Solar Photovoltaics:
Fundamental Technology and Applications
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Lecture-17
Lab Fabrication Procedure for DSSC

Welcome everyone to our course solar photovoltaics today we have module 4 and lecture 2. In the last few classes we have started introducing you the concept of different generations of the solar cell. So far we have learned about first generation solar cell, second generation solar cells and in the last class we started with 1 particular kind of third generation solar cell namely dye sensitize solar cell.

And we have also learn that this idea behind the dye sensitize solar cell was inspired by the artificial photosynthesis. People thought that whether we can mimic the natural photosynthesis process in the lab. And what you found that the method of fabrication of dye sensitize solar cell was quite inexpensive and also the processing method and processing cost is very insignificantly lower in comparison to the first generation and the second generation solar cell.

In today's lecture we will learn about how to fabricate this kind of solar cell and we will see that at the end of this lecture it is very easy and even using some of the very day to day objects we can make this kind of solar cell ok. Let us have a look on how to make dye sensitize solar cell. Today we are going to show you how to fabricate a dye sensitize solar cell. In next 10 to 15 minutes we will go through this process starting from some simple components or elements we will show how we can make a DSSC device.

Today along with me we have 2 students in my left side Mr. Naveen kumar (()) (01:48) on my right side Miss. Yugtha.
(Video Starts: 01:52)

So as you can see on this table there are certain components are there which is use to make a dye sensitize solar cell. The first component if you remember we talk to about 2 electrode. One of this electrode is photo anode which is made on putting ITO or FTO on a glass substrate. The second component is the semiconductor which is titanium dioxide. So as a semiconductor we are using this titanium dioxide here which is kept in this bottle in a slurry form.

The part was a dye or sensitizer you can use as we mention that any kind of dye or sensitizers like for example here you can use porphyrin dye which is one of the components or constituents of the chlorophyll also or you can use for example laser dye like rhodamine 6g and then finally to regenerate the whole process we need a electrolyte solution and we are using iodine tri iodide as an electrolyte solution.

To complete this circuit we have to put a counter electrode you can put or you can fabricate the counter electrode by making the platinum on the glass substrate. But in a very simplistic case I can even take a glass substrate and I can put this graphite layer on that which will also be a conductive layer and it can be used as a counter electrode. And finally all the device will be sandwiched by using this clip.

And to measure the current and voltage we are using here and ammeter where you can measure it the current and the voltage ok. So let us start this process one by one, so first like you know we will show you, so this is a normal glass substrate. So what is the difference between this glass substrate and this ITO substrate, so as you said that this substrate is not conductive. So how can we say that like you know we can we have this multimeter.

So for example like you know if we connect thus 2 lids of the multimeter here you can see that there is no current inside the multimeter. But whereas like you know if I take this another substrate like ITO for example this one and if I contact the 2 probes of the multimeter you can see a current here on the multimeters. So that is why we can distinguish whether a substrate is conductive or not, now what makes this substrate different from this substrate.

So one is like you know we have in one of this layer is more shiny in comparison to the other. So in one of the layer we put it like in every thin layer of indium dope tin oxide or fluorine dope tin oxide. In our particular case here we are using an ITO substrate, so this is my photo anode, the next thing to make the devices we need a titanium dioxide.

So titanium dioxide is a slurry or titanium dioxide is a semiconducting material, so we have to make a slurry of the titanium dioxide. So slurry means some viscous solution, titanium dioxide comes as a powder, so we have to put that powder in some kind of solvent and control the viscosity to make the solution a viscous or semi viscous liquid. So that we can put and make a very uniform thin films on the glass substrate.

And here we have done it by putting the titanium dioxide on a PH3 acetic acid solutions. So what we will do we will take this PH3 acetic acid, titanium dioxide slurry and we will put it on a ITO substrate. So let us do that ok, so this is our ITO substrate, so now let us take a slurry this is, so this is our titanium dioxide slurry and this is viscous. So we have to take it from this thing and then we will put it on the ITO substrate like this, this is really viscous.

So we are doing it 2, 3 times to take it more of this TiO2 or titanium dioxide here. We need a thick layer because this thick layer will help you to absorb the more and more light. And as I said that this layer should be mesoporous layer that means there can be lot of spongy structure inside it. So then next thing is that, so you can see that we have put some titanium dioxide slurry on top of this ITO substrate, so now I need to make a film from this slurry, so how can I do that.

