Solar Photovoltaics: Principles, Technologies and Materials
Prof. Ashish Garg
Department of Material Science & Engineering
Indian Institute of Technology, Kanpur

Lecture – 35
Generation II Technologies :CdTe Solar Cells

So, welcome again to the new lecture of this course Solar Photovoltaics: Principles, Technologies and Materials. So, we have been talking about thin film solar cells for past couple of lectures. Let me just brief the recap of previous lecture.

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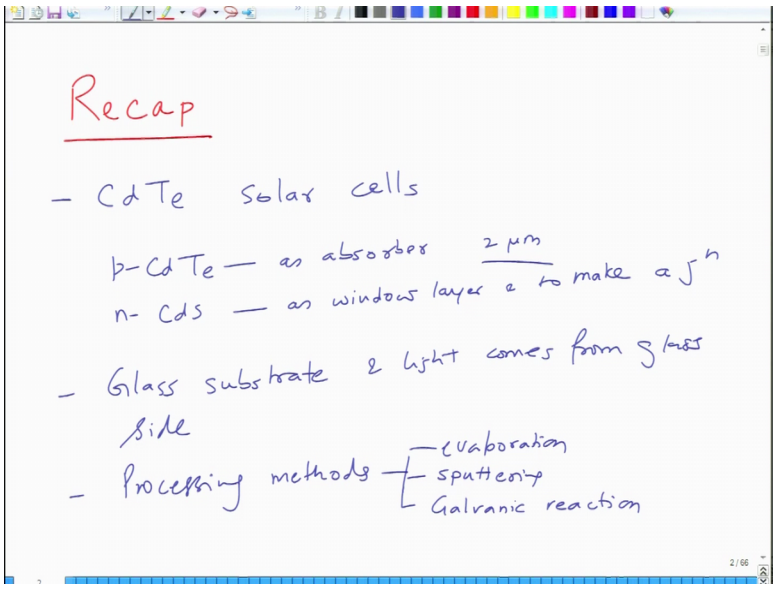

And the last lecture we started our discussion with cadmium telluride solar cells. So, cadmium telluride solar cells are basically thin film solar cells, where we use p-type Cd Te as absorber. And so this is about 2 micron thick layer, and an n-type Cds is used as window layer and to make a junction.

And then appropriately choose the contacts and this is basically a device which is on glass substrate, and the light typically comes from glass side. And we also looked at a few processing issues of this processing methods. So, we looked at evaporation, sputtering and galvanic reaction.

So, it is a, very good material from the perspective of properties, it has a almost ideal band gap, the efficiency of the devices are a very good, they are about 21 percent of so in

the laboratory scale, and very promising technology for the future. And potentially they want to replace the silicon eventually. So, let me now move on with the some more things about processing.

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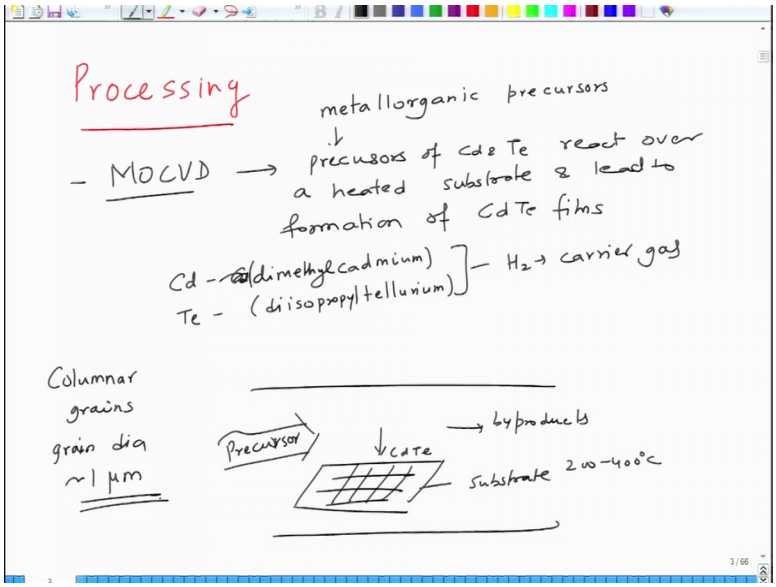

So, as we said about processing. So, not only you can process CdTe by sputtering evaporation galleria reaction, you can also process this by MOCVD kind of process, where in you know the precursors of Cd and Te react over a heated substrate and lead to formation of cadmium telluride film, and these precursors are basically metallorganic precursors.

