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Course Title
Advanced Characterization Techniques

Lecture-01

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So in this lecture we are going the discuss about the scanning probe microscopy.

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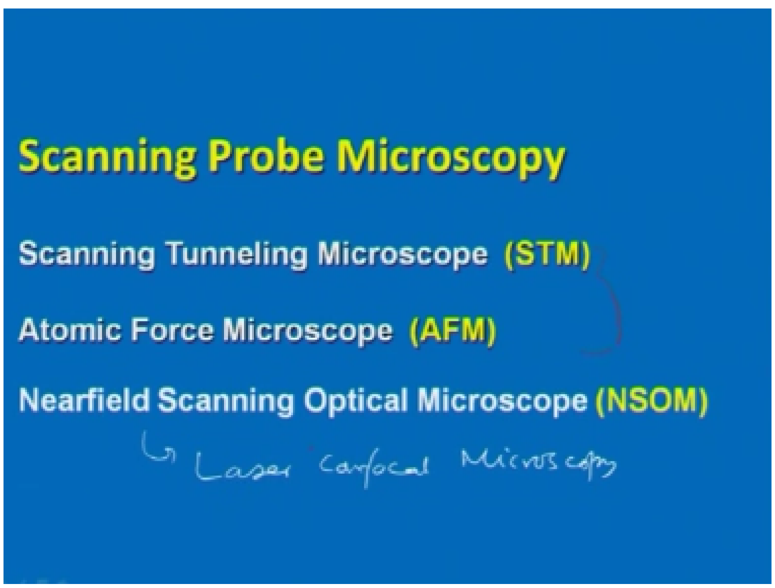

This microscopy techniques have been developed late 1980's in early 1990's and there are lot of development taken place even after 2000 so we are going to discuss only 3 important methods in this tunneling scanning microscopic techniques atoms force microscopic technique and near fields scanning optical microscopic techniques so as you understand scanning Probe means there is a probe which is going to scanner surface of a material.

And these techniques are widely used for study of surfaces both external and internal surfaces the 1st 2 technique that is scanning Tunneling microscopy and the atom force microscope both are used for the surface imaging of the material on the other hand near field scanning optical microscopic technique is used for both surface and also internal surfaces over the material what I mean to say is that the external internal surfaces both can minimize using the scanning near full scanning optical microscopic.

So most important technique which is used for near field scanning optical microscope is the laser confocal microscopy and this is gaining more importance about the time scale lattice can give us information regarding the structure of the internal surface initially it was used for biological specimens now a day's people where using is for material stands application also so in this lecture when we discuss one by one this 3 techniques like there is stage TM, AFM and NSOM and part of the NSOM is basically LCM that is lesser confocal microcopy. So let us first discuss about the scanning tunneling microscopy.

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As you understand it is scanning technique so therefore like any scanning electro microscope you probably have used it there is a rustier which makes the tip of this microscope or the prove of the microscope to scan of the surface and tunneling is basically coming for the tunneling of currents so let us first see history of it.

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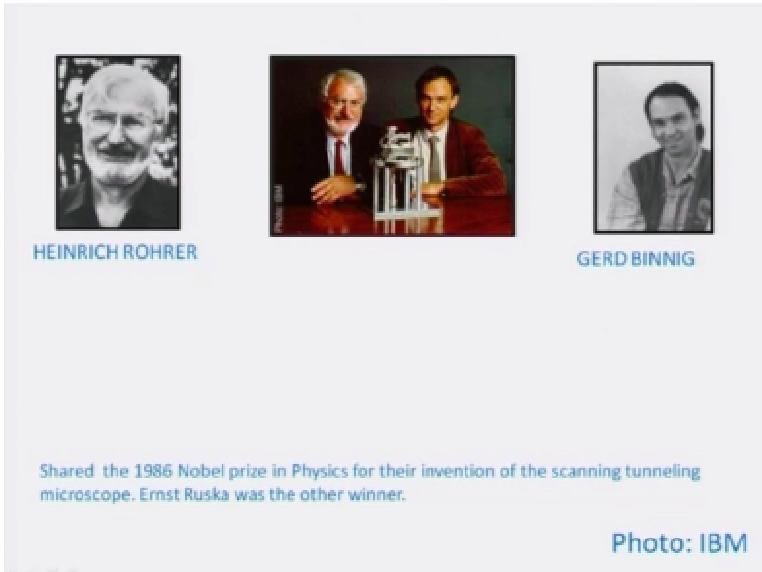

It is discovered quite some time back about 30 years back by 2 scientist Heinrich Rohrer and Binning bat the IBM labs anyways and for this discovery immediately after few years they got noble prize in 1986 for this discovery along with another stale what in the microscopic technique that is and Ernst Ruska so Ruska actually finding at the discovery of transmission electro microscopy.