So I can do it either by spin coating technique or by doctor blading technique. But since here the viscosity is very high, so if I wanted to spin coat it that means if I pour some solution which moves it by the centrifugal force and make a uniform thin film that is not possible here. But we can do doctor blading technique, it is very easy you take another glass substrate like this and you hold this ITO substrate and you pour this thing, you fix it on the top of ITO substrate and slowly roll it like this.

You can even use the other substrate like this, you can say that we can make a, so we have been able to make a film of the TiO2 on top of this conductive ITO substrate. Now next thing what we need do is that we need to make this structure mesoporous. That means we need to create a spongy kind of geometry in the substrate, how can we do that.

So TiO_2 is a semiconductor if we heat it beyond a particular temperature for example 450 degree Celsius, so this structure will become a spongy structure or a mesoporous structure. So we can do it by putting on a heat substrate, so which we call is a hotplate which is showing here this is an example of a hotplate where you can control the temperature in the hotplate. Usually we go to 100 to 150 degree Celsius for going to further temperature like 450 or 500 degree we really need a specially designed chamber like furnace or vacuum furnace.

But here we are just showing it as a low temperature sintering method, so what we will do, we will put this thing on top of this substrate and we will keep the temperature on. And we will allow it as you can see from this dial here you can control the temperature as well as you can control the rpm that the speed of the rotation. Now if I put it on the this glass substrate on this hotplate, so you can see that the color will started changing.

Now let us wait for 2 to 3 minutes to observe a change of color or unless until this film is become solidifies. Meanwhile what we will do we will prepare a dye solutions, so as I said that this is the dye molecule or the sensitizer's molecule which is a porphyrin compound dissolved in some organic solvent. Here for this particular case we are using an organic solvent which is has a name called NMP.

Now NMP is a highly polar solvent and this dissolves this dye molecule very well, you can as I said that you can even use any solvent, you can even use any fruit extract, you can use any laser dyes also as a sensitizers, so dye molecule. Now next thing what we will do, we will take this beaker and we will pour it on this solution, so that we can dip the this glass substrate on inside this solutions after sometime.

So you can see here this dark green color solutions as you say that the DSSC color can be tuned and this green color is coming due to it is absorption property. So it actually characteristics of a material, now we have our sensitizer's molecule ready and now we are waiting for our titanium dioxides to become like more thick and more solid and heat. So maybe we can increase the temperature little bit high, so that this process become little bit faster.

So right now can we make it something like you can see that as I rotate this the temperature is changing. So we fix the temperature here to 120 degree Celsius, if you look the reading of the temperature is 120. So it will take sometime 2 to 3 minutes for this substrate to become the temperature of 120. And already if I touch it, do not touch it although during the experiment you can feel the heat, so this plates or this substrate is really started becoming hot.

And now on the other hand I have this electrolyte solution which is also ready and this electrolyte solution is made from the iodine tri iodide electrolytes and we try to also add some of additive solvents there. For example a common additive which we used here is 4, tertiary butyl pyridine. So this the role of the additive is to increase the conductivity, we can add it finally at the end of the device fabrication or we can even put it is little bit amount of additive inside the electrolyte solutions.

Now we need to wait for 2, 3 minutes like you know so that this film become solidified and as you can see that color has already started becoming change. And if you wait for 5 to 6 minutes it will become a white color things. In this particular example we are taking this porphyrin molecule but we can also take some other molecule right. We can take any kind of organic dyes or any kind of polymeric molecule or even some inorganic dyes are laser dyes, quantum dot as a sensitizers as a dye molecule.

And even as a semiconductor, in this particular case we are using titanium dioxide but we can even use zinc oxide or some other large band gap semiconducting oxide provided they will be able to transport the charge whatever have been injected to the semiconducting oxide. So as you can see that this film has already started changing it is color and it is becoming a from dark yellowish to like you know some grayish whitish right.

We need to wait for another 3, 4 minutes, so that it really changes color and becomes a solid film. So that we can take out this film from the here and we can dip it inside our dye solution. So usually what we do like we take this titanium dioxide coated glass substrate and we put it in a muffle furnace which is a specially designed furnace and we heat the substrate at 450 degree Celsius and we kept it to 3 to 4 hours, within 3 to 4 hours.