So, basically we are looking at example for cadmium, we are using cadmium dimethyl, cadmium dimethyl, for cadmium dimethyl cadmium, and for tellurium, we use di isopropyl tellurium ok. And these are put into a carrier gas hydrogen, which is essentially you have a substrate here. So, this is substrate, which is kept inside a chamber at a temperature of 200 to 400 degree centigrade.

And then precursors arrive, so this is precursors. And then they react to give rise to CdTe film and the by products go out of the system. So, this is a very useful process and it gives you columnar grains, whether grain diameter of about 1 micron or so ok.

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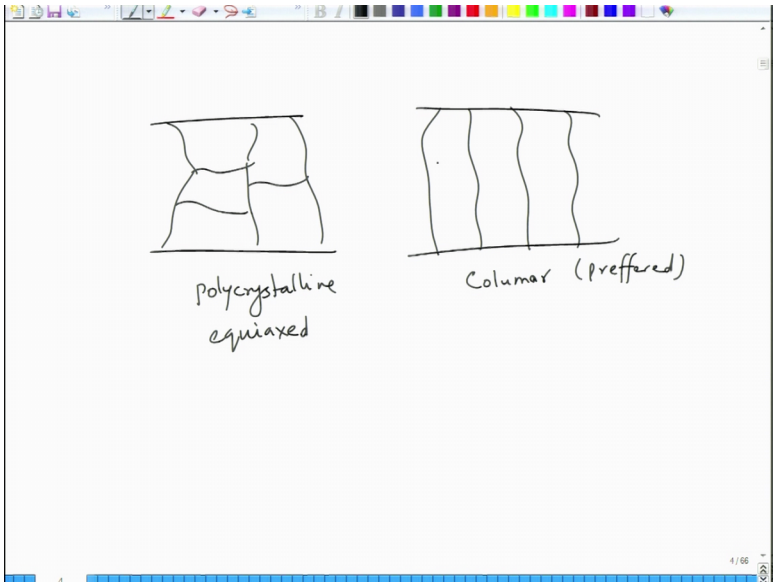

Columnar grains are good, because see you can have a in a device, you can have a grain structure like this; like this or you can have a grain structure which is like this. So, this is you can say a polycrystalline equiaxed grain structure, and in this case you have so this is a preferred grain structure, because it prevents recombination sideways.

There are no leakages and recombination paths in the film, so this preferred over; you cannot make a single crystal films which is difficult to make, but you can certainly make a columnar poly crystal structure which is better over equiaxed structure of the films. Then the processing of CdTe can also be done by spray deposition.

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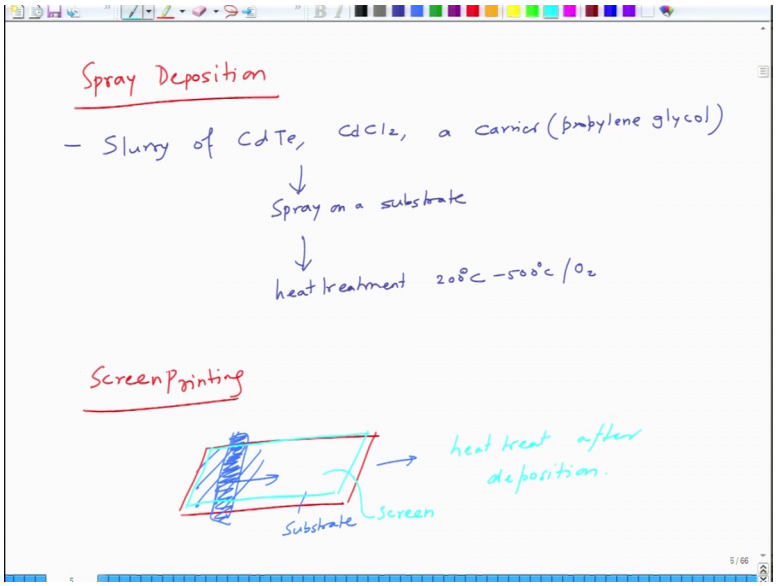

