

## Chemical Engineering Principle of C V D Processes

Professor R. Nagrajan

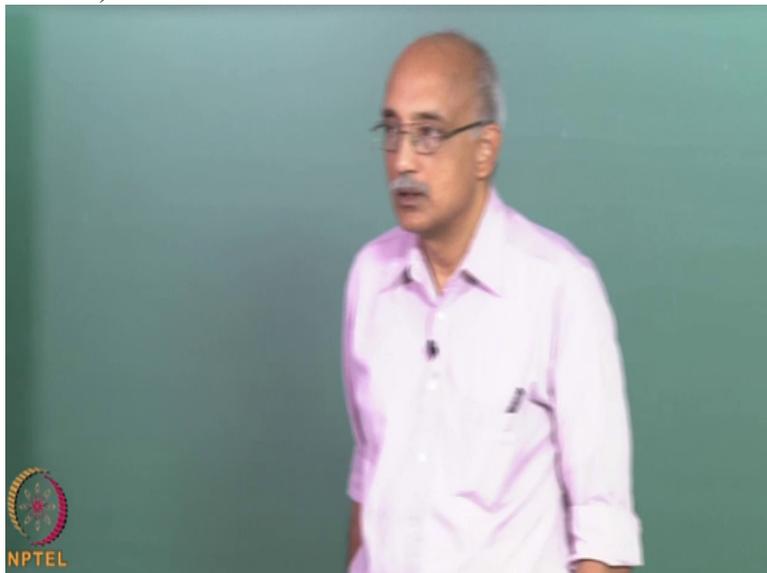
Department of Chemical Engineering

Indian Institute of Technology Madras

Lecture No 11

### C V D Film Property Measurements: Qualitative and Quantitative

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Good morning and welcome to this lecture in our Course on Chemical Engineering principles of C V D process. In the last lecture we covered some of the basic techniques that are used for doing analysis of C V D films particularly the indirect measurements which yield the physical and chemical properties of C V D films.

So we actually established like a hierarchy of evaluation techniques where initially you look at the film using visual or microscopic means and then based on what you see with simple microscopic analysis you will decide if this is predominantly an inorganic material you are looking at or predominantly organic material and based on that you again go to different classes of measurement and characterization techniques.

So for example, in the case of inorganic materials if you want to increase your magnification, your resolution, your position of the imaging, you go to the techniques like S E M and T E M and so on. And then you can also do depth profiling by using techniques such as Auger spectroscopy and SIMS.

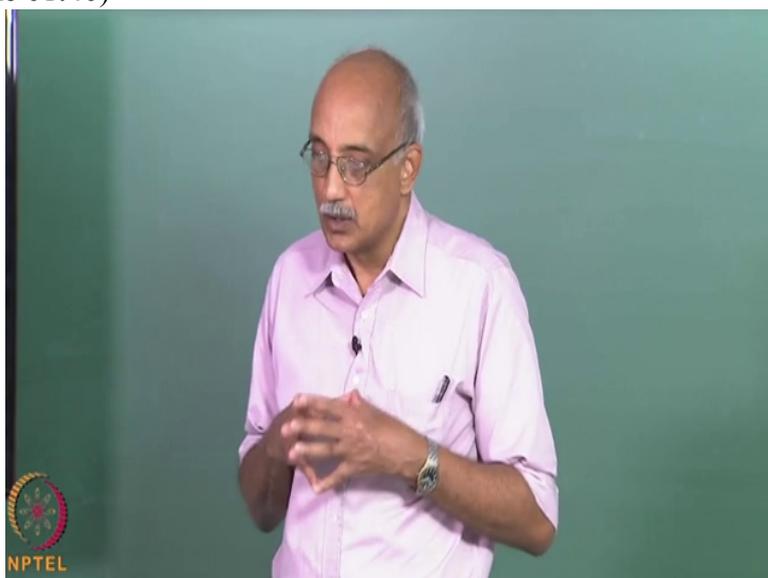
And we also mentioned that

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you can do not only elemental composition analysis using techniques like Energy dispersive spectroscopy and wavelength dispersive spectroscopy,

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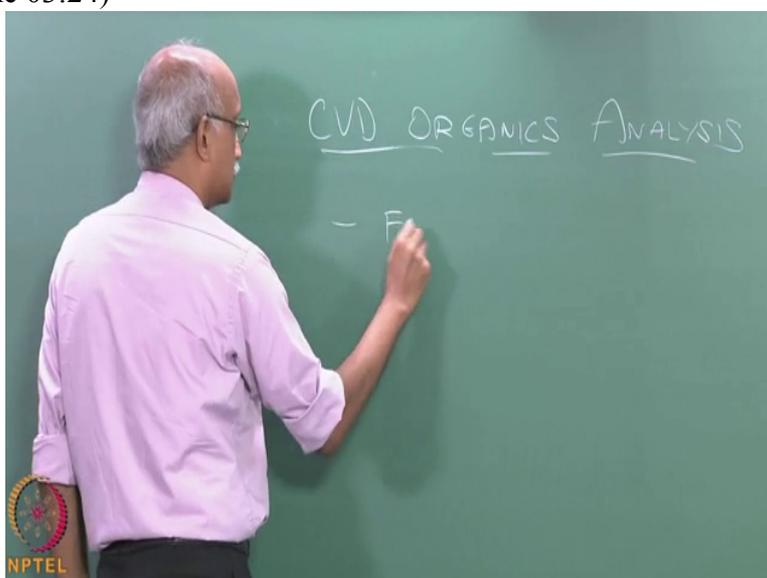
you can also do compound level analysis to identify species by using ESCA as the primary technique. So now let us discuss some methods for orga/organic, analyzing organic films.

Now organics are actually much more difficult to characterize compared to inorganic films. The primary reason is they are materials that do not stand up very well. When you irradiate them with high energy beams for example, they will start burning. So that really limits our ability to do, for example S E M or T E M type of analysis where you are bombarding the target with electrons or ions and looking at their scattering.

Essentially that won't work unless you coat the organic material with some kind of a metallic film but when you do that you lose visibility to the surface morphology and structure and details. So the electron bombardment-based techniques do not really work very well when you are talking about CVD films that are predominantly organic in nature.

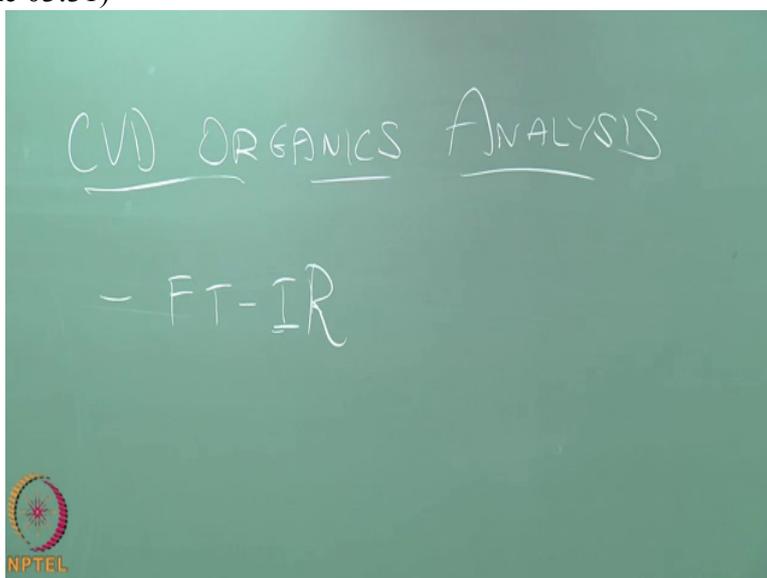
So instead we go to essentially Infra Red or white light based spectroscopy techniques. A technique that is very popular is FTIR, Fourier Transform Infra Red spectroscopy. In FTIR essentially what you are doing is...

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So you

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take the sample and you expose it to a broadband I R signal. Now when you do that, you have a wide spectrum of I R frequencies to which the sample is being exposed. However it will absorb the light at specific frequency that corresponds to the molecular vibration modes of the species that you are looking at.

So essentially what you will get is an interferogram. You will get a signature of what is the frequency at which the I R light is being absorbed by the sample that you are looking at. So you can then take this interferogram and use Fourier Transform techniques to convert it into a spectroscopy. So you have this I R, F T I R spectroscopy now or spectroscopic signature and you compare it to a library that you have. So you have to have a reference library.

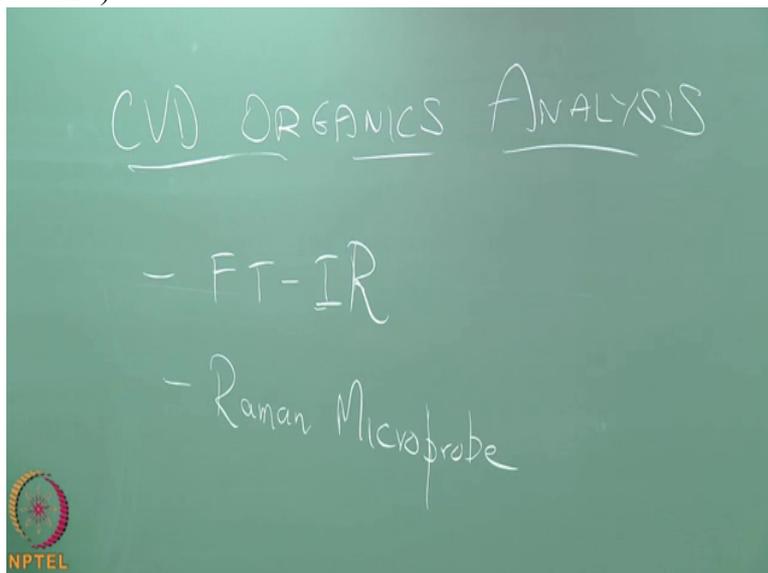
That you compare the ion spectrum for the sample to various reference spectra in your handbook and you find where you get the closest match. Because you do not have to do it manually, essentially there are automated programs that will do it for you and they will pop out an answer that says this spectrum looks closest to some x molecule that we have in the reference library.

So that is the way the organics identification is done. It is never clear-cut absolute answer like you get for inorganics. There is always a little bit of ambiguity in the data. It kind of depends on how extensive your library is. If it turns out that it is a compound which does not exist in your library, then you will never be able to identify essentially.

It also depends on how good your software is for doing comparisons of your sample spectrum with various reference spectra and how well it is able to establish a correspondence. The other drawback of F T I R spectroscopy is that it is really limited to fairly large size samples. You need about 10 microns of material.

Or another way to look at it is you need about 10 micrograms of the sample in order to be able to do a reasonable identification of the species. Now in many C V D applications, clearly that lower limit is not adequate. So the technique that is frequently employed, something called Raman microprobe which actually

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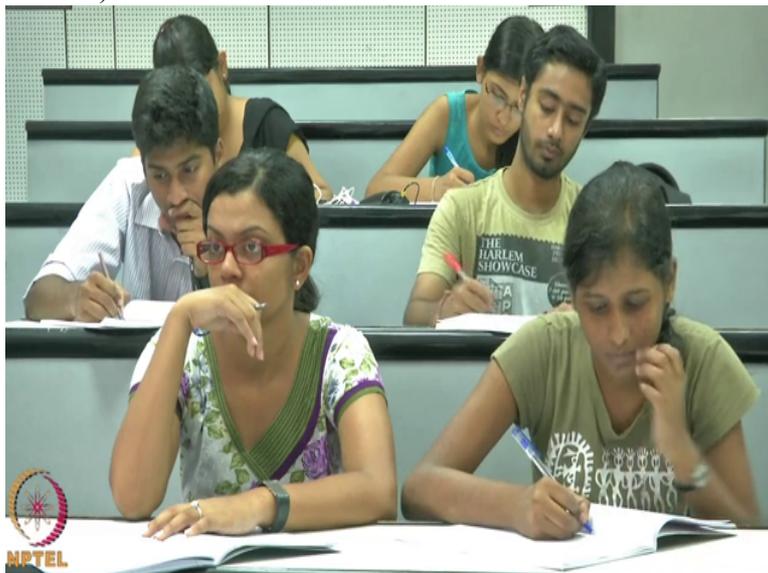
can reduce your resolution or your lower limit of detection to a micron.