So he along with these two scientist Rohrer and Binning received a noble prize in 1986 for the discovery the central figure shows the mission which these 2 scientist made that the IBM labs.

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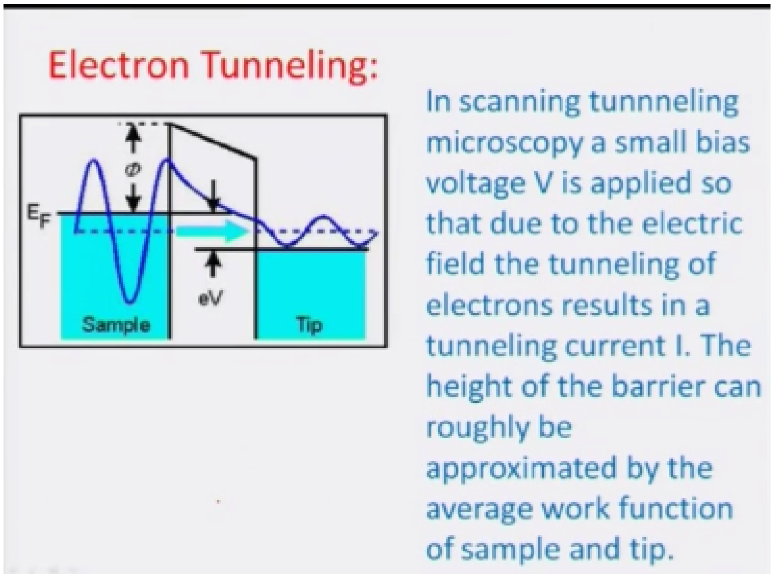

So before discussing about the scanning tunneling microscopy let me just talk about something about tunneling the concept of tunneling came after the advent of quantum mechanics as we know the if we take a small tip very fine tip of the diameter of suppose few nano meters 1 to 2 nano meters and bring close to a material surface and then if we apply a small bays voltage V to the tip because of this small bays voltage there will be electrical field generated.

And this electrical field will lead to tunneling of electrons from the tip to the sample surface and this tunneling electron can relate into tunneling current this is well known in the literature thus this is the reason and pack this current depends on the height of the barrier and it has been found that this height of the barrier this is the tip here you can see and this is a sample so therefore once the tip is brought cost of the sample and a small voltage basically bays voltage applied between the sample and the tip.

And then there will be tunneling of current like this a electrons like this and it has been found that the height barrier that is the distance between the tip and the sample surface this is a strong function of average work function of the tip as a sample so therefore obviously tip material as to behave as to have very low work function material normally tungsten is used for that very fine tip tungsten tip which is oriented along 110 is used for sustain tunneling.

In fact this same tungsten tip is used for the fake electron guns which you discussed for tons electron microscopes so therefore this concept to tunneling can be used for imaging the surfaces of a material let us see how it is done.

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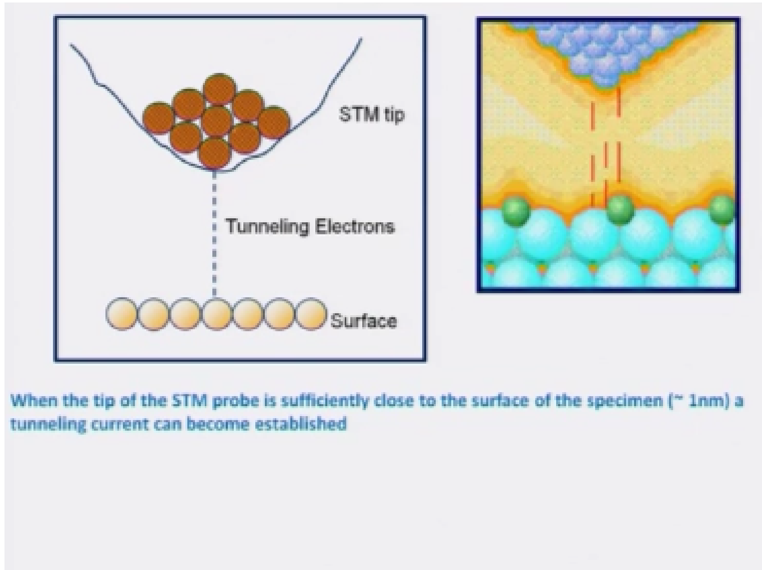