So, this is spray deposition process fuses basically a slurry of CdTe, CdCl2 and a carrier, and this carrier is typically propylene glycol ok. So, basically you make a sort of mixture and a in a sort of solvent and then you spray it on a substrate.

And then you heat treat. So, basically you spray it followed by heat treatment at about you know 200 degree centigrade to 500 degree centigrade and sometimes oxygen is also used in the later stages. And this after this, one deposits Cds layer on it. So, this is the processing these are the processing methods for cadmium telluride. And again in this case, it can also be screen printed, there a possible to the screen print it also, so one can also screen print.

So, screen printing is basically, you have a substrate, you put a, you put slurry on it and the slurry is taken away using a roller. So, this is a roller this roller is going to go forward to through a screen, the film will deposited. So, you have a substrate with and then you have a screen on top of it. So, they could be a screen on top of it, this is the screen with certain mesh size and then on top of screen you put in the slurry, and the slurry is rolled over using a roller manually or automatically to give you a film, so this is also a process.

And then you of course, heat treat after deposition. So, these are certain processes, which one can undertake to make these films. And cadmium sulphide is typically deposited by ok, you can deposit cadmium sulphide by solution deposition.

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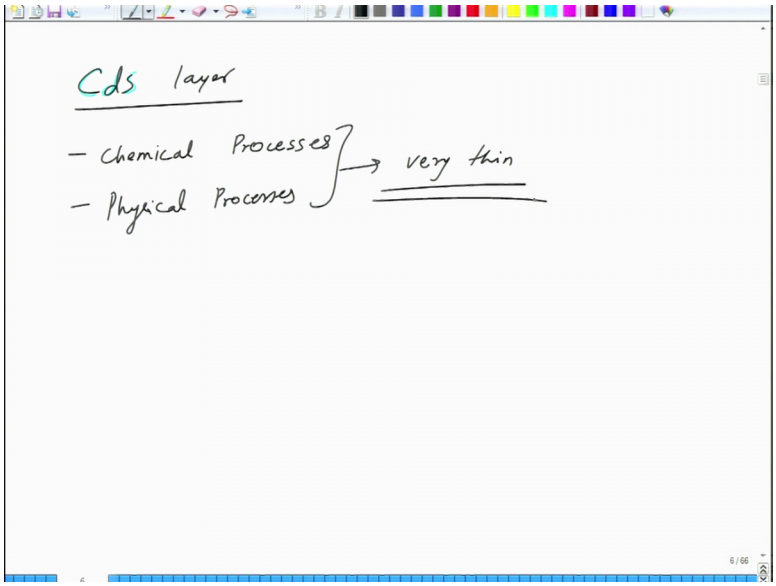

Chemical bath deposition, so you can have Cds layer, oops Cds layer can be deposited by chemical, chemical processes or you can also be use using physical process and this thin film is very thin ok. So, the issues which are there in, in the process what are the things that one adopts to improve the process. So, the device structure that we get a something like this.