It is actually, can be used both for organic as well as inorganic materials. It is a little more flexible in terms of its applicability. The way that Raman microprobe is used is that you essentially radiate the sample with laser light and you look at not the absorbed wavelengths but actually you look at the scattering wavelengths and frequencies.

And it turns out that the scattered frequencies are indicative of not only the, again the molecular vibrational modes of the material, they can also give you information about the molecular structure. It can tell you something about the bonds that are present, the bond strength that is present in the molecule. It can even tell you the atomic mass of the material.

So using Raman microprobe you can actually get a much more definitive answer regarding what is the nature of the organic material that is contained in the film. Of course the Raman microprobe technique is more expensive. It does require more skill.

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In F T I R, pretty much you know, a lab technician can do. It is a virtually independent of human intervention

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whereas Raman microprobe is a more specialized tool that does requires some expertise to be able to run and it is also very sensitive to even small amounts of contamination. Because F T I R spectroscopy is such a macroscopic method, trace impurities will not affect your data to the extent that they can in Raman microprobe analysis.

Other technique that is used for analyzing a particularly extractable or mobile organics on a surface is something that is based on gas chromatography. The way this works is you actually use an organic solvent to extract the material from the surface and then you analyze the

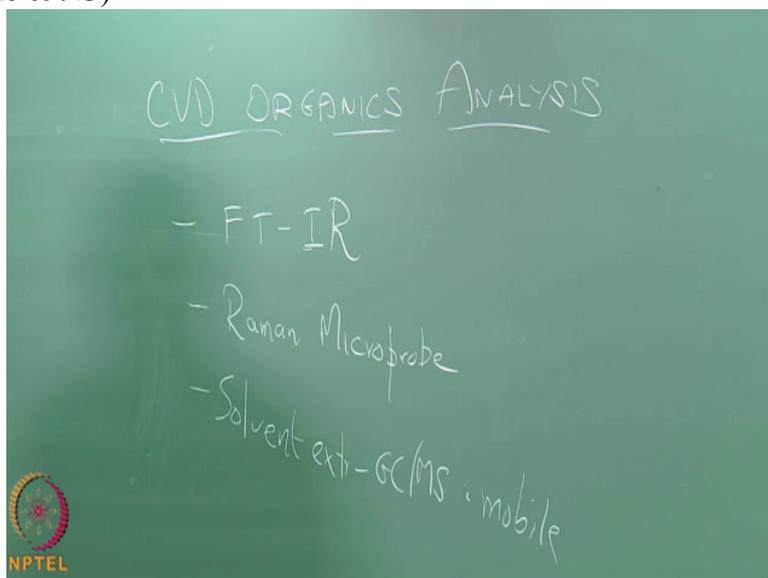
extract in the solvent to identify what is contained in the solvent. So it is basically a before and after.

You take a pure solvent, run it through a gas chromatograph; you can also attach a mass spectroscopic analysis. So solvent extraction G C M S can be used to identify not only the total organic content in the solvent but also the, the mass spectroscopy signal of the species that are present in the solvent, the pure solvent.

And then you extract your film with the same solvent and again you do at the same analysis. You look at total organics as well as the presence of various species in the solvent and you look at the delta, what has changed before and after. So this methodology of solvent extraction G C M S is good for detecting, as I said mobile organics on a surface.

Now typically C V D films are not supposed to be mobile.

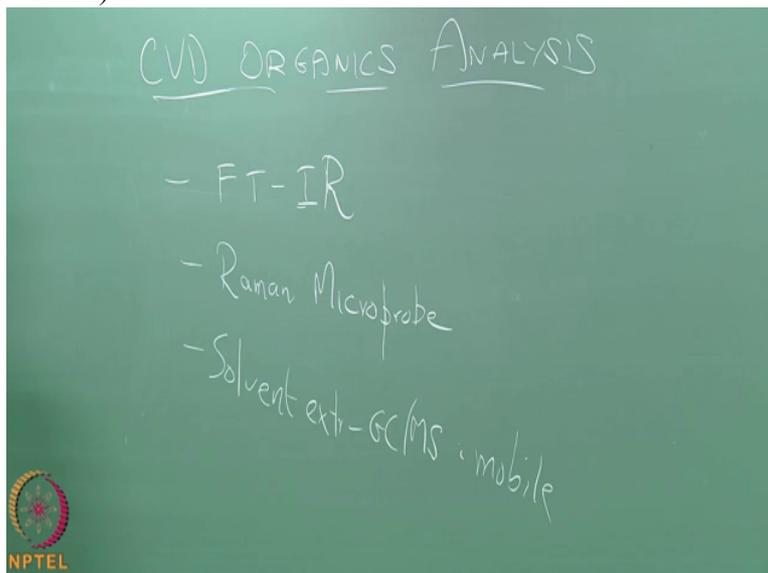
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So if you have a good well-adhered C V D film and you use this technique, unless the solvent completely dissolves the film, you are not going to see anything. So it is actually a better technique for impurities because in your C V D film which may be predominantly let us say, silicon you may have some carbon that is adsorbed, as an impurity.

This technique can enable you

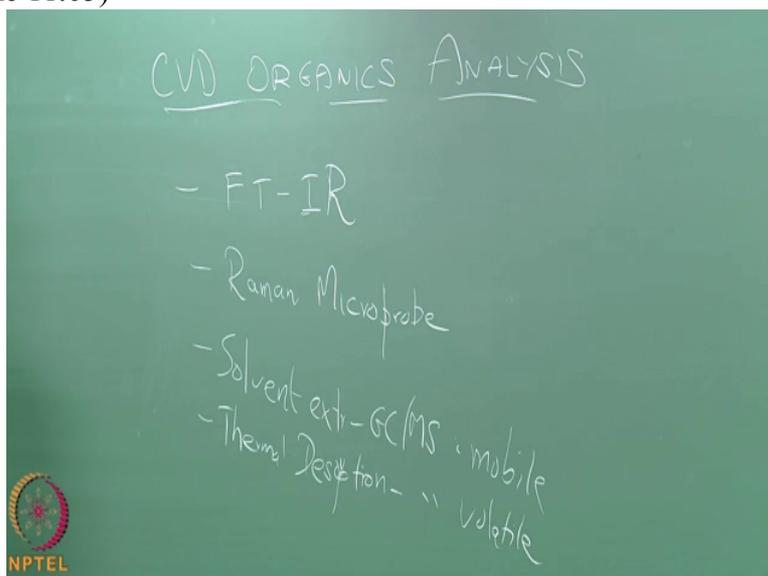
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to detect the carbon in the film because it is a trace impurity which can be effectively removed by the solvent then analyzed. So typical solvents that you would use in this case would be like hexane, chloroform, isopropyl alcohol, these are all good solvents for non-polar as well as polar materials that may be present in the CVD film.

Another technique that may also be used is thermal desorption followed by GCMS. Now this is used essentially for, again impurities that are present which can be volatilized. So primarily for volatiles, so instead of extracting the organics using a solvent

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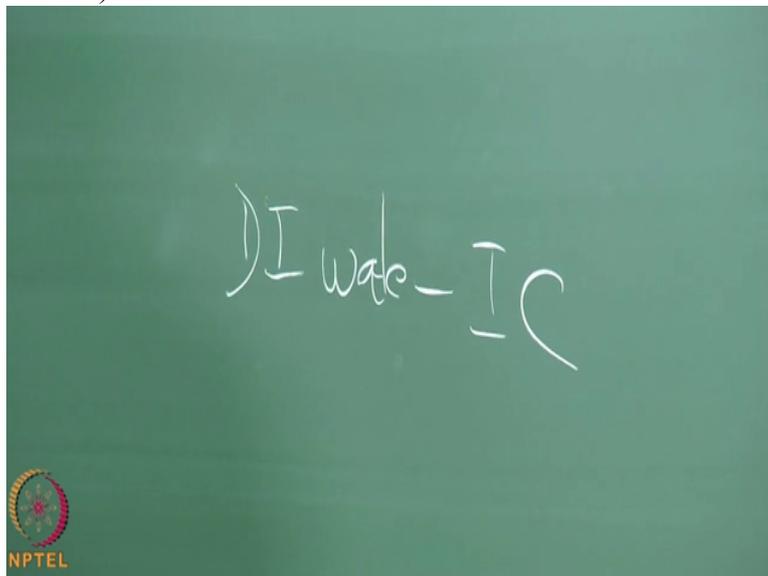
you extract them using heating and you can keep the temperature at different levels in order to extract different materials.

So it kind of gives you an ability to tune your extraction process. So here again the C V D film itself, unless it is unstable at the temperatures that you are exposing the substrate to, will not show up in this technique, impurities will.

So both of these techniques, the solvent extraction as well as the thermal desorption technique are primarily used to locate and quantify organic impurities that are present in the film rather than the film itself.

A corresponding technique that you can use for inorganic impurities is ionize/ionizing, extraction using D I water followed by ion chromatography. So we take a C V D film

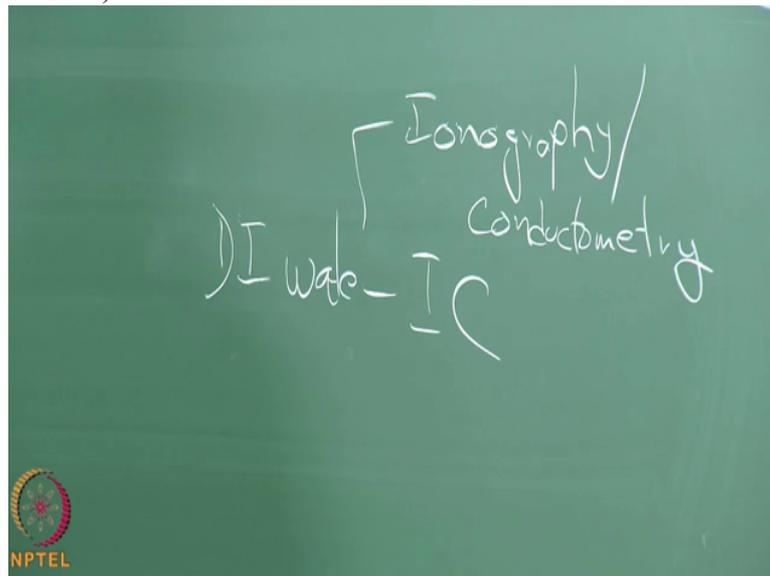
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and just expose it to purified deionized water and again you look at the delta of the total ionics in the water before and after extraction as well as the species that are present before and after extraction you can get a good idea of ionic impurities that are present in the film.

