipment and budget in a high school classroom. This new type of cell holds a lot of potential to eventually replace traditional silicon based cells because of its high potential efficiency.

METHODOLOGY

Our Original Procedure, which created our first working solar cells. From here we expanded and tried new ways of cooking and new temperatures to find the best solar cell using this procedure.

1. We combined 3:5 grams to ml of Vinegar and Titanium Dioxide (TiO2) in a Mortar & Pestle. Using a bent stir rod, the mixture was spread across the conductive side of a 25cmx25cm FTO glass slide to form a thin layer.
2. Using a hotplate set to 500c, bake the TiO2 coated slide for 10-15 minutes. Once the time had elapsed, we set the temperature to 0 & let TiO2 cool slowly on the hotplate. This prevents cracking.
3. Separately, combine Methylammonium and Lead Iodide at a 1:1 Molar Ratio. Mix using a Vortex machine for no less than 60 seconds. Then add 1-2 drops of Glycerin per 200uL of Methylammonium, and Vortex again for ~60 seconds.
4. In a final tube, mix triphenylamine and ethanol at a 0.001g/100uL ratio. Vortex this tube for 60 seconds.
5. Remove TiO2 coated glass from hotplate and place into modified Centrifuge with adapter or spin coater. Spin at 3,000-6,000 RPM while dropping 100uL of the Methylammonium Lead Iodide mixture from a Pipet. Spin until the the mixture is spread across the entire slide, then place onto a hotplate pre-heated to 140c. Cook for 5-10 minutes
6. While the Methylammonium slide is baking, take a new FTO coated glass and use a candle to form a carbon soot layer on the conductive side of the glass. The glass should be completely opaque.
7. Spin coat the previously mixed Triphenylamine mixture onto the soot layered FTO glass.
8. Once the Methylammonium slide is done baking, remove and place conductive side down onto the Triphenylamine slide. Make sure to leave an overlay on each edge to place the alligator clips.
9. Use superglue, nail polish, or similar sealing agent around edges to prevent moisture from reaching the Perovskite.

CRITERIA & CONSTRAINTS

Criteria:

- Made using only the tools of Mr. Wolverton's lab.
- Produce ~.3V
- Produce measurable current (>0.1uA)
- Mobile, able to be moved and repositioned for testing.

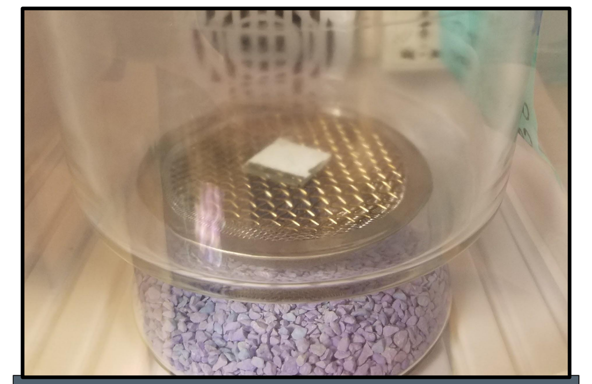
Constraints:

- Each conductive glass is 25mmx25mm
- Total cost for each cell should not exceed $10
- Must be sealed to prevent moisture degradation
- Cell must be finished with all testing done by end of April

INDIVIDUAL PROCEDURE FOLLOWED

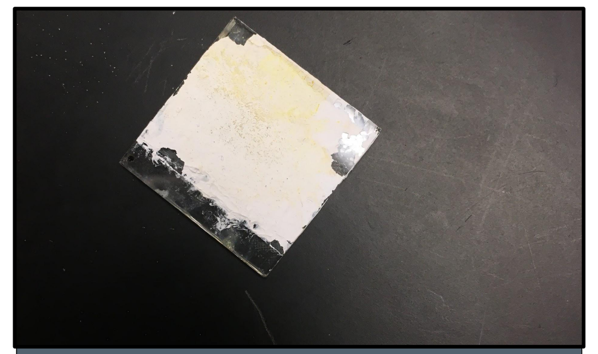
Jared Arave

1. Coat conductive side of FTO with TiO_2 & bake at 160 degrees C for 5 minutes.
2. Coat another FTO slide with carbon soot from candle.
3. Spin-coat 100 µl of the lead iodide perovskite solution onto TiO_2 layer.
4. Bake on hot plate at 160 degrees C for 5 minutes.
5. While other slide is baking spin-coat 100 µl of the triphenylamine dissolved in ethanol onto carbon soot layer,
6. Sandwich both layers together, slightly offset to allow for alligator clips
7. Use binder clips to keep slides pressed together while you seal with super glue, then remove clips.