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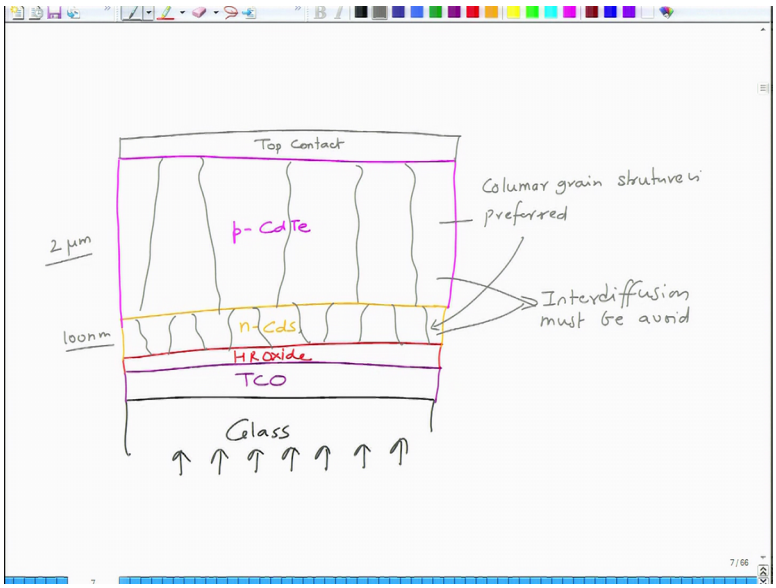

So, we have glass substrate. So, this is glass transparent glass the light comes from this side, and then we have TCO. So, you can have a TCO here TCO means Transparent

Conducting Oxide, then we have a thin high resistance oxide HR oxide; then we have a layer of Cds this is Cds, this is n-type layer.

And then we have a layer of CdTe this is p-type CdTe and then we have the secondary contact. So, you can make a contact on top here, top contact. Now, generally there are certain issues in this device structure one, it is important to have a particular grain structure. So, your grain structure maybe it is preferred that you have a grain structure like this ok; so be pre preferable.

So, columnar grain structure is preferred here in the CdTe layer. Similarly, within Cds layer also you would like to have you would have grain boundaries, these grain boundaries of their columnar; it is better. So, again for this layer also we would like to have a columnar grain structure. We should prevent see this layer is very thin, it is about 100 nano meter or so and this is about couple of microns ok, 2 to 3 microns and so.

So, the intern diffusion must be avoided inter diffusion or inter reaction bit or reaction between the layers must be divided. And so, because this layer is very thin, it is possible that you may consume some of this layer with the inter reaction, as a result the Cds thickness effectively may get reduced and you may form some sort of layer at the interface. So, these are certain issues in CdTe solar cells, which one has to overcome by optimising the process and studying the inter diffusion of various elements.

Of course, there is cadmium on both sides, but sulphur can diffuse on this side, tellurium can reduce from the other side, making a alloy of Cds and CdTe, which should be avoided.

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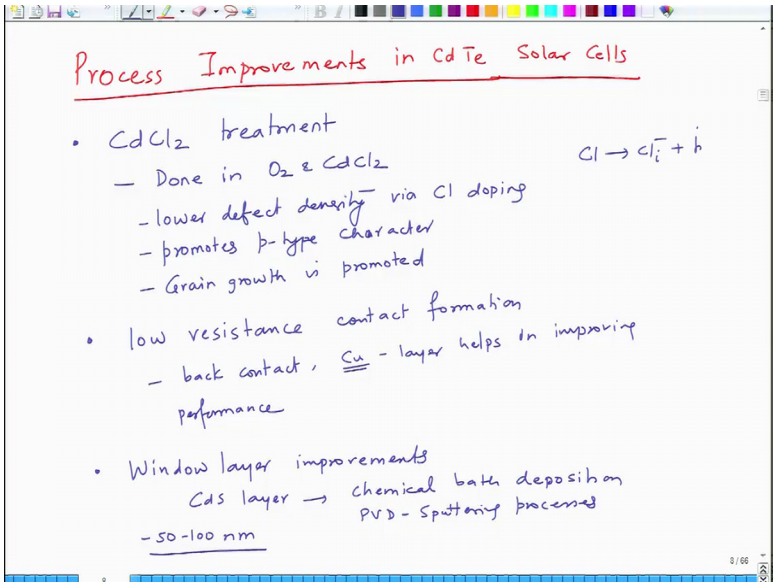

So, what are the so there are few things one does to improve the process solar cells. The first thing one does is CdCl 2 or cadmium chloride treatment, this is generally done to this is and it is done in, so basically done in oxygen and CdCl 2 presence cadmium chloride. And this leads to lower defect density, so chlorine doping of films is useful, so basically you dope the chlorine in it. So, lower defence defect density via chlorine doping after CdCl 2 treatment, it also promotes the p-type character.

