**CEI Perovskite Fabrication Video Script**

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**Scene 1 – Intro:**

First I’ll give a quick introduction about how a solar cell works. A solar cell uses a semiconductor to generate electricity. When light gets absorbed by a semiconductor crystal, negatively charged electrons surrounding the atoms in the crystal lattice absorb the energy of the photons and are promoted to conductive electronic states in the crystal, known as the “conduction band.” In turn, a conductive positive charge called a “hole” is left behind in the lower energy states of the crystal, known as the “valence band”. If the positive and negative charges can be collected at opposite electrodes in a solar cell (known as a cathode and an anode), then the charges can conduct electric current through an external circuit. At the same time, the potential energy difference between the positive and negative charges collected at the cathode and anode results in a voltage, which allows the solar cell to drive current through a load in the external circuit to generate power.

The perovskite solar cell that we’re going to make today consists of three layers that are sandwiched between metal contacts. We start with a transparent contact on a glass substrate. The transparent contact is made of fluorine doped tin oxide, also known as FTO. On top of that we deposit a layer of titanium dioxide, which is an n-type semiconductor that is used to conduct electrons. These first two layers make up the anode in the solar cell. On top of that we deposit a methylammonium lead triiodide perovskite (CH3NH3PbI3). The perovskite is the semiconducting crystal that absorbs sunlight to generate electrons and holes, which are then transported down to the anode for electrons, and up to a cathode for holes. On top of the perovskite we deposit a layer of the small molecule Spiro-OMeTAD, which is a p-type layer that is used to conduct holes. And then on top of that, we evaporate a contact made of gold. The Spiro-OMeTAD/Gold layers make up the cathode in the solar cell.

**Scene 2 – Etching FTO:**

First we are going to take a piece of FTO/glass and etch off FTO around the edges of the substrate using zinc powder and 4 molar hydrochloric acid. We do this to prevent short circuiting between the top and bottom contacts the device during testing, since our test leads press down at the edges of the solar cell. We start by covering the conductive side of the FTO/glass with a piece of polyimide tape that leaves the edges of the substrate exposed. Next we cover the substrate fully with zinc powder. The zinc powder will react with hydrochloric acid to remove FTO underneath all of the areas that aren’t covered by the polyimide tape. Next we drop the hydrochloric acid onto the substrate and let it react with the zinc powder. The reaction causes the zinc powder to bubble. We add hydrochloric acid until the bubbling stops, at which point the etching is finished. When the reaction is finished we’ll rinse the substrate with deionized water. When we take off the tape, you can see that FTO has been etched off of these edges, so that now FTO is only in the middle, and the outer edges are glass. Next we’ll take this substrate and sonicate it in 1% Micro 90 Detergent, deionized water, acetone, and finally isopropryl-alcohol sequentially for 20 minutes each to clean the FTO.

**Scene 3 – Spincoating TiO2**

After the sonicating wash cycles are finished, we’ll take out the FTO substrates and blow them dry with a stream of dry nitrogen.

Before we deposit the titanium dioxide, we are going to plasma clean the FTO substrate. We plasma clean with pure oxygen at a flow rate of 100 mL / min. The bright purple light is due to the ionization of oxygen gas and indicates that we are generating oxygen plasma. After 10 minutes of plasma cleaning all residual organic substances are removed from the FTO surface.

Now we’re going to spincoat the TiO2 precursor solution. We drop 60 uL of the precursor solution onto the substrate and spincoat at 3500 rpm for 1 min to form a thin film. After spincoating, we anneal the TiO2 sol-gel film on a high temperature programmable hotplate. This is the program for annealing the TiO2:

-Ramp to 100° C for 10 minutes, soak for 10 minutes

-Ramp to 150 C for 5 minutes, soak for 10 minutes

-Ramp to 325 C for 10 minutes, soak for 30 minutes

-Ramp to 450 C for 5 minutes, soak for 5 minutes

-Ramp to 500 C for 10 minutes, soak for 30 minutes

-Cool for 3 hours

After the program is finished and the hotplate has cooled, we remove the substrate from the hotplate.

**Scene 4 – Spincoating Perovskite**

We’re going to be spincoating a precursor solution for the methylammonium lead triiodide perovskite (CH3NH3PbI3). The precursor solution is a 3:1 molar mixture of methylammonium iodide (CH3NH3I) and lead acetate trihydrate [Pb(CH3CO2)2 · 3H2O] dissolved in anhydrous dimethylformamide (DMF) to a concentration of 40 wt% solids. We spincoat the solution at 2000 rpm for 45 seconds. Now we let the precursor film dry in the glovebox for 15 minutes. Then we anneal the film on a hotplate at 100° C for 5 minutes to fully form the perovskite. As the perovskite forms the film will start to turn black. After 5 minutes of annealing the perovskite has fully formed and we remove it from the hotplate.

**Scene 5 – Spincoating Spiro-OMeTAD**

Now we spincoat a solution of Spiro-OMeTAD on top of the perovskite layer at 4000 rpm for 1 min to form the Spiro-OMeTAD film. After we spincoat the Spiro we then leave it in a dessicator overnight in air. This allows the Spiro-OMeTAD to oxidize, which will further p-dope the Spiro making it more conductive for holes.

**Scene 6 – Evaporating gold contacts**

We load the device into a shadow mask. This allows us to deposit a predefined pattern of metal electrodes for the top contact. We then load gold pellets for the top contact into a tungsten evaporation boat. We secure the tungsten boat onto metal posts which will pass current through the tungsten boat, heating the gold pellet through resistive heating. We then pump the evaporation chamber down to a pressure less than 10-6 Torr, which will allow the metal to vaporize under resistive heating. Now we deposit the gold contact at a deposition rate of 2 Å/s. We start by heating the metal at a slow evaporation rate to burn off impurities. Once we reach the desired rate for deposition we begin depositing the gold by opening a shutter which will allow metal vapor to condense on our substrate through the pattern in the mask. Once we reach the thickness that we want, the shutter closes and we ramp down the power. When the deposition is finished we re-pressurize the evaporation chamber and remove our samples and the metal boat. We then take the samples out of the evaporation mask and can see that we’ve deposited our contacts. Now the device is complete, and we are ready to silver paint the edges of the gold contacts and test the device.