And there is actually another technique called ionography or conducti/ conductivities detection. Call it conductometry. Now this technique

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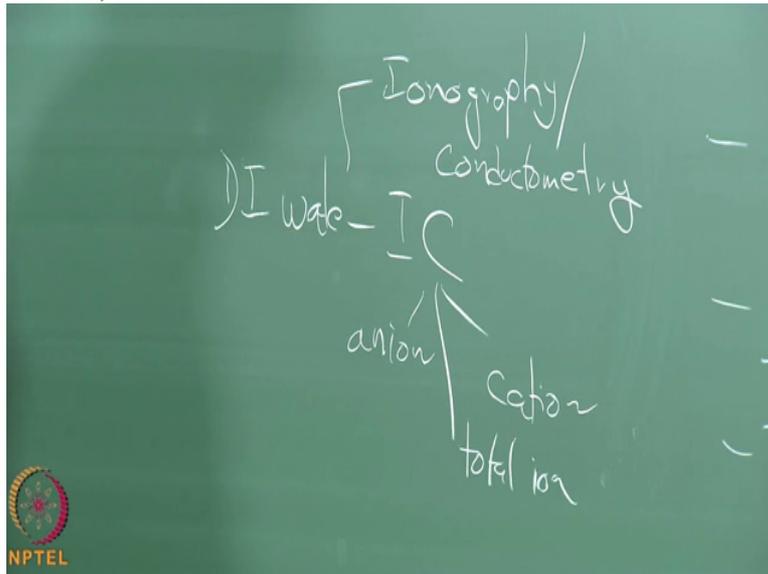
will not give you the speciation, it won't tell you how much chloride there is, how much fluoride there is, how much bromide there is. It will give you total quantity. So it will tell you what is the total amount of extractable ionic species that are present in the C V D film.

And this could improve the film itself if the film itself is ionic in nature. But again we hope that a C V D film cannot simply be extracted just by splashing deionized water on it. It should be a lot more stable than that.

So just like these two techniques, this technique of either ionization slash conductometry to get total ionics or ion chromatography to get the speciation, it is more suited for measuring trace impurities that are present in the C V D film rather than the C V D film itself.

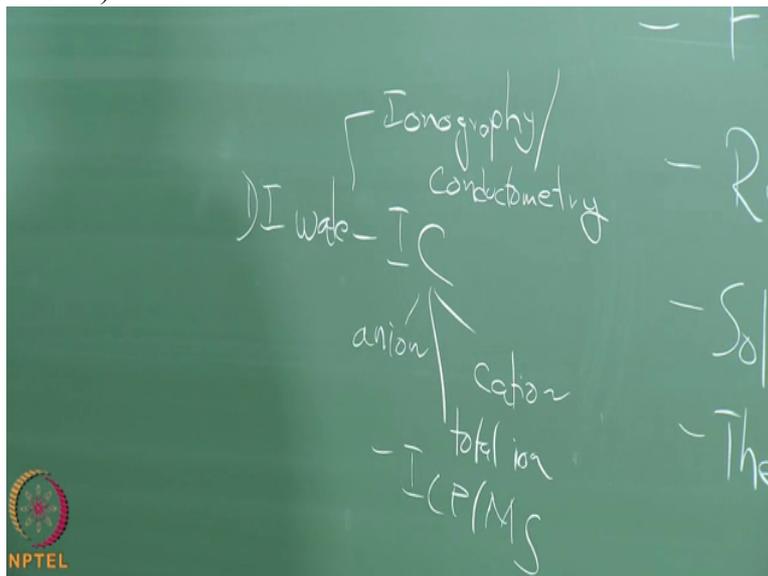
Of course in ion chromatography there is anion chromatography and cation chromatography and of course there are also total ion chromatograms

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that are available. You can also do I C P M S, inductively coupled

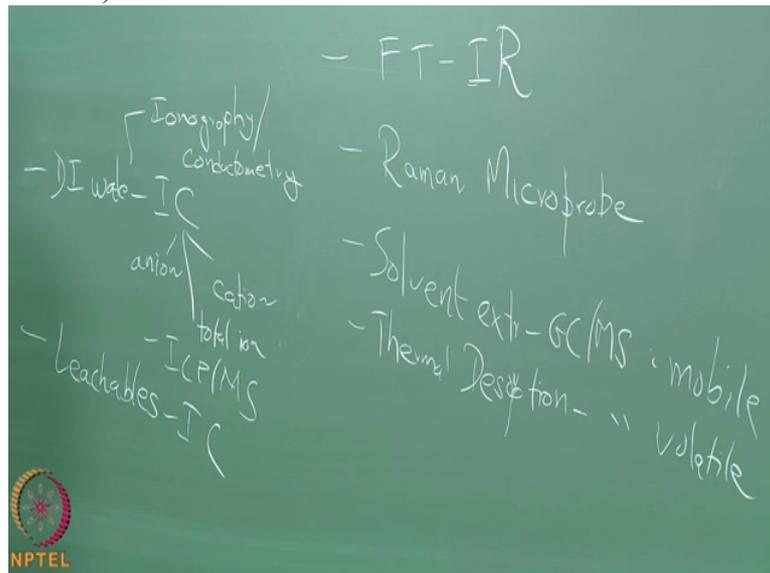
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plasma mass spectroscopy which is a more sensitive methodology to detect very specific ions in the solution.

In terms of the extraction technique, just like you have two different methods here for extracting, you can also extract the ionic or inorganic species either by just using simple room temperature deionized water or you can extract using a process called leachable, the technique is called leachables ion chromatography where you not only remove the

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material that is loose on the surface but you actually leach out materials that are sub-surface or more strongly adhered to the surface.

So this leaching can be done in one of two ways. You can use time, you know, usually to do just the D I water ion extraction chromatography may only take you 30 minutes to do. If you want to look at the leachables, you would just extend the time to 24 hours.

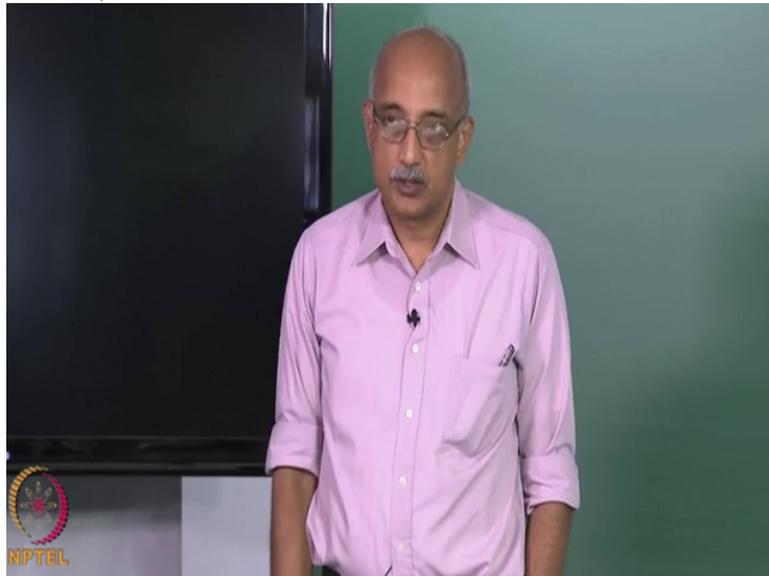
So when you expose the surface to deionized water for 24 hours, you are going to be removing not only what is on the surface and easy to remove but also the materials that may be

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sub-surface and more strongly bonded to the surface.

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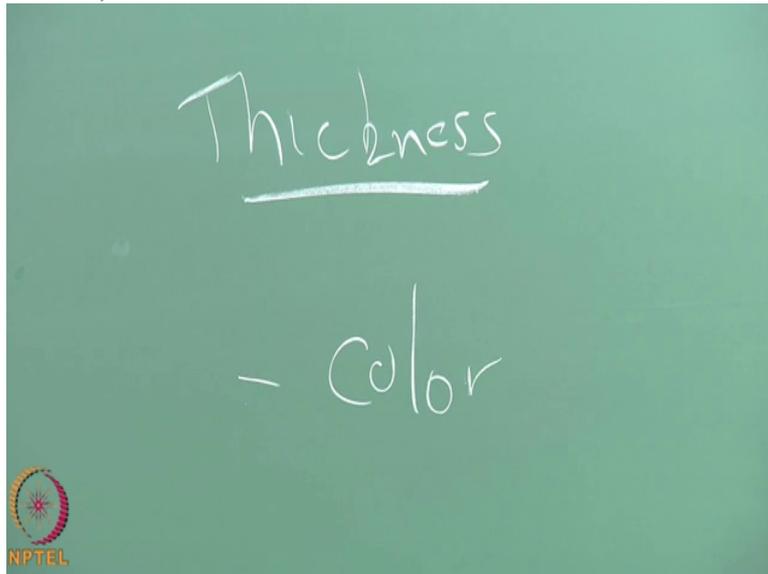
Or you can use temperature as your intensifier.

So instead of doing the extraction at room temperature, if you do the same extraction at elevated temperatures, 60 degrees, 70 degrees, 80 degrees, again your method of removal becomes much more aggressive and you can now start removing materials that would not come out, you know normally but which can be leached out over time and when, when the temperatures are elevated.

So these are some of the additional techniques that we have to characterize C V D films both in terms of their bulk properties as well as in terms of their trace impurities. I mentioned the other day that from a physical viewpoint, possibly the most critical measurement you can do on a C V D film is the thickness. So we should talk about some techniques that are used for thickness monitoring.

The simplest technique is one that just looks at the color. There are

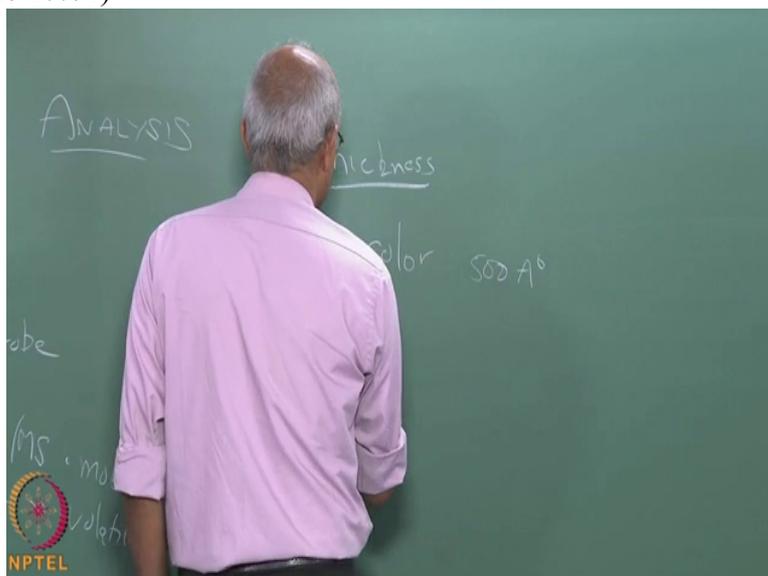
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color charts that are available for various CVD film types where the thickness of the film is actually correlated to their visual appearance in terms of color.