So, when Cl goes in it goes as Cl minus plus if it goes to interstitial site, let us say and then it gives rise to a whole ok. So, it promotes the p-type character and this also promotes the grain growth. And one also does low resistance contact. So, if you couple this CdCl 2 treatment with load low resistant contact formation, this leads to better device properties.

So, so for example you can have at the back contact or on the other side, where you do not have glass between the contact and CdTe, if you put a layer of copper; so copper layer helps in improving performance. So, copper basically improves the back contact an improves a p-type conductivity.

And one can also do, window layer improvements. So, window layer means cadmium sulphide layer, which is made by either chemical bath deposition or PVD such as sputtering. So, basically it should be as thin as possible, it is about 50 to 100 nano meter thin; so 50 to 100 nano meter thin, so that it does not lead to any losses and it allows

most of the light to reach to cadmium telluride as in a absorber to absorb most of the lights. So, it does not prevent any light, it does not block any lights. So, it basically a window, it should not act as a blocker.

So, the quality of Cds layer, which is deposited using chemical bath deposition and PVD or PVD process is quite important. And as I said that CdCl 2 treatment is important, because that promotes p-type behaviour, it also promotes the grain growth for this is essential for getting good properties along with some modification in the back contact.

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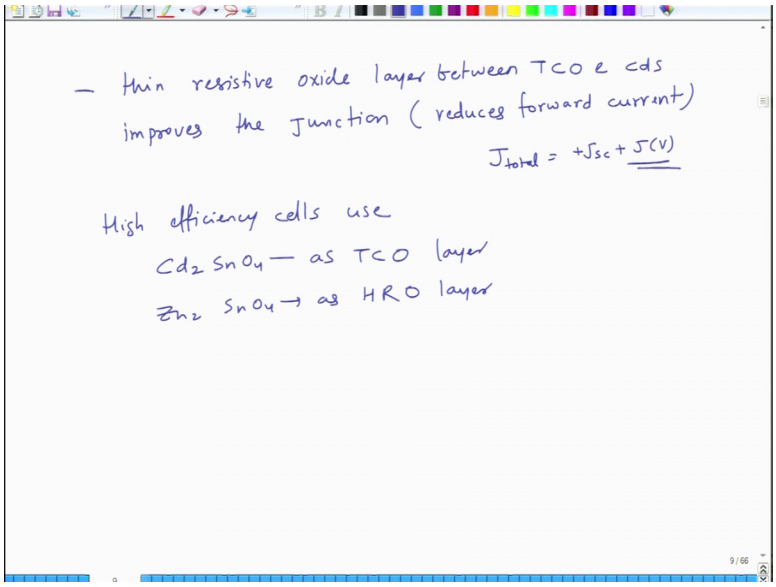

Sometimes also if you, put a thin resistive oxide layer between TCO and Cds improves a the junction. Basically it reduces the forward current ok, because you know you your J J total is minus J SC J SC plus J V, so it keeps the J V under check, it keeps the J V little lower.

And generally we use, so some of the high efficiency cells for example, some of the high efficiency cells used cadmium tin oxide as TCO instead of indium tin oxide and z n 2 S n O 4 as high resistance oxide layer, because they have they are nearly similar structures, so the interface is very good and recombination laws are smaller. So, these are certain parameters that these are certain process improvements one can do in the CdTe solar cells. The CdCl 2 treatment is done by how do you do Cd CdCl 2 treatment.