Weston Goff

1. Mix TiO2 and Vinegar in mortar and pestle at a 3:5 molar ratio, and paste onto the FTO glass.
2. Bake the FTO glass for 5 minutes at 500 c on hot plate, then turn hotplate to 0c and let TiO2 cool slowly.
3. Spin coat 100ml Perovskite liquid (Methylammonium Lead Iodide) onto TiO2 glass.
4. Place cell into a desiccant and place into incubator set to 60c. This prevents moisture from destroying the Perovskite crystals over the longer bake time.
5. Cook for ~70 minutes.
6. While cooking, create Triphenylamine and soot FTO glass as described in steps 6-7 of Methodology.
7. Once bake time is complete, remove and place conductive sides together. Seal with glue.



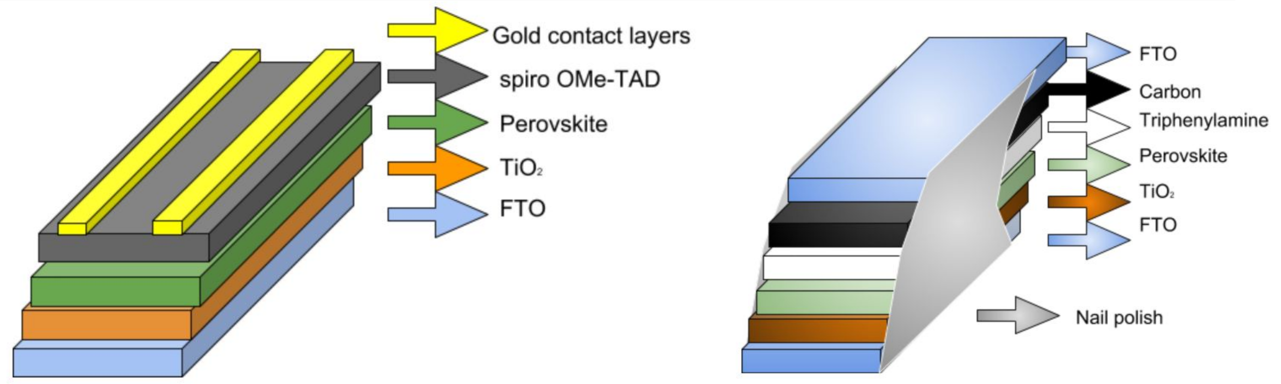
Timothy Karn

1. Create a carbon layered FTO glass slide
2. Create a triphenylamine solution
3. Spin coat triphenylamine solution onto carbon layered FTO glass slide.
4. Create a 3:5 ratio Titanium Dioxide layer
5. Spin-coat lead-iodide and methylammonium iodide solution onto titanium dioxide.
6. Heat the FTO Glass (now including the Perovskite liquid) at 350 °C for 2 minutes to crystallize the Perovskite layer.
7. Quickly place both layered slides together and seal edges with nail polish.

Jeremy Ginter

1. Mix Acetic Acid and Titanium Dioxide in a 3:5 Molar Ratio. Paint it on the conductive side of a FTO glass slide and bake it on a hot plate at 500 C for 10-15 minutes.
2. Mix Methylammonium and Lead Iodide at a 1:1 Molar ratio and add a drop of glycerin. Mix in a Vortex Machine.
3. Spin coat 100uL of the Methylammonium mixture on the Titanium Dioxide slide, and heat at 150 C for 10 minutes.
4. Mix Triphenylamine and Ethanol at 0.001:100uL ratio and and mix in the vortex machine.
5. Coat a FTO glass slide with soot from a candle.
6. Spin coat the Soot covered slide with 100uL of the Triphenylamine.
7. Place the conductive sides together slightly offset so there is room for alligator clips. Seal the edges with super glue.

DESIGN



Before constructing any cells, we came up with a design based on pre-existing literature. Once we researched the price of these components (mainly the Spiro-MeOTAD and the Gold), we realized that this design was not feasible with our lack of funds and our lack of equipment. In our revised design, we swapped spiro-MeOTAD out for Triphenylamine to create the insulating layer. We also switched out the gold contact layers with a carbon-layered FTO glass, the carbon acting as the anode. When light hits the solar cell, it is diffused by the Titanium Dioxide layer (TiO2) and knocks the electrons from the perovskite layer. The electrons are pushed through the Triphenylamine layer which acts as an insulating layer, preventing them from falling back into their holes in the Perovskite layer. Choosing the path of least resistance, the electrons travel through the load and return back through the other FTO glass.