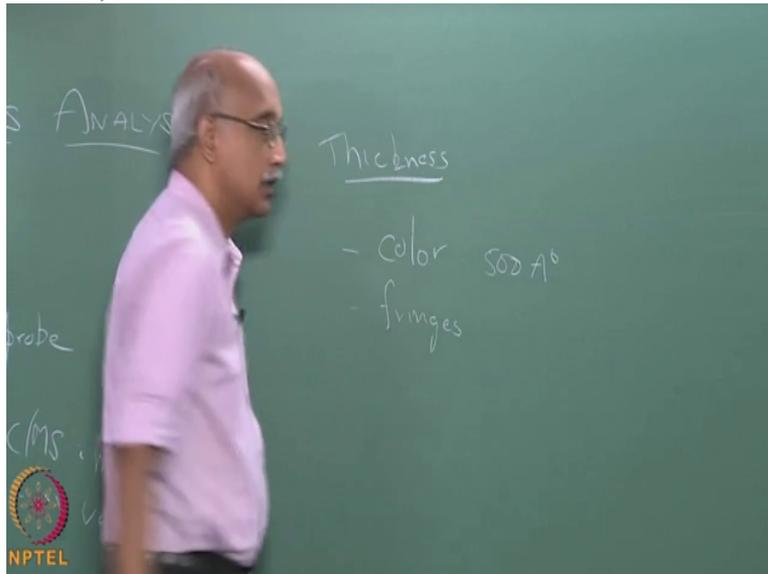
So particularly for the dielectrics  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and so on, these color charts are extensive. So essentially you can look at your film and then compare it to like 20 different colors and see which one matches the closest. Based on that you can actually get an estimate how thick it is. And by the way this technique is sensitive to about 500 Angstroms.

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The second technique which is little more

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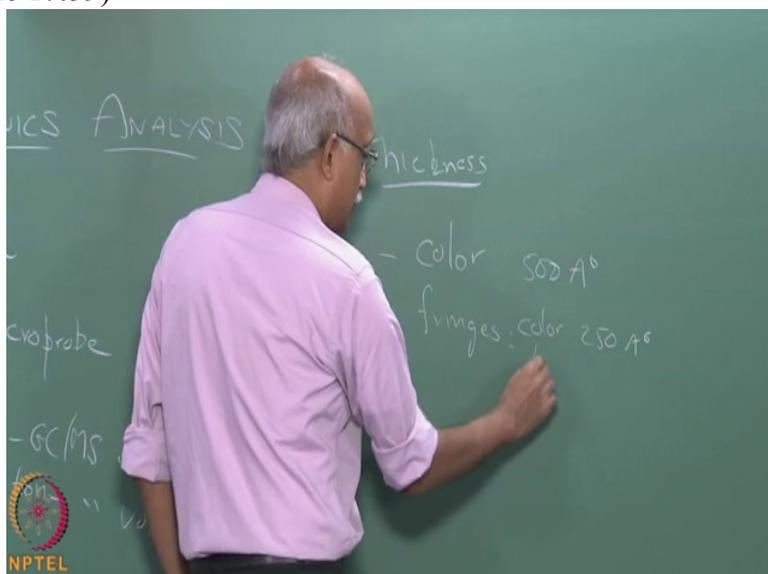


accurate or precise is one that uses fringes. When you shine polychromatic light on a C V D film sitting on the substrate, between the top layer of the film and the substrate a fringe will form.

And this fringe is quite visible when you look at it. It only exists between the top of the film and the top of the substrate. By evaluating the distance that this fringe extends you can actually estimate the thickness of the C V D film itself. And actually this technique is good enough.

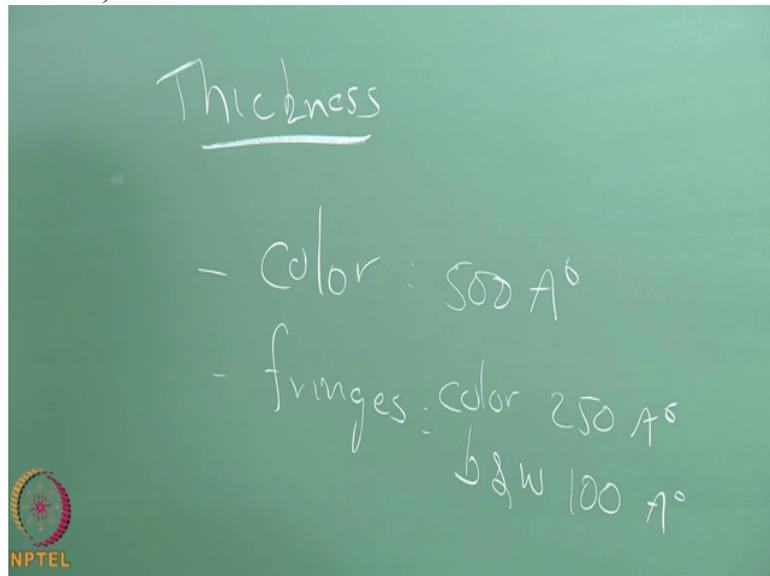
If you are using polychromatic or color light gives you about 250 Angstrom resolution,

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if you use black and white light you can actually extend it to about 100 Angstroms resolution.

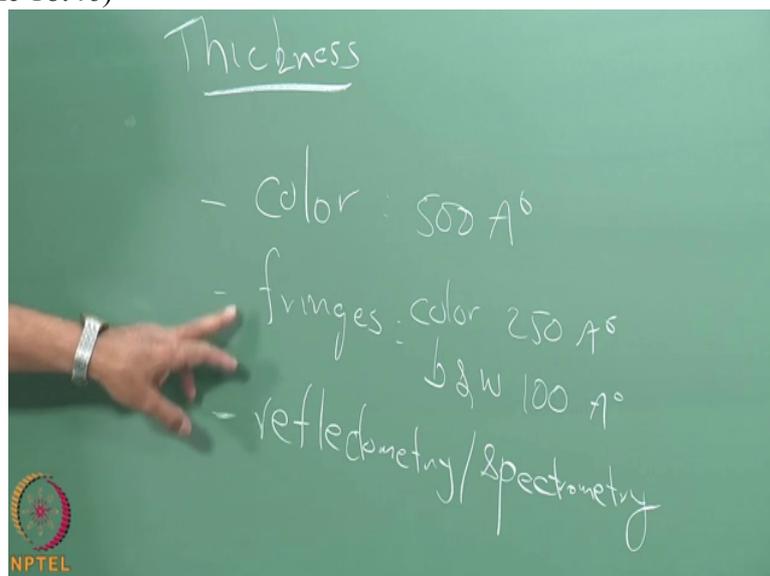
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So basically the way you would be doing this is you have to shine light on the film, look at it under a microscope that has sufficient sensitivity to be able to measure these kinds of distances.

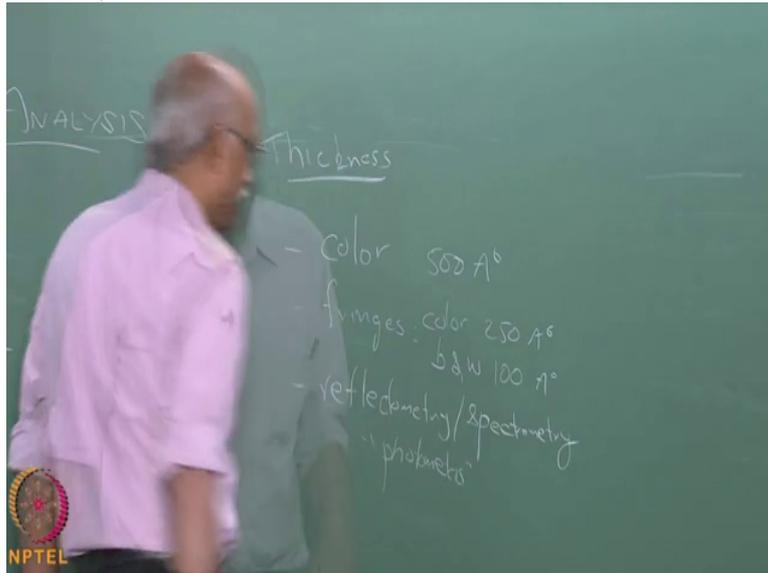
Ok the third technique that is used is reflectometry slash spectrometry. Now this technique is actually

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quite similar to the fringes technique except that now you are shining laser light on the, on the film and you look at its reflectance characteristics and you do spectrometric analysis of the reflected signal. So you use instruments called photometers to collect the reflected light

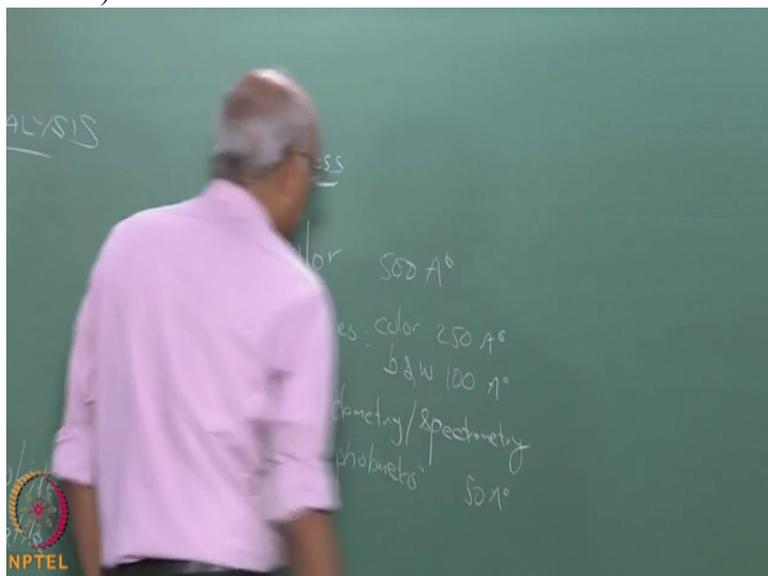
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and then you analyze it.

The way this works is that if you, if you have a CVD film on a surface, the reflectance characteristics are entirely different from when you have a clean substrate. So you essentially have a two, the boundary conditions you know. What does the signal look like when there is no film and what does the signal look like when you have the start of the film on the surface. This technique by the way is sensitive down to about 50 Angstroms.

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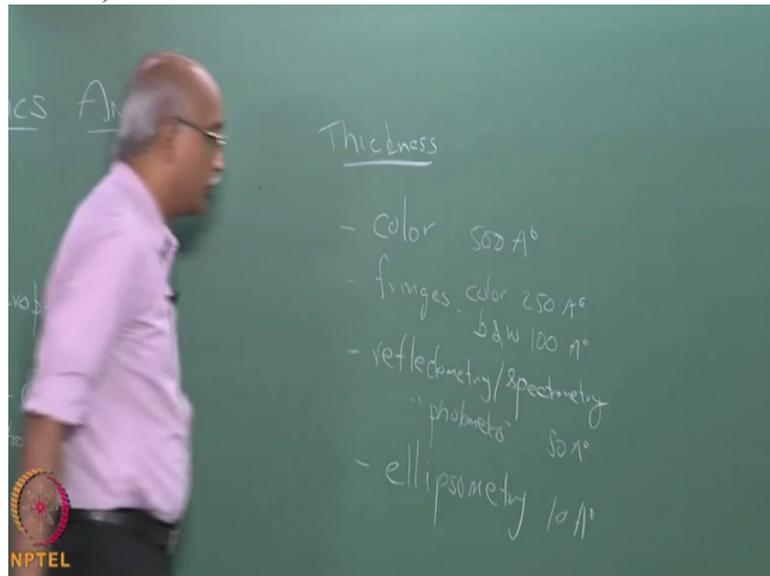


So as soon as you have a 50 Angstrom thick film on the surface this technique can detect its presence as a change in the reflected signal. And as the thickness starts to build up the

reflected light also changes in its intensity. And so essentially you use the signal that you get, the reflected signal as a quantitative indicator of how thick the film is.