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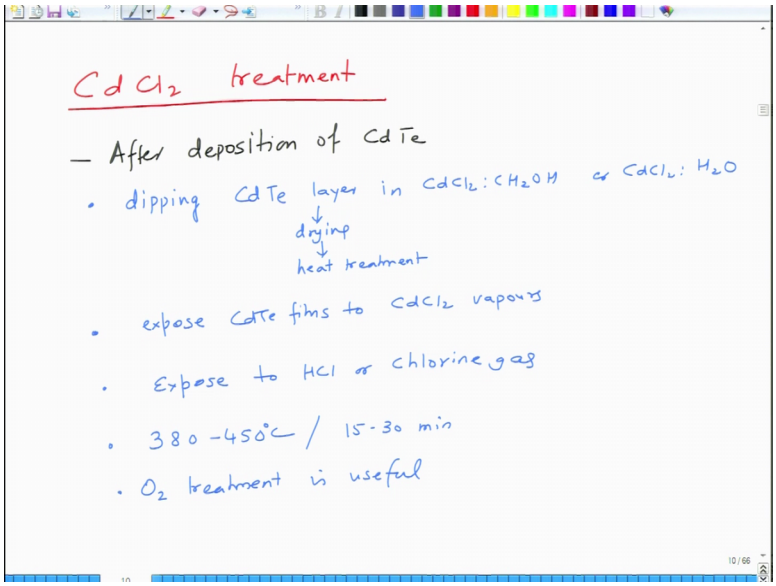

So, the cadmium chloride treatment is done by its done after the deposition of so it is a post position treatment. And it is done by few methods, so you can have first method as dipping CdTe layer in CdCl 2: Ch2 OH bath or it could be CdCl 2: H 2 O bath followed by drying and then heating ok; so followed by drying and then heat treatment ok.

It can also be done, so you can also expose CdTe film two CdCl 2 papers. You can also do expose, to Hcl or chlorine gas, because the main thing is to get introduce the chlorine in it. And the temperature generally of this treatment is 380 to 450 degree centigrade and the treatment is done for 15 to 30 minutes. And oxygen treatment is useful, so if you do a oxygen treatment at about 450 degree centigrade is useful. So, all these things they lead to reduction in the sheet resistance.

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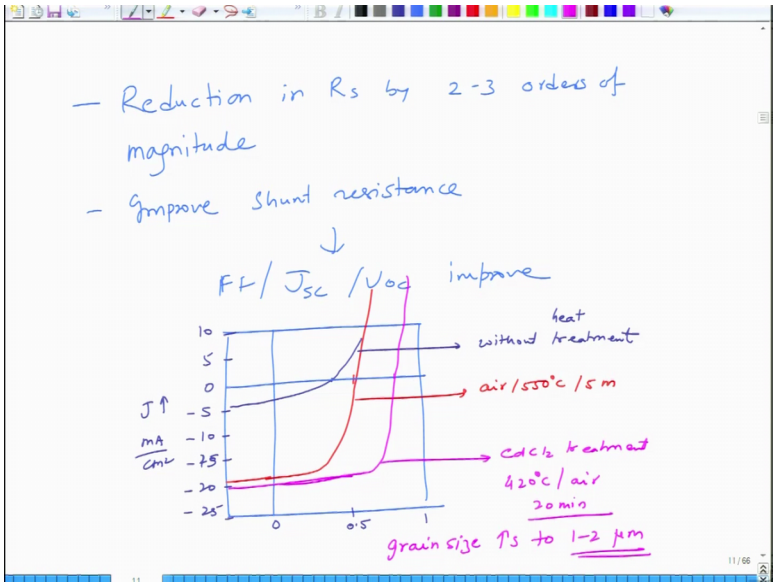

So, these so what you obtain is reduction in sheet resistance by about 2 to 3 orders of magnitude, remember it is not 2 to 3 3 times its 2 to 3 orders of magnitude ok. So, it was 1000 earlier, it will become 10. And they also improve, the shunt resistance and as a result J SC and V OC improve also the fill factor.