So here I am showing atomic skill view on the left hand side of this picture is the STM tip consisting of atomic atoms of the material which is used to make this STM tip normally tungsten and then there is a surface so therefore when the tip is brought very close to the surface as I have already told they are unless small bays voltage applies to tunneling of electron from tip to the samples surface.

And this highest h which is known as a barrier for tunneling is directly proposal to the average work function of the STM tip and the surface now so therefore if we do some kind of arrangement to scan this tip or the sample surface and depending on the height tunneling current will vary so therefore we can use this tunneling current variation to image the surface of the material.

The other ways of doing that also which I will discuss subsequently now this is so the right side the picture that is shown in a schematic video which is made by making many number of images so as you see there is a small tip here at the top consisting of several atoms several atom and several 100's of atoms and the surface and this is scanning either here actually sample is show to the scanning or moving by CMC plate or CMC device.

A device is very control velocity and a distance between the tip and the sample surface is kept constant deepening on the atoms the height atom plane or atomic positions height of this variable will change as you see the green atoms there are blue atoms at a lower height than the green atoms.

So therefore the tunneling current will vary and once we obtain this kind of information's and store it we can plot it that is a function of special variable and we can get the image.

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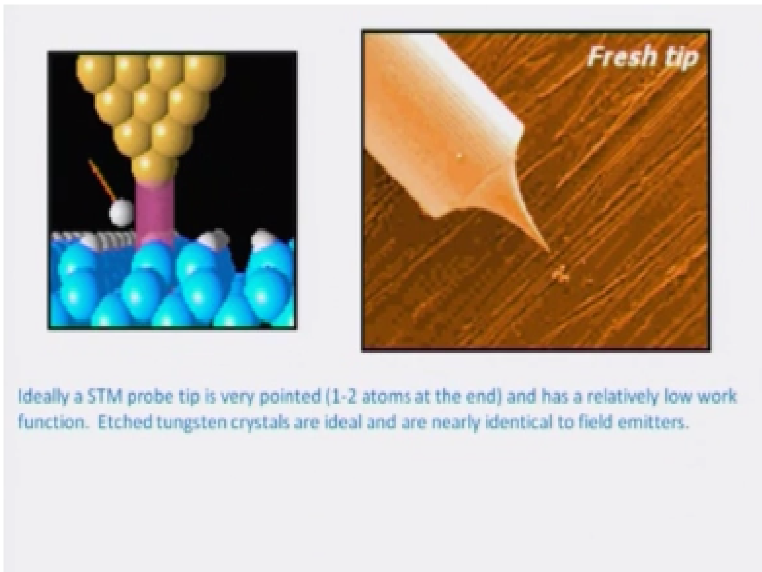

This is the basically principle of scanning tunneling microscope this was well known even after the discovery of the quantum mechanics and other theories came up in 1910 and even 1920, 1930's by the actual device making took a long time all the in 1980's the actual device could be made because of the preparation of the fine tip at the same time controlling these movement of the tip.

Because teams needs to be brought with the very close to the sample surface for tunneling to happen so ideally tunneling STM tip is very much pointed in fact it should be as pointed as that it will contain 1 to 2 atoms at the end and relatively very low functions so why does used is basically aged tungsten crystals the ideal and in fact these edge transfer crystals which oriented along 110 direction this is 110 direction of the tungsten crystal.

This is also used as a fill a meters as I show it in a free lay machine gun and so therefore by there are lot of what is called complex mechanism by the STM works which I will not going to discuss but I will discuss about the basic things of the principles of the scanning transmission electro-microscopy and scanning tunneling microscopy and also some applications.