The most sensitive measurement that people use for C V D film thickness measurement is ellipsometry which extends

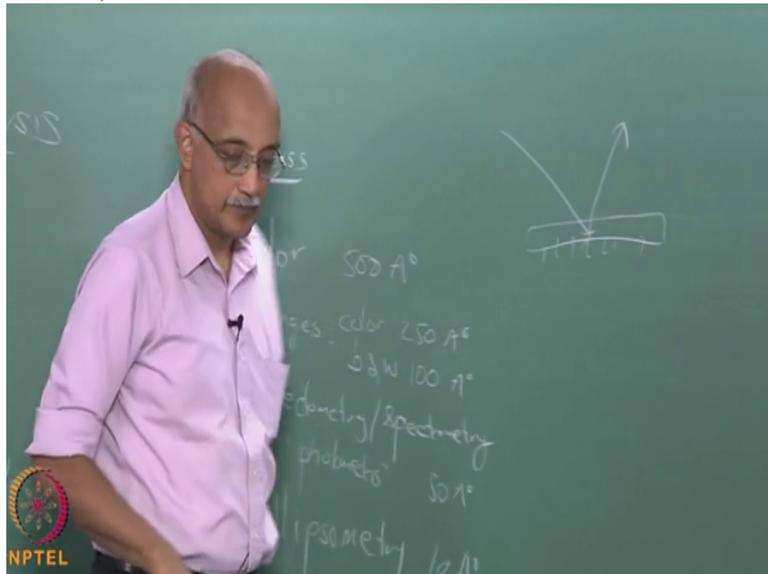
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the lower limit of detection to 10 Angstroms. Now in ellipsometry basically what you look at is how a polarized laser light beam is transmitted through the film and reflected from the film.

So here the technique that you use is, if you have a substrate and you have a C V D film on top of it, when you shine light, laser light at

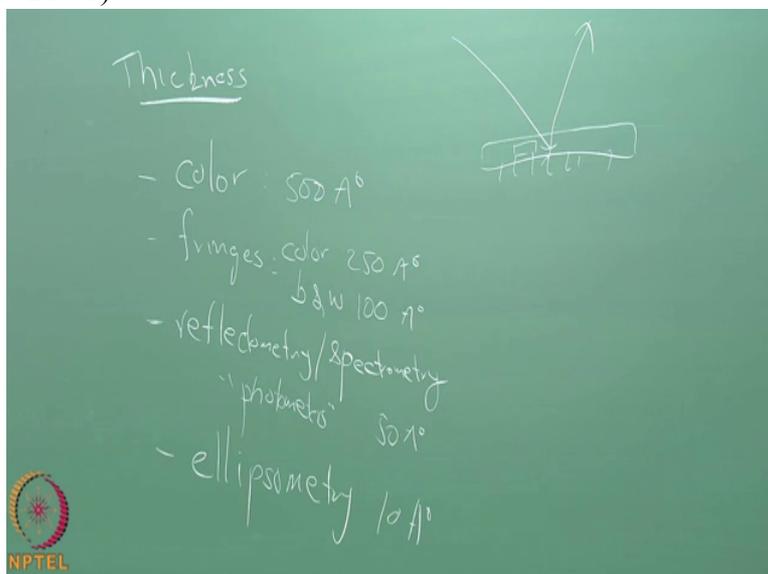
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an angle it gets reflected and it gets transmitted as well. Now as the light gets transmitted and by the way this is a polarized beam of light, the plane of polarization actually gets twisted when it goes through the film.

So this change in the

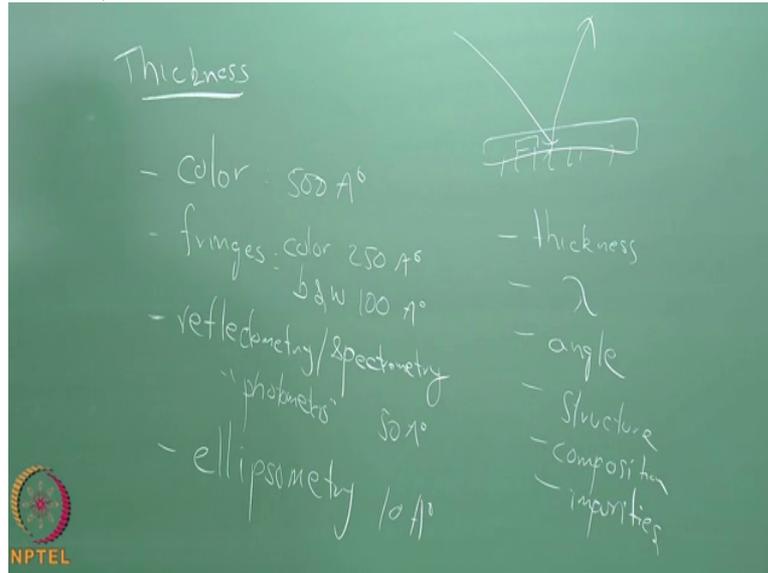
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plane of polarization of the laser light as it goes through the C V D film is a function of thickness, the wavelength of the light, angle of incidence and also the structure of the film, as well as composition, impurities and so on.

So in order to measure thickness

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using this technique obviously you have to keep everything else constant. So the way this works is once you have the stable process and once you have a stable repeatable film on the substrate, you keep the wavelength fixed, you keep the angle of incidence fixed, make sure that the structure does not change.

For example the crystalline film will, will rotate the plane of polarization completely differently from an amorphous film, right? So you have to ensure that the structure of the film remains consistent. That its chemical composition is uniform and stable and the impurity level must be maintained close to zero and then you look at how this change in the plane of polarization varies with thickness.

The thickness is then a very, very sensitive influence on the extent to which this rotation happens and you are able to get a very precise answer on the thickness of the film using this ellipsometer technique. Ellipsometry, the ellipsometer is quite a capital intensive equipment close to a million dollars but once you have it, it is very easy to use.

It is essentially, virtually a push button operation. Now it also requires calibration because the, again the extent to which this rotation in the plane of polarization happens depends on, you know so many parameters. And so for the C V D process that you are running what is suggested is that you take a blank wafer, not, not one that has all your circuits and so on and actually you deposit C V D films on it of known thicknesses measured by a different technique which can be an offline technique like a T E M for example.

And then you do a calibration to actually match your measurement of the rotation in the plane of polarization to the thickness. Once you have done this calibration once for your process, as long as the process does not deviate and you maintain good control over the process, this data can then be used for future estimates of the thickness of the C V D film.

The other technique which can also be used more to characterize whether or not a C V D film is there is something as simple as a, you know mechanical stylus which is used to measure surface roughness, right?

So you essentially get very close to the surface and use your stylus to scrape off a small portion of the C V D film. Again you do not want to do this on product wafers, typically you do this on blank or dummy wafers that you run to characterize your process.

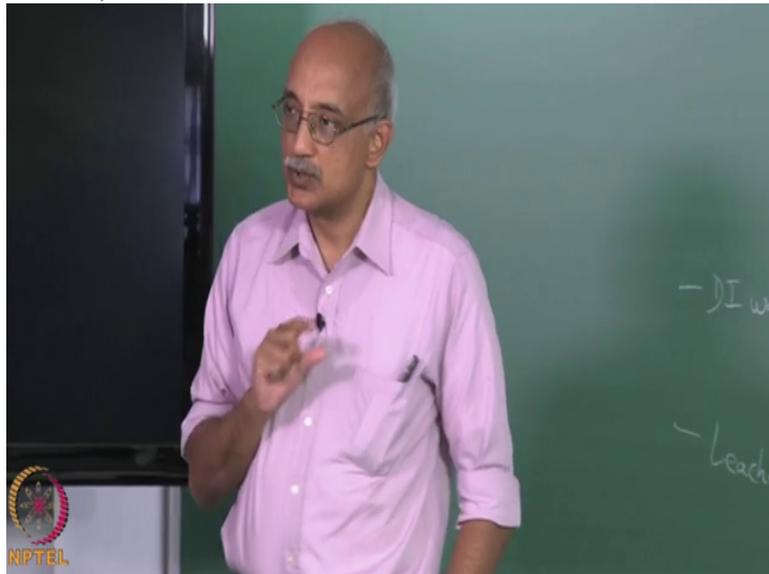
And then you look, you know at what distance of separation does, is there actual physical contact between your stylus and the film top, sitting on top of the surface. So you can actually estimate,

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just like you can estimate roughness using a mechanical stylus, you can also estimate a thickness of a C V D film using

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a mechanical stylus.

Of course this technique will not really give you Angstrom level resolution. A simple mechanical level stylus will probably give you sub-nanometer resolution but not close to one Angstrom. If you want to get 1 Angstrom resolution, then the best technique for that is atomic force microscopy.

So A F M in combination with ellipsometry, these are the two; I would say the two most powerful techniques for characterizing

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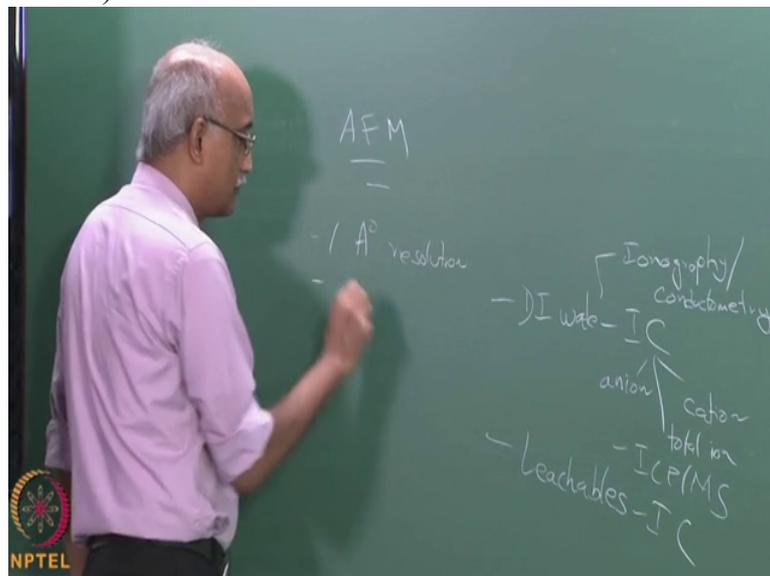
C V D films. Ellipsometry gives you a good indication of the thickness of the film but it is not going to tell you much about the actual morphology or structure of the film.

The big advantage of A F M which by the way is simply a glorified mechanical stylus you know, you are essentially taking a pin and bringing it either in contact with the surface or very close to the surface and as you approach the surface you look at some signal, some feedback signal to decide what the surface looks like.

In the case of atomic force microscope it is a very sensitive technique where the pin is drawn to the surface due to the van der Waal's forces, inter-molecular forces and the signal which obviously is then very weak, because you are talking about, you know just van der Waal's forces is then amplified by using a cantilever arrangement. And it is translated into an electrical signal.