So, if you just qualitatively want to look at the effect of this treatment. So, if you plot for example, it is a the plot of J versus V. So, if this is 0, this is so let us say 5, 10, 15, 20, 25; this is milliamps per centimetre square J is J. So, this would be 5, 10, the voltage let us say is about 0.5 and 1 volt here. So, the 1 without any heat treatment would give you properties property is something like that. So, this is without heat treatment.

If you do a heat treatment in air at 550, so if you do in air at 550, you will marginally increase the V OC and you will get so this is for air 550 degree centigrade 5 minutes, but if you do CdCl 2 treatment the current increases and the V OC is nearly somewhere here, and you get a very good I V curve. So, this is for CdCl 2 treatment 420 degree centigrade in air, so Cd is 20 minutes.

So, CdCl 2 treatment in oxy in air is a critical think to improve the performance. And this is what one observes in the solar cells, and the grain size tends to increase substantially, the grain size becomes of the order of about a micron more. So, after this treatment the grain size increases to about 1 to 2 micron, so objective is to obtain. So, this chlorine treatment is important for Cds cadmium and the xrd also tends to show changes.

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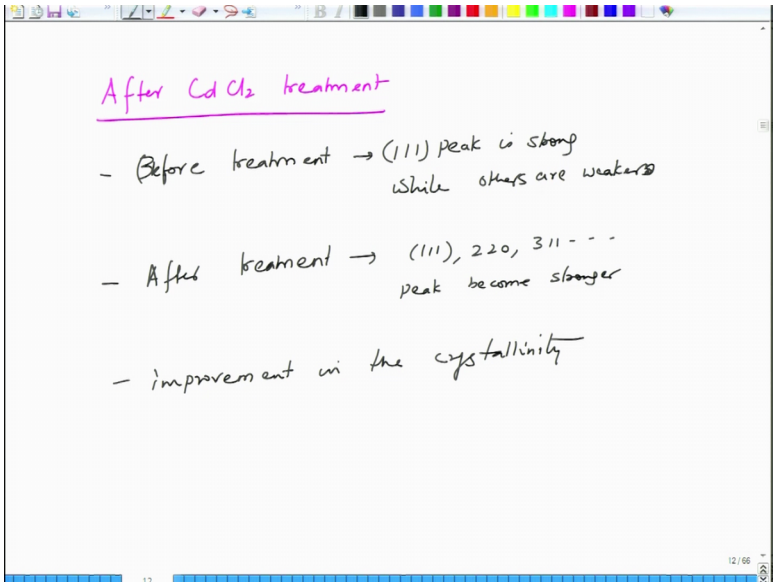

So, after CdCl 2 treatment the 1 1 1; so before the so before treatment 1 1 1 peak is a strong, while others are weaker. After treatment, the other peaks also become strong, so 1 1 1, 2 2 0, 3 1 1 so peaks become stronger. So, basically you can say that there is a improvement in the x-ray diffraction pattern or you can say crystallinity improvement. Improvement in the essentially crystallinity.

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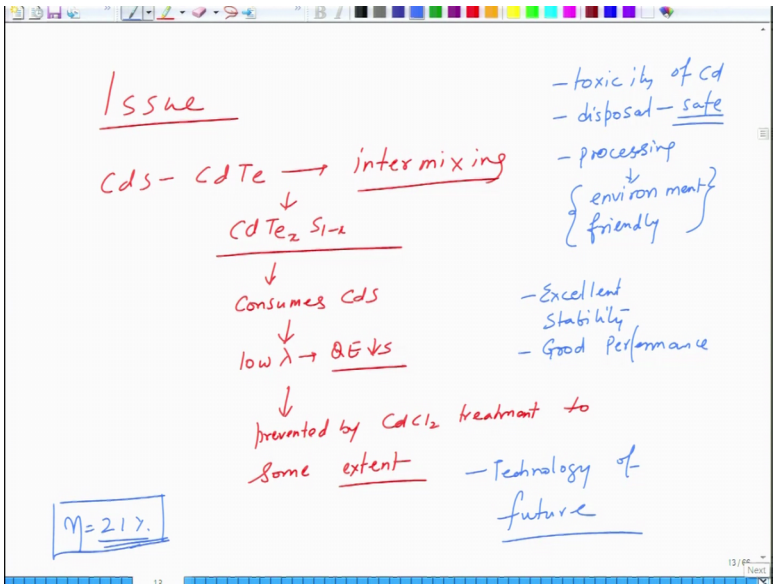