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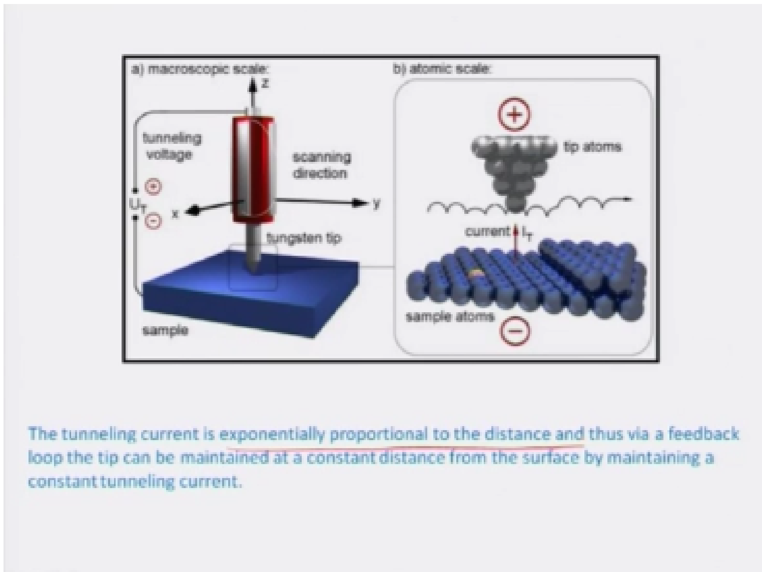

So as is no this is actually the device the low wage looks like schematically sample surface this is tungsten tip and then there are attachment here and which we will make this device to move on x, y plane and this tunneling voltage applied across the tontine and the sample and image of the current.

So an automatically this can be shown like this again showing several times this thing so that it make nuclear to you there is a tip here which is a positively bays as compared to the samples surface and because of that current electoral 4 from the samples at surface to the tip and current will flow opposite directions a tunneling current is basically exponentially varies as proportional to the distance and thus a feedback loop.

Thus why a feedback loop the tip can be maintained at a constant distance when a sample surface or it can be even being close or to see the variation of the tunneling current so there are obviously there are 2 ways of operating it if the tunneling current is kept constant suppose which in the tip and the sample surface the j position of the tip must be moved up and down depends on a sample surface as you see sample surface is very rough here it varies.

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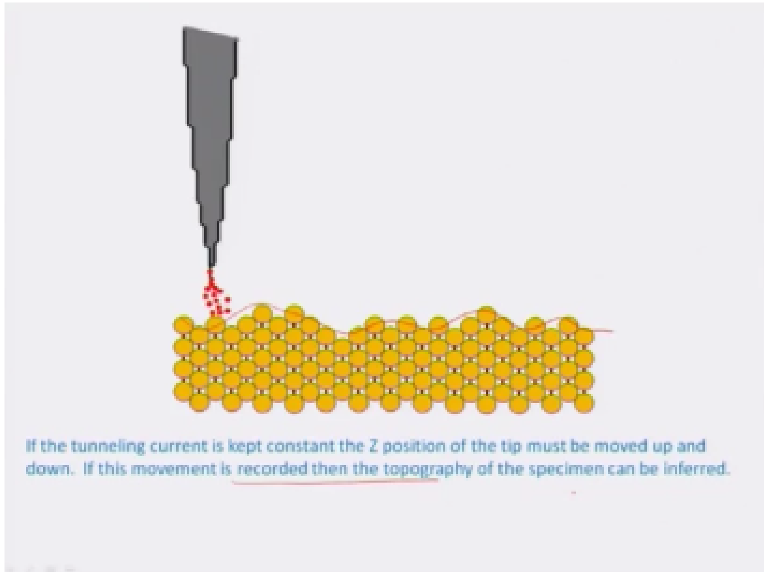

So therefore the as a tip grant turning current is constant is to maintain this constant current in a tunneling current in the tip one is to bring the tip closer or longer distance depends on the sample atom positions on the sample surface so this movement is directly recorded the movement of the tip can be recorded as is moving on the sample surface and then it can be plotted and on a sample surface on a basically raster mod it can be plotted and we will give a spectrographic image this is the first mechanism.

By which so in the first case we keep with the tunneling current constant and move the tip is move up and down to keep it constant, and the position of the tip is then use to plot are is obtained spectrographic image this is the first or the A we can say mechanism of scanning time microscopy another way we can do is that we can keep the z position of the tip constant that is the distance of the tip on these another samples are face can be kept constant, and tunneling current obviously will change.

Depending on the surface configuration so whenever the atoms are closer to the tip there will be more tunneling current atoms are close avoided to the tip there will be less tunneling current, so therefore if this changes in the tunneling current is recorded and then if we plot the tunneling currents are rays of unction of special variable x and y or z then basically we can get into photographic image, so this is called B so in this case z is kept constant and that a distance between the tip and the sample surface.