And that is why the A F M technique is huge advancement over conventional mechanical stylus technique where you do not have this amplification built in. So the A F M actually has 1 Angstrom resolution. It can be used

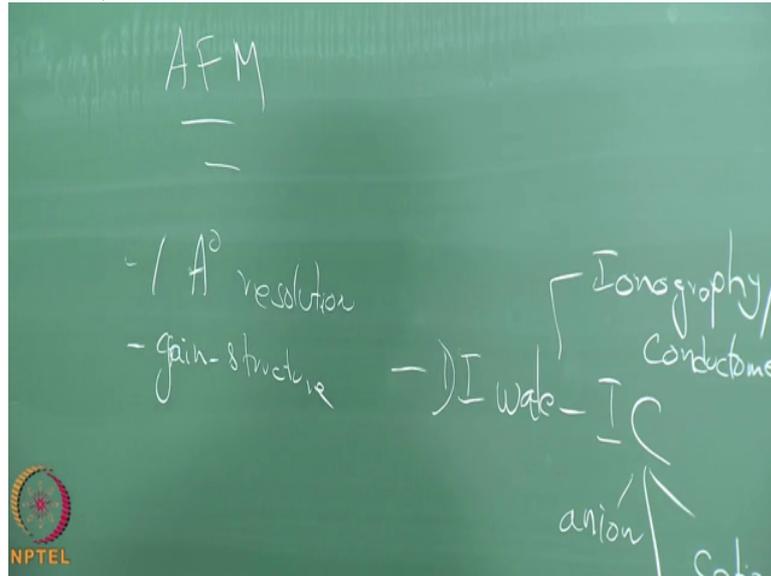
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for various purposes.

In fact you know we have been talking about grain structure of a film. Really the best way to characterize the grain structure,

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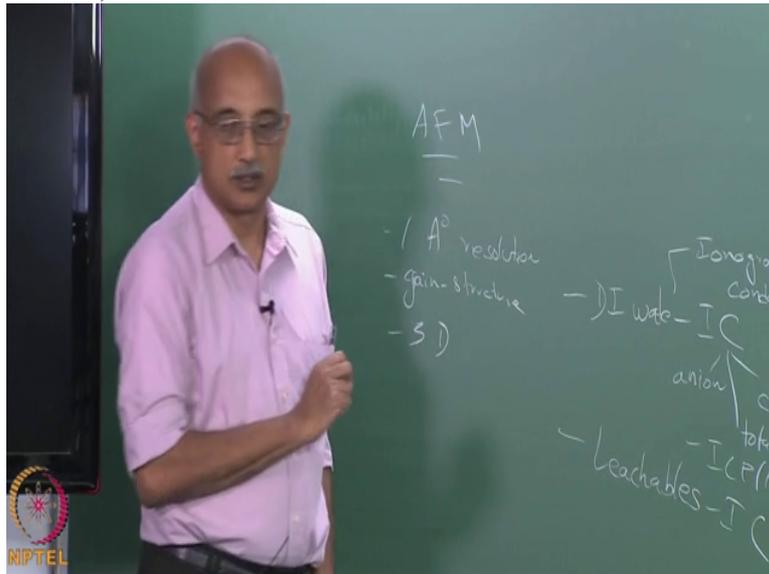
particularly the grain boundaries is using an A F M. It is sensitive enough to be able to detect the transition from one grain structure to the next.

And it is, in principle it is a much easier technique to use than other techniques like, for example, T E M, high resolution T E M which you may have to employ in order to look at, you know the grain transitions on a C V D film.

This technique is, even though it is very sophisticated and it has such good resolution it works pretty much like, you know, I do not know if you are familiar with the perthometer or a mechanical stylus. In principle it is no different.

The only difference between a mechanical stylus and an A F M is the cantilever arrangement which amplifies the signal by close to a million times. Other big advantage of the A F M technique is it is three-dimensional

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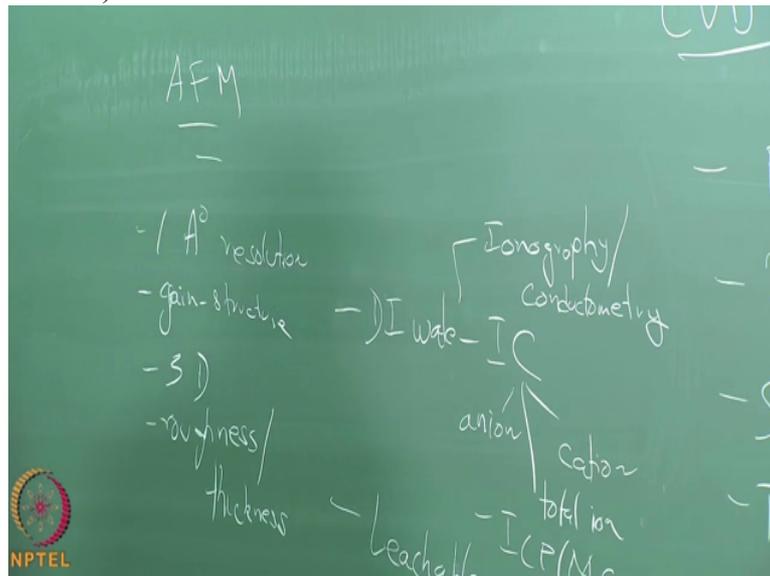
in nature.

So you can get not only the, you know the x and y planes but you get very good granularity in the z plane. You can actually look at what the surface of the CVD film looks like, you know, in a, in a three-dimensional sense.

So you get 3D morphology which can be very, very critical when you are trying to use the CVD films for certain types of precision applications particularly in microelectronics. So AFM has this huge ability to do that.

Certainly surface roughness measurement and by extension thickness measurement can also be used, can also

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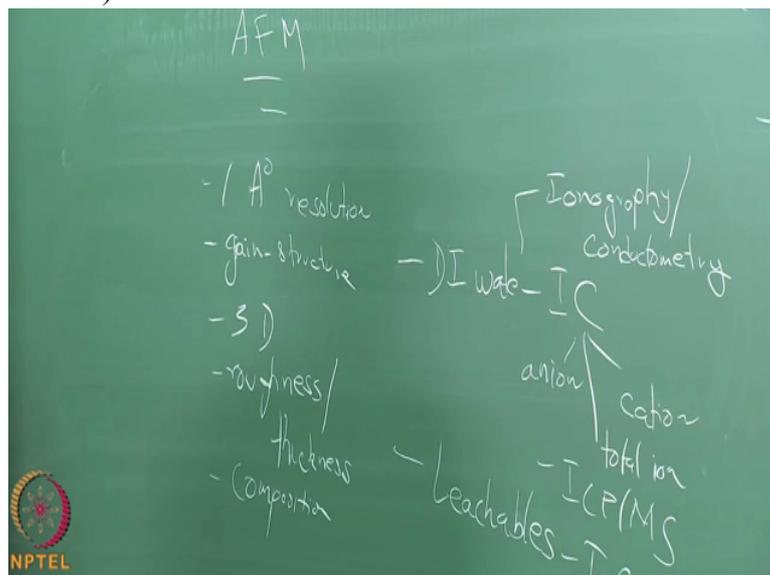


be used, can also be done using A F M. For thickness measurement, unless your C V D film itself is of the order of Angstroms it is probably an overkill.

But for looking at particularly the surface finish on the C V D film, A F M is an excellent technique to use. Because it gives you the, you know, Angstrom level resolution plus it gives you the 3 D imaging capability. A F M can also be used for composition analysis.

Can you guess why an A F M would also give you composition analysis

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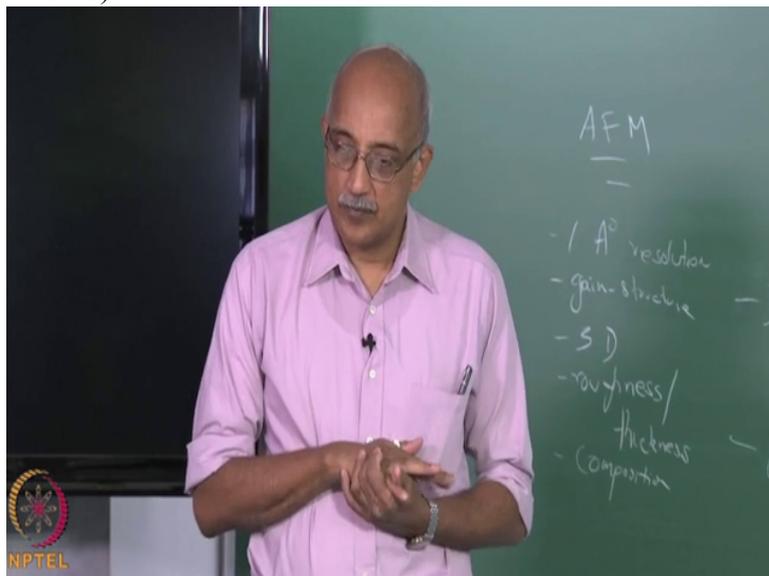
information?

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The reason is that

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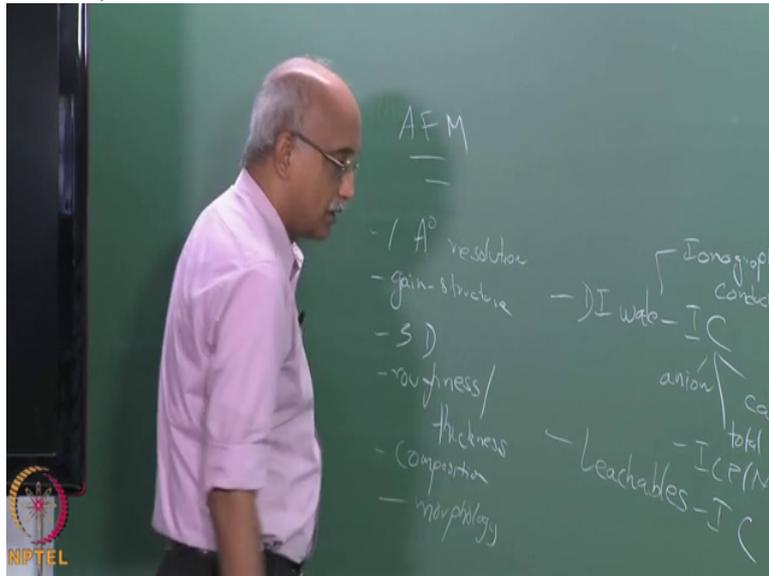
the AFM, I mean essentially it is measuring the force of attraction between the surface and a very small probe that gets close to the surface and I mentioned that this is basically a van der Waal's force.

But the van der Waal's force itself is determined by the materials that are in contact. So for example if your surface is silicon and your pin is let us say titanium oxide, there is a certain force associated with the molecular interaction between the silicon atoms and the titanium.

However if the silicon now has let us say some impurity, adsorbed silane then the interaction force will be different. Because the molecular character of the interacting surfaces is now different. So again provided everything else remains constant, if you have concerns that there is some impurity getting into your film the A F M can be used to actually verify the presence or absence of this, of this impurity.

So the other thing that the A F M can also tell you is the morphology. Now morphology

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is different from structure. You know when we talk about structure you really have to look at the crystallinity of the material. So you have to bring in techniques like X R D, for example to really do a good investigation and characterization of the crystal structure of a material.

However if you just want to know whether the film is crystalline or polycrystalline or amorphous, techniques like A F M do quite well because again the interaction force between a crystalline film of the same material and an amorphous film of the same material with the A F M probe are quite different.

And so by looking at, again the gradations of force between the probe and the surface you can determine whether the film is crystalline in nature or not. A F M by the way can be operated in what is called the contact mode as well as the non-contact mode.

When you look at the interaction between the surface and another surface there is actually two kinds of forces. There is an attractive force and there is a repulsive force. And in fact the equilibrium position that the two surfaces will ultimately occupy is based on a balance between these forces. So the van der Waal's force is essentially an attractive force.

But there are repulsive forces as well. What are some repulsive forces that you can think of between two surfaces? Why would they repel? Electrostatic forces you know, for example, if the charge is something that is naturally obtained then most likely there will be a distribution of charges so that two adjacent surfaces may have either like charges or unlike charges.