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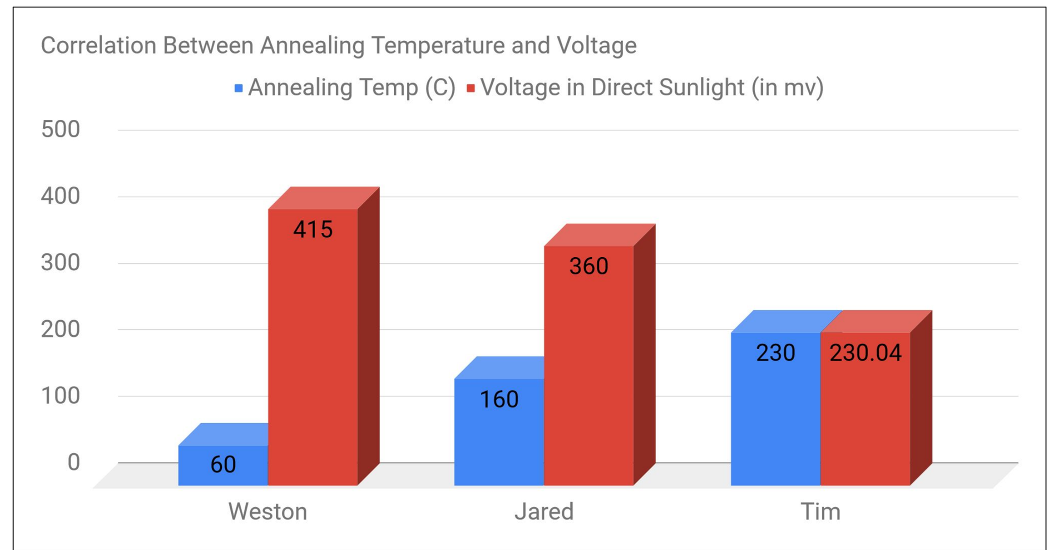
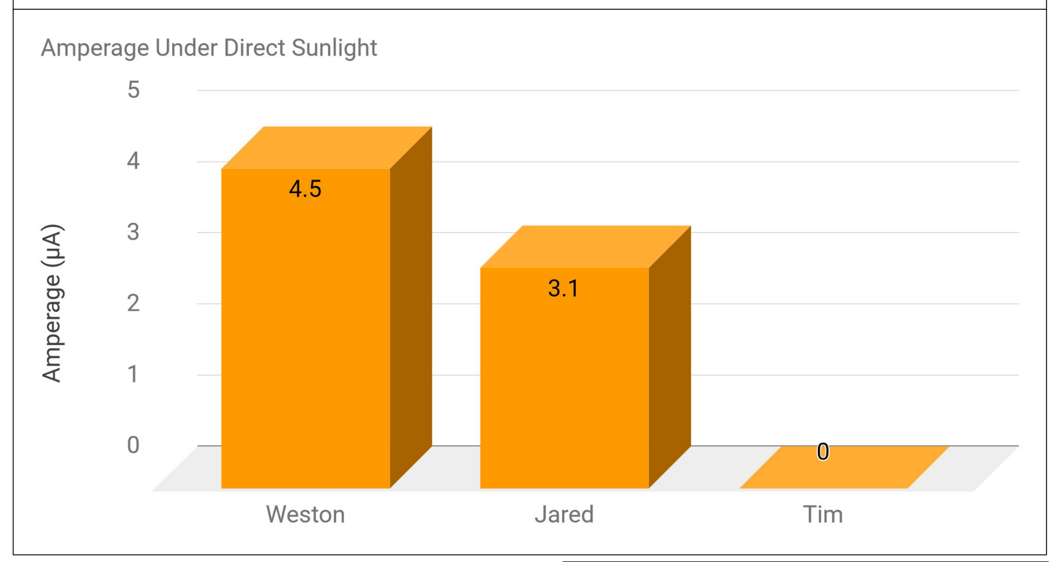
FINDINGS