At a particular position and then tunneling current is measured it will change as a function of sample position and then this is plotted ITC is plotted as a function of special variables to obtain a topographic image, so this is very simple this are all well known even long back by discovery allows takes time because of the implication because of the problem of integrating the whole instrument, so and obviously as you understand the problem is to scan or post is to be scan actually of the sample surface this scanning is done by raster is similar to.

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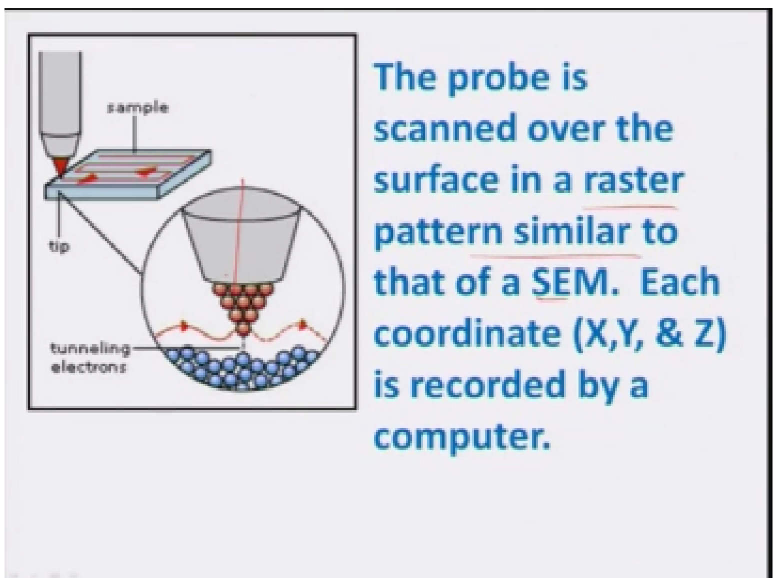

Like a SEM and this is coordinate is can be recorded it is going of the sample tip can be recorded on a computer just like that so whether you use a or b it does not matter all the positions are recorded and then values of the current or values of the distance of the movement of the tip can be recorded and whichever you want you can plot on the computer and get the image, so this is basically the way this are the ways before scanning tunneling microscope can be used and this array used normally.

So a humor this requires the tunneling of electron therefore the whole thing has to be kept under way high record system this is another problems second problem is that the sample must be conduct other than there will be no tunneling of current so these are the basically routine problems one phase the sample is not conducting much there will be not must standing happening of the electron from the sample surface to the tip and because of that current flow in all it will happen.

And this microscope will not occur second important thing is that the whole system has to kept under ultra high vacuum and that makes the process wide costly because you need a vacuum system attached to it.
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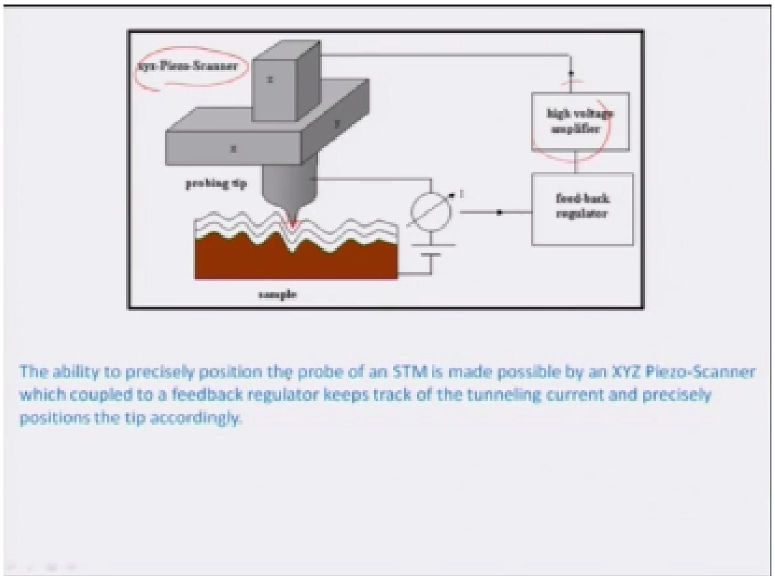

On a broad scale actually if you remove the increase this scale so this will look like this then this scanning TP is control by PGOs electric scanner, and now-a-days well precisely control PGS scanner available and this tip is basically can be brought close or wider on the sampler surface as you understand the sample surface solution very rough there will be atoms are arranged in differently atom manner and so there will be observe atoms sitting on the surface so all those things makes the sample surface very rough.