So if they have like charges they will repel. If they have unlike charges they will tend to attract. There are also surface tension based forces which try to keep surfaces away from each other. There are electronic double layer forces, there are image forces, there are many forces that essentially try to bring surfaces together and forces that try to move the surfaces apart.

As two surfaces get closer and closer, the repulsive force will increase in magnitude. As they get farther away, the attractive force will start to dominate. So that is why you will eventually reach a position where the two balance each other and the two surfaces will prefer to remain at that distance from each other.

So in A F M when we talk about contact measurements you try to bring the probe closer to the surface than this equilibrium position so that you essentially make tapping or intermittent contact with the surface. And the signal that you read back is the tapping signal, when the two surfaces stay in contact.

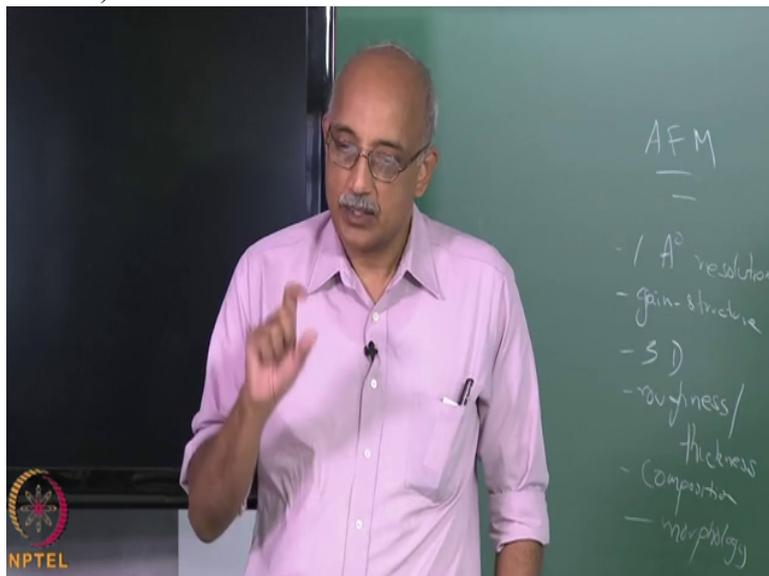
Whereas in non-contact mode you keep the A F M probe sufficiently far from the surface so that it is primarily in attractive, in an attractive

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field. But it never really touches the surface, right? So there are again advantages and both, and disadvantages to the two types of the techniques.

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The contact mode is the one you use when you are trying to assess for example, the structure of a, of a film. Because you really want to know what is the force as the probe gets very, very close to the surface. So you can see that when you have a rough surface, essentially the distance of separation between the probe and the surface will change depending on the height of the roughness asperities and that will be reflected as the change in the measured force.

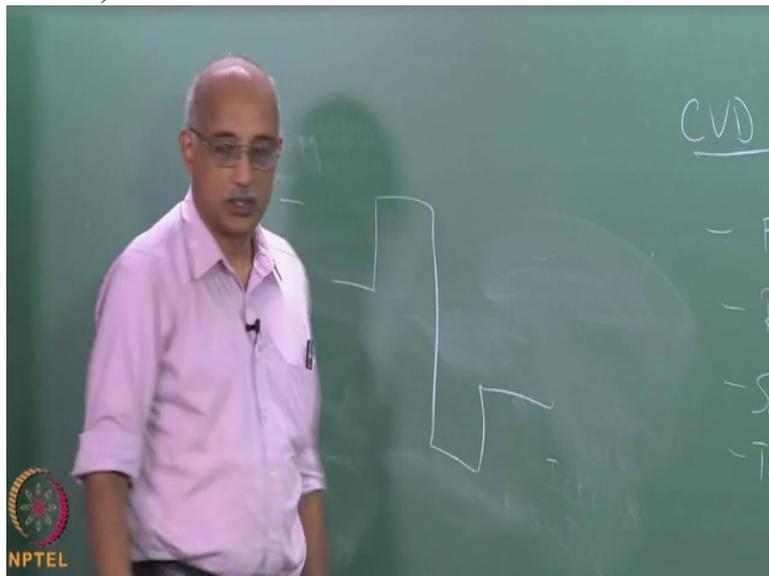
And that is why you know A F M is a very sensitive method for detecting surface roughness and for the same reason, for film thickness also that technique is sufficiently sensitive to be

able to detect that. So these are techniques that are commonly used when you are trying to quantify the amount of CVD film on a surface such as the thickness and so on and also when you are trying to estimate their structural and compositional properties.

But there are also other techniques which enable you to simply say, is there a film or not. Because these techniques while they are very, very good, they are also quite complex and they do require, you know additional time of analysis and so on. If you are running a process, frequently what you want to check is whether the process is even going on the way it is supposed to and you are getting a film on the surface.

So there is another battery of tests that you can do simply to verify the presence of a film. This is especially important when you have surfaces with features on it like deep cavities and so on. So if you are trying to, you know coat

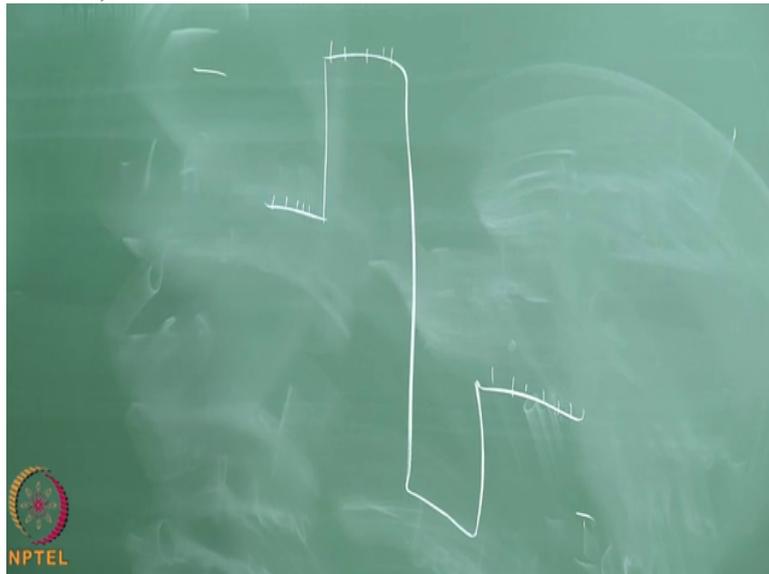
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a substrate that looks like this, obviously coating here, you know is easy.

But frequently

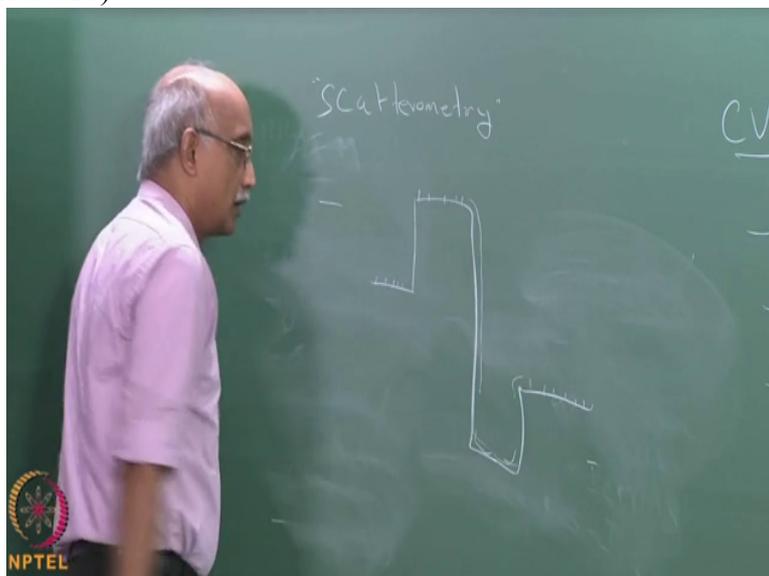
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you want to know whether you are achieving a continuous film as you go through this transition or this transition or this transition or this transition and you also want to know whether the vapors are getting far enough into the trench to also form the film at the substrate.

So the technique that is used to assess this is called scatterometry

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where, as the name suggests it basically looks at scattered light. And the idea is quite simple. You just essentially scan your surface with laser light and you look at the scattered light through image capture.

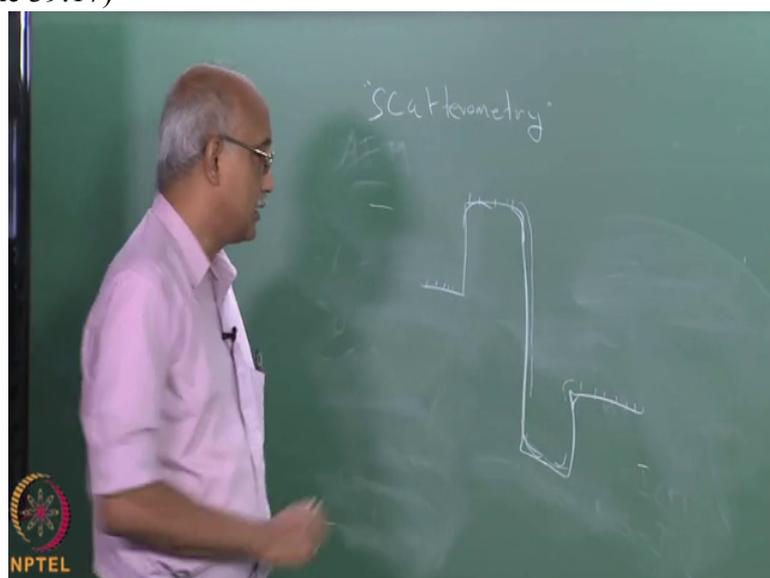
So you have some sensitive C C D type of cameras set up to, along with the photometer so that it can now capture the scattered light and then convert it to the series of images. So here what will happen is that when you traverse this light through here, when you have a film on the surface you will get a very different light scattering signal compared to when you do not have the film.

So previously if you remember we looked at reflectometry and spectrometry. The difference between the reflectometer techniques and the scattering techniques is that in general the scattered light is not as sensitive an indicator of the quantity of material that is present but it is a, it is a very good indicator of whether the material is present or not.

And scattered light is typically easier to detect. Because you are not even trying to detect 100 percent of the scattered light. All you are trying to do is fix your probe in a certain position and catch the scattered rays that are coming in that particular direction... So it is a go- no go test. Depending on the signal that you see you can assess whether, yes there is a C V D film or no there isn't.

Now when you have sharp step changes, you know for example when you have sharp corners this technique finds it a little difficult to keep up with that. It is, it is a better technique to use when you have more rounded corners where the transition from one height to the

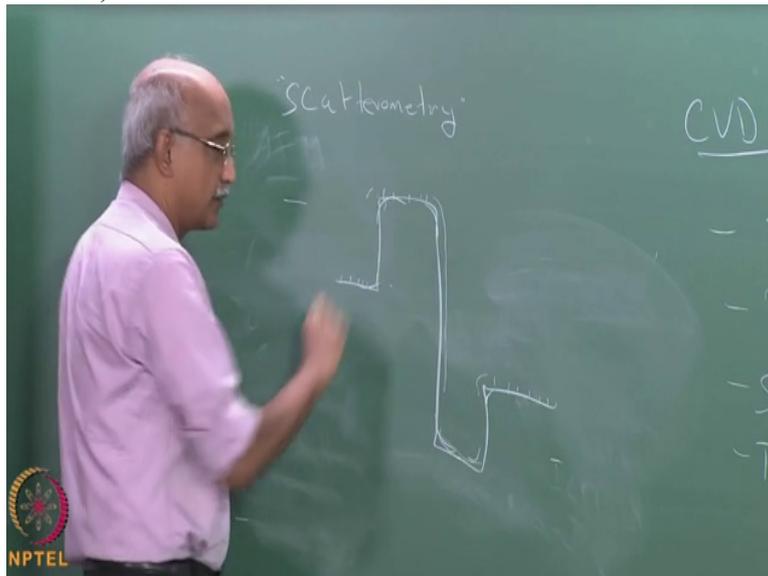
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next, you know this, this, this step change is actually what is difficult for many of these scattering instruments to be able to accommodate.