So, this is what is the sort of CdCl 2 processing about, there are issues as I said the issues are since you have Cds and CdTe, there is a issue of intermixing at when you do the heat treatment them.

They tend to make an alloy CdTe x S 1 minus x. So, this has to be prevented from formation. So, it will it leads to basically in the con it leads to redact, so basically it consumes you can say Cds, as a result low wave length QE reduces ok, because Cds is high band gap material. So, as a result it is mainly used for the lower wavelength side absorption and as a result, when it gets consumed the amount of Cds is reduced and hence is reduced, its it reduces the quantum efficiency on the lower wavelength side or higher energy side.

And again this is prevented by prevented by CdCl 2 treatment to some extent. There are certain other issues such toxic nature of toxicity of cadmium. However, there are both supporters and tractors of the same thing some, some people say it cadmium is very nasty, it will get it will pose health concerns, but other people say that you know, there is not enough cadmium in it to prevent and since it is a solar cell is going to be recycled in the same manner, there is no way cadmium gone a reach out so much.

So, there are both sides, but in the end disposal must be safe. So, safe practices in terms of recycling and disposal are needed and processing should be made more environment friendly, but by enlarge it is a very, very good technique it has good atmospheric stability, excellent stability, good performance. So, it is a technology of future.

It already consists of 10 percent market of the solar PV devices in worldwide and there are hopes that this will pick up soon. So, this is where we end our discussion on cadmium telluride and next we will move on to so cadmium telluride as I already told you, the efficiency is of the order of give me the efficiency number.

The efficiency of cadmium telluride I think, I told you in the last class. So, efficiency of cadmium telluride is about 21 percent efficiency, which is which is a pretty good number and the costs are expected to come down in future. So, this is where we stand today discussing CdTe solar cells completely.

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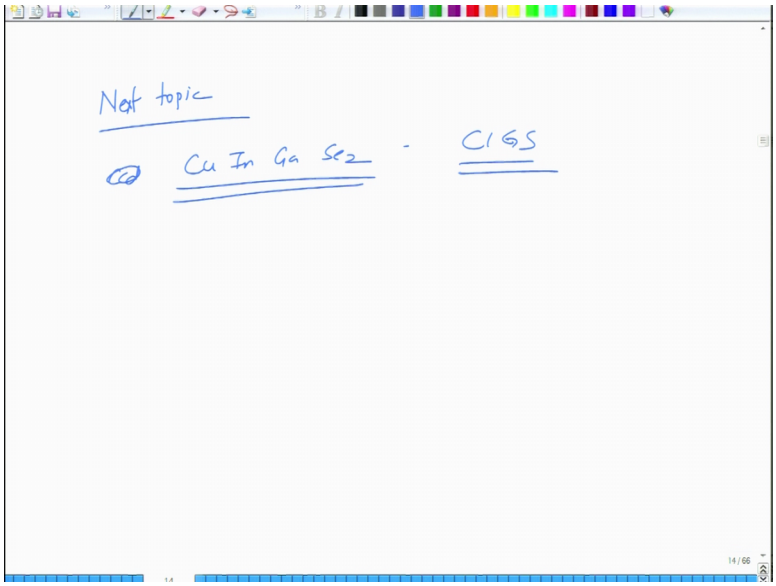

Next, we move on to our discussion to the next topic will be, will be discussion on Copper, Indium, Gallium, Selenide solar cells, which is called as CIGS. Another important thin film technology, which has lot of potential to make it success to make it commercial.

Thank you.