So and then there is a feedback loop to control the we want to keep this tip at a constant distance on the sample surface there is a feedback loop or and you need a voltage amplifier also to amplify the whatever voltage is coming recorded, so ability to precise the position of the prove of an STEM is possible all because of xyz previous scanner and this xy is PGO electric scanner came long to belong time or it be operational and to make it be too might be use for this kind of microscope purpose.

This kind of PG electric scanner is always capital to feedback regulator to keep the triangular tunneling current also precisely positioning the tip, so therefore we need several electronics for such kind of device to run and this all become possible all when the technology where advice surface handling.

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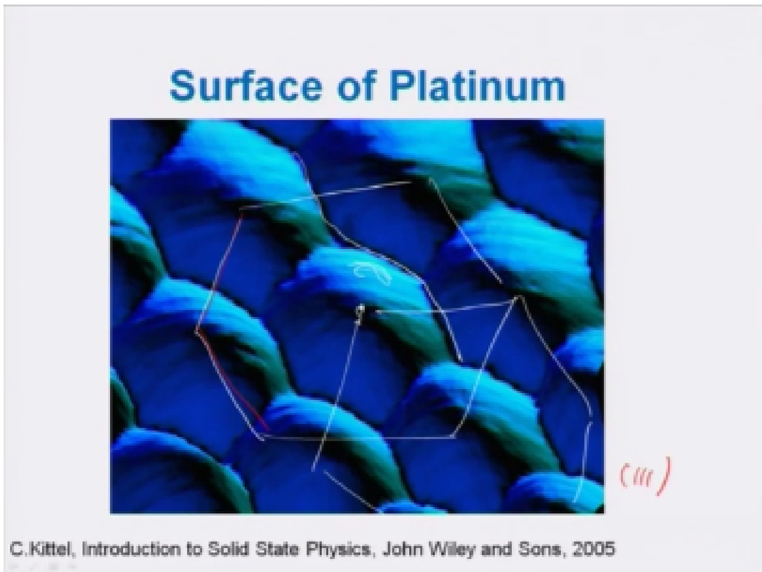

So give you some examples and I am just taking example from the literature because we have personally I know I am not worked on STEM and some of a colleagues has but the images from the books are much better let us look at that this is actually taken from solid state physics book by Charles kittle which is very standard book you can see the same is available in black and white contrast, this is actually platinum atoms and 1 1 plane what you see is that x similar array of patterns 1 2 3 4 5 6 this is an hexagonal.

So one on plane the surface will be continuing this kind of acting element this is simple atom and this goes on repeating, so what you can see here this just goes on the another one here like this so it gives us very good got not even that this are actually images of atoms looks like but they are not as you can understand they are not actually images of the atoms they this are basically plot of the tunneling current.

As a function of the space so this sides and this is the higher height so this will give us there is no high tunneling current that is why it looks like a dark on the other hand this surfaces which are at deeper side which are looking like bright and what again the groups here looking like also darker when very black color, so they need to base small amount tunneling current so that is how we can actually generate images, to show the another one.

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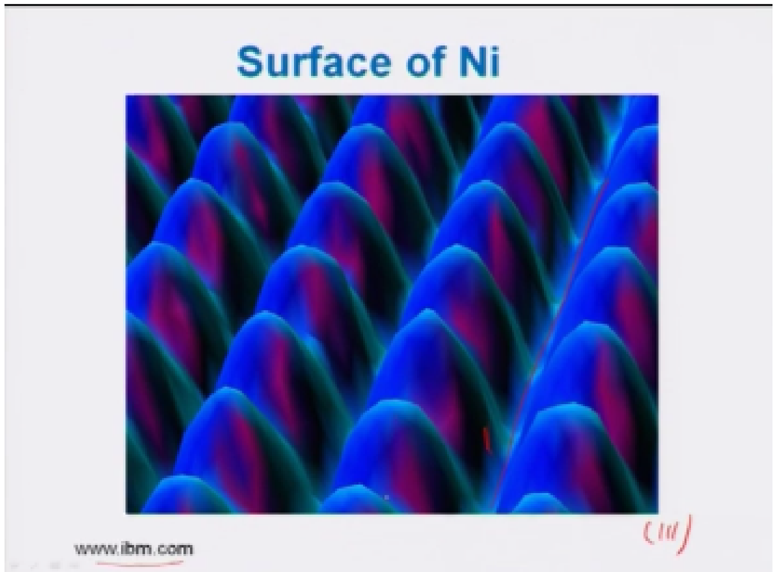