And so when you have cases like this if there you have very, very sharp corners, sharp transitions and features on the surface that are not well-rounded then the scattering, I mean basically what will happen is you will get a lot of

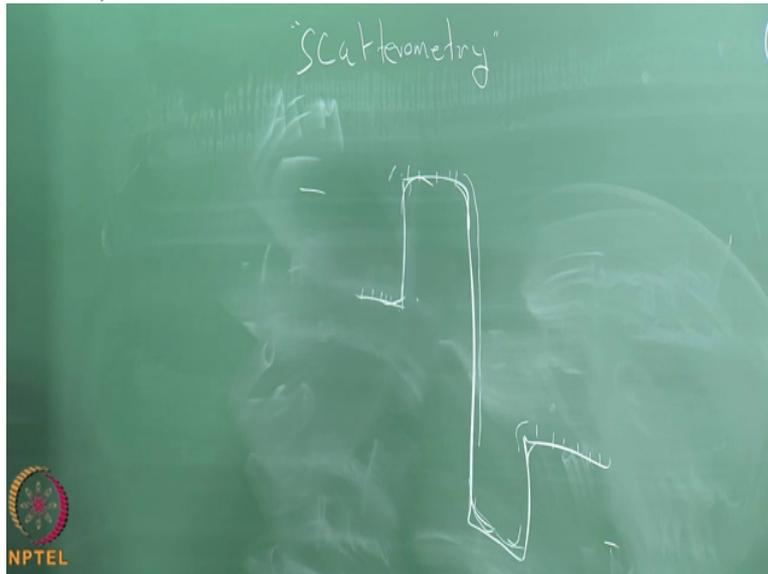
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interference from the scattering that happens around sharp corners.

And that can again confound 0:39:53.3 the signal that you get. So in cases like that actually a preferred technique to use is again something which has

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molecular resolution. So something like a scanning probe microscope or an A F M is a much better bet if you are trying to assess the, the presence of C V D film around sharp corners.

By the way many devices these days because you are trying to put down a certain pattern particularly for electrical functionality do have features that are very sharp and also very small in dimension. So you need not only the ability to follow the sharp transitions but you also need resolution typically to the Angstrom level to be able to keep up with these transitions.

And particularly scanning probe microscopy which is really the precursor to atomic force microscopy is very widely used in order to be able to characterize C V D films that are sitting on top of these surfaces. Ok, so we have kind of looked at a whole battery of tests that can be used to characterize C V D films.

The things that you need to keep in mind as we discussed in the last lecture is you know, direct versus indirect measurements, in situ versus ex situ measurements, online versus offline measurements, quantitative versus qualitative measurements, structural versus compositional.

You have to have a clear picture in your mind as to what are the critical properties of the film that you want to measure and what are the most appropriate techniques to measure these

properties. Because always remember, as a process engineer you are not getting paid to do measurements. You are getting -paid to ship good product.

So any measurement that you do is a non value-add activity. So always try to drive to a process where you can minimize the number of measurements you do so that you maximize your cost efficiency, your productivity and you are putting your best people you know where they can do the most good.

The engineers should be designing new products. They should be developing new processes. A measurement is not something that typically an engineer would be proud of doing. In a way it is for analyst. Engineer is supposed to be engineering a process. You are not supposed to be sitting and measuring.

So while measurements are very important and you really cannot run a process without them, they should be minimized and they should be directed in such a way where with minimum investment, you are getting the maximum effectiveness of these measurements. Ok. So let us stop at that point.

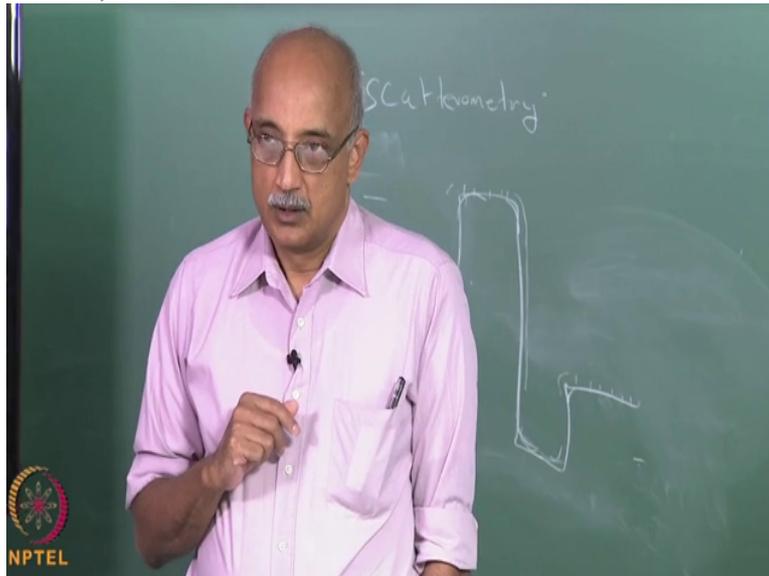
Any questions on measurement of C V D films, any aspect

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that we have not covered that you want to ask about or talk about?

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(Professor – student conversation starts)

Student: That C V D film when deposited on surface, how long it is,

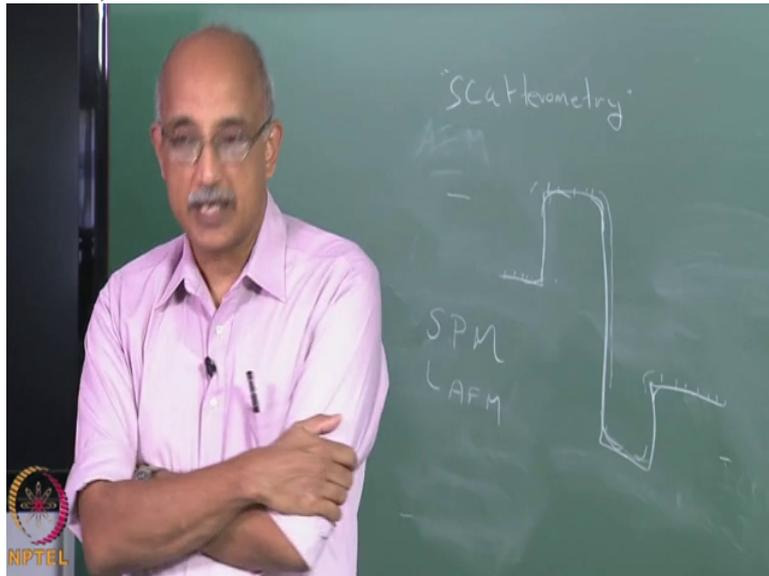
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thermal condition it can sustain?

Professor: So one of the techniques we talked

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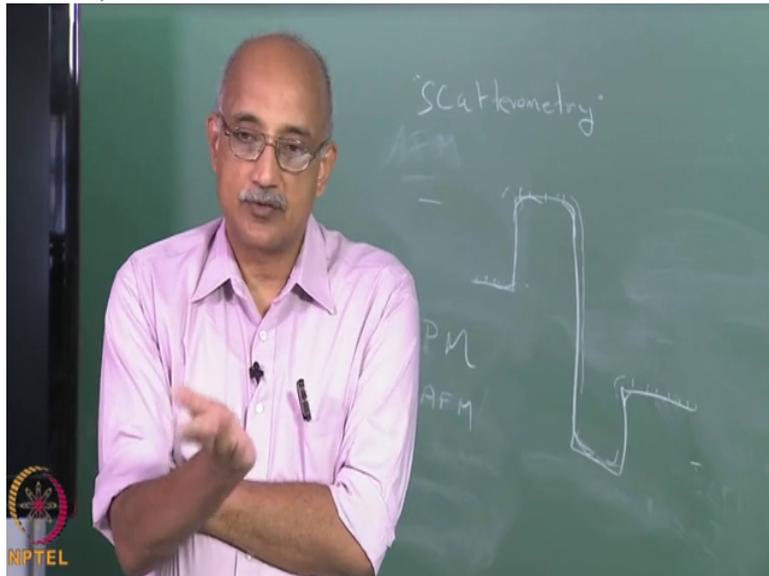
about is etch rate which is actually a very good indicator of how, you know the integral the film is. Because that looks more at the chemical stability, you know, because essentially you use hydrofluoric acid as the agent and as far as physical strength,

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I think some of the same methods that we have been talking about, you know something

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like an AFM or any contact measurement is also a good measure of how strong the bonding is but there are you know standard tests as well.

(Professor – student conversation ends)

If you want to look at the strength of a film adhesion to a surface, there are standard techniques that have been developed in the, more in the context of particularly polymeric films on the surfaces. So there are tests that again require you to essentially scrape some material off and see how much force it takes to scrape that material off.

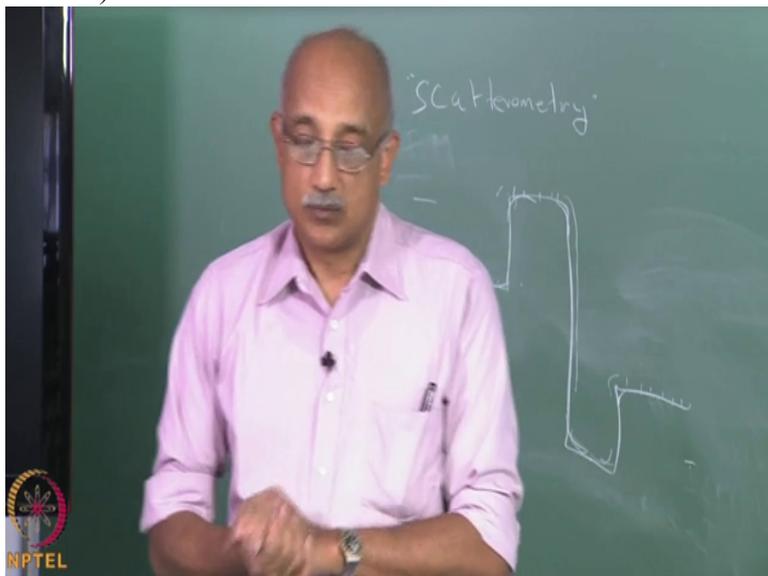
Now to look at something like thermal stability, that we can do using the thermal desorption technique that I mentioned earlier. It is a pretty good indicator of how

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stable the C V D film is if it is subjected to high temperature environments.

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More important actually is the cycling. You know, it turns out that many C V D films may be stable at room temperature, they may also be stable at high temperature but if we continuously cycle between them, then they can start delaminating.

So it is not only the testing at different temperatures but it is the cycle. And the same thing with humidity. So you have to have a testing protocol that involves some cycling of temperature and humidity levels if you want to look at the stability of the film under those conditions.

Ok so we will stop at this point and in the next lecture we will begin discussing some examples of C V D processes in real life and then start focusing on the transport phenomena that are going on. Ok.