So the titanium dioxide not only change it is crystal phase it also made it like you know more mesoporous structures. But here we are doing a low temperature sintering for demonstration purpose. So here we are trying to heat at 120 degree Celsius and we wait how much color change we can see from here ok**.** The solvent whatever is inside this titanium dioxide slurry that is slowly evaporating and the film has been started drying although it has not dried completely.

There are still some liquid portion we can see it here and since it is a very very viscous like the color is yellowish. I think we can probably take it out we can take it out using tweezer and hen dip it inside this dye solution like this. So usually we dip it over night but here we will try to dip for 1 minute and you can see that the color has been started changing and it will depend upon the absorption coefficient of this the dye molecule.

So we just soaked it here and you make sure that the substrate get as much as dye contactor as possible that is why I tilted this beaker little bit as you can see here. Another trick which we do that like in a usually we dip it inside the dye solutions as soon as you take it out from ou hot chamber. Now you see that the titanium dioxide anode has started absorbing the dye molecule, **the** here sensitizer porphyrin.

Meanwhile it dips it we prepare the counter electrode, so let us say this is the glass substrate. Now which is one part which is left as a glass substrate now this is a pencil which we use for writing every day. But you can even be useful for making a counter electrode, how we can make it like you know we can put it on the top and put it like that. So this graphite piece we can take it ok so we see some color changes and because this substrate is very shiny like you know reflective probably we do not see the color change.

But if we do the same thing on a glass substrate you can see it like here yeah like here you can see this. So you can see that there is a layer of this carbon graphite has put on the glass substrate and this has become conductive. So to match the size or dimensionality let us take this as a counter electrode ok. And I have a binder clip like this one and this one which is use to sandwich this devices and finally we can take it out this devices.

And if we emptied it let us say we empty al this glass side ITO side from here and we put it back and then we take it out you see there is a color change, you can clearly see there is a color change. So now this TiO2 layer has started absorbing the porphyrin molecule, now whatever the loosely bound dye that we can wash out with some kind of solvent or here we are just trying to wipe it out and I put it back it on the substrate ok.

So the photo anode is ready now and my counter electrode is also ready, so next thing is to make the complete sandwiched type of structure. So what we will do we will take this photo anode and we have this counter electrode, so we will sandwich like this. And then we will put this 2 electrode first I will put 1 electrode, so that the contact between the counter electrode and the semiconductor is fine now.

Now what happens if the light falls on this TiO2 layer, so TiO2 layer has absorb the dye molecule. So the dye will absorb the electron and it will go from it is valance band to the conduction band. And then it will inject that electron to the titanium dioxide and that electron now will percolate through the external circuit. To regenerate this process we mention that we need to add some electrolyte.

Now usually the electrolyte is done by putting a drill on top of the this glass slide but here we can also put the electrolyte by the diffusion process. So we need to have a pipette like this and we will take few drops of the electrolyte like this and we will add it slowly like drop wise like this. So the electrolyte solutions is now diffusing inside the TiO2 layer and we complete the device configuration by putting the counter electrode on the other side ok.

So my device is ready, so which is sandwiched between a cathode and anode and the titanium dioxide is containing a particular dye. In this particular case it is a porphyrin dye and we put few drops of the electrolytes. So the dye sensitize solar cell or the gradual cell is now ready, the next thing is that to characterize the solar cell. Now there is a very standard instrument to characterize this solar cell called solar simulator where we can simulate the artificial sunlight.

Like we can take a broadband light source and pass through a filter which is a AM 1.5 filter we have already introduced you the concept of AM 1.5. So that it can mimic the sunlight, natural sunlight and then the light falls on the material it absorbs the light and it converts the electron into the electron hole pair. The photon which is converted to the electron hole pair and that passes through the external circuit and we can measure that thing.

But here in our daily life our in the lab undergraduate lab we can also a multimeter like this all we have to do you have this device. And then if you wanted to measure the current, so you can flip it like this ok, so one of the substrate is transparent, so light falls on it. So I will put 1 contact on the conducting substrate and 1 contact on the back substrate like this. And you can see like right here it is in a we can also change.

This is the using this multimeter we can also measure the current and voltage from this devices. If you know the current and voltage for different values from a calibration curve we can find out what is the fill factor. If you know the fill factor, if you know the current and voltage and if I know the input power then we can calculate the efficiency of this devices ok. So now our DSSC device is complete, now we can put 2, 3 of this devices to make a module and we can use it for practical application, thank you very much.

(Video Ends: 23:17)