This for the nickel surface see there is a distinct difference between nickel surface 11 surface nickel 11 and the platinum 111 in a platinum 111 we could see big atoms filling the whole space here you can see large gap between the rows of the atoms this is these are the rows of the atoms and this is again obtained from the same group meaning and the stu work which they have done on when they are working an IBM labs, so these are the tips of the these are the positions which are close to the tip of the scanning.

Tunneling microscope and so they are looking like very bright and blue on the other hand this surface is looking darker because they are at an angle and this is again looking the brighter depends on the obviously how the surfaces is along to the spector tip the surface are inclined they are not flat really at even at any scale surface is non wave perfectly flat because the atoms at a very constrictions takes place in a surface all is.

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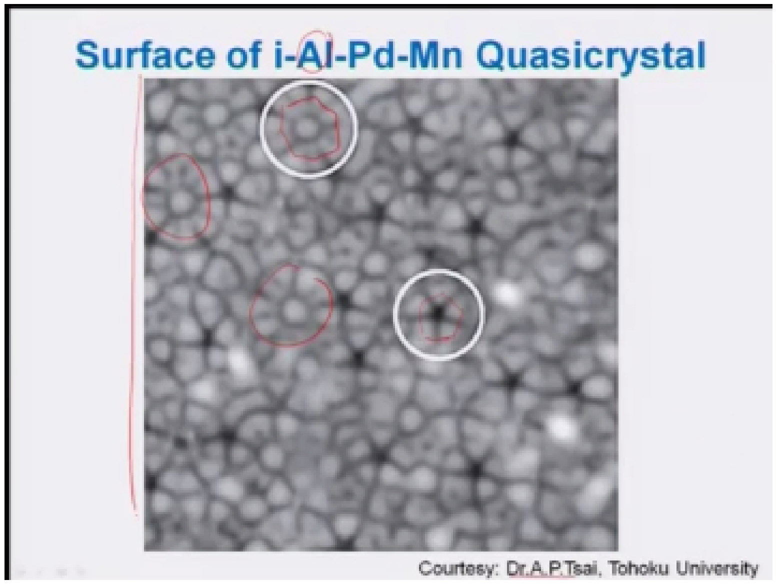

To give you another example which is from very recent work this one micro courtesy Tohoku university from Quasicrystal surfaces we know that Quasicrystal are very you know new and very exacting materials people think about it also that the Nobel prize for the discovery of Quasicrystal was awarded easier in last year actually 2011 to professor Dan segment for discovery of that, so this is become a big aspect of registers now-a-days this is a scanning tunneling microscopic of the hydro central ALPDM and Quasicrystal's multiple even alloys.

So what you see here is that five atom plasters here 1 2 3 4 5 attain atom cluster like this you can see in the surface and there are many such clusters here one there one okay many, many such clusters which are deemed too represents on this Quasicrystal you know this is the atomic as mean so really cannot say which atom is quite but we can really say that on the surface of the Quasicrystal also the same atomic augment is observed as in the bulk, so one can actually see it why doing the STEM.

Remember to do this STEM analysis we need to clean the surface so any aluminum alloy will have very thin layer of aluminum oxide presents so these samples are taken in a alter high vacuum and then they are sported using the organ gas to remove the whatever oxygen atom presents and this then the versus is created which was then wrote by the STEM and images are taken so therefore STEM is obviously very costly equipment.

Because you not only need a vacuum system and other things but also you need sputtering devices also goes to study different metallic examples and as I told you mostly the contact sample can be studying some metallic sample looks to be ideal for this contact in samples that is why they are done. Now let me go to the next the space probe technique that is called atomic force microscopy as I told you this scanning turning microscopic technique has his own problem like it can be use for non collective samples.

It cannot be used for liquids or it can be used normal atmosphere because you need to have tangling currents that requires time of electron that requires vacuum system to be very good and whole system could kept on the vacuum, so therefore this limitations let to the discovery of another microscopic technique called atomic force microscopic.

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