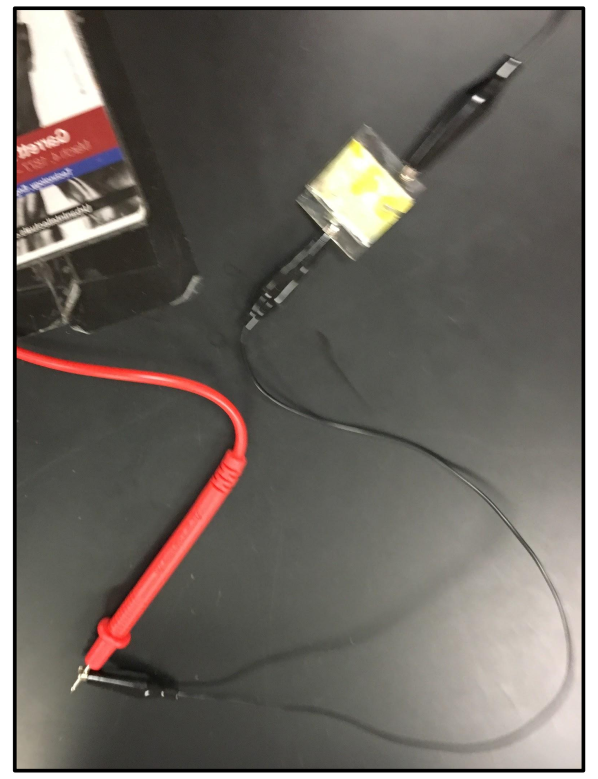
Overall, our experimentation was a success. We succeeded in creating Perovskite solar cells in a high school lab. By substituting quite a few items suggested by other procedures, we were able to create cheaper, easier cells using much more basic materials and chemicals.

Once we found a methodology that worked well with our criteria and constraints, each of us used different cooking techniques to find the best combination of cook time and cook temperature. We found that as the annealing temperature rises and the cook time shortens, the amperage and voltage of a cell decreases.

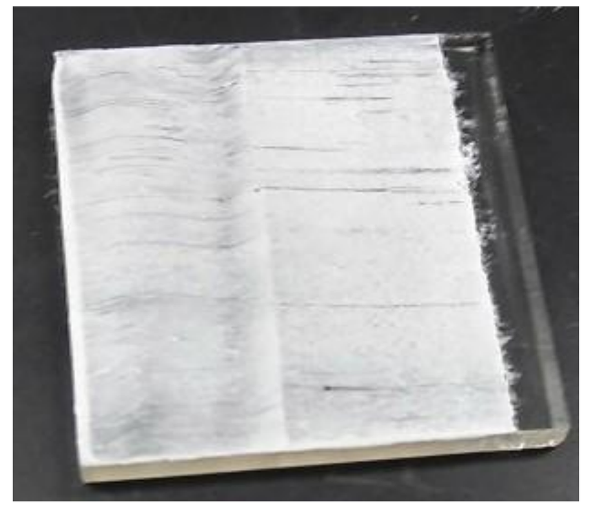
Creator	Date	Cook Time	Cook Method	Cook Temp	Voltage Outside	Amperage Outside
Weston	3/26/19	45 minutes	Incubator	60 C	415 mV	4.5 µA
Jared	3/26/19	5 minutes	Hot Plate	160 C	360 mV	3.1 µA
Timothy	3/22/19	30 minutes	Hot Plate	230 C	230 mV	0



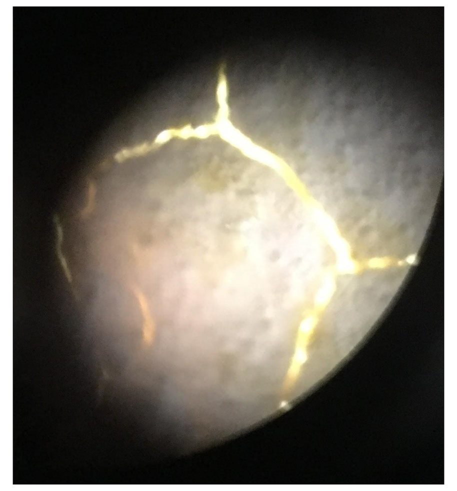




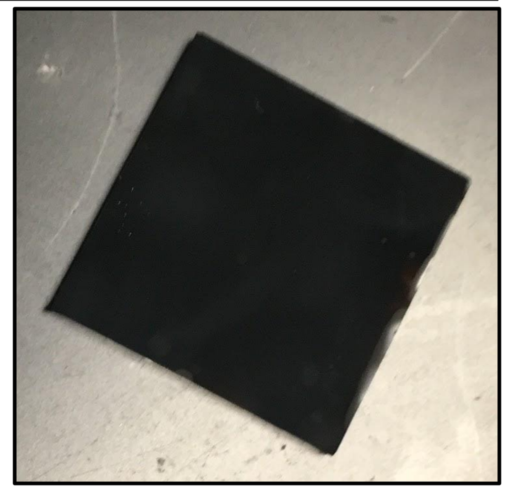
Cell Attached to Multimeter



Titanium Dioxide Coated FTO Slide Before Baking



Perovskite Crystal Under Microscope



Carbon-Coated FTO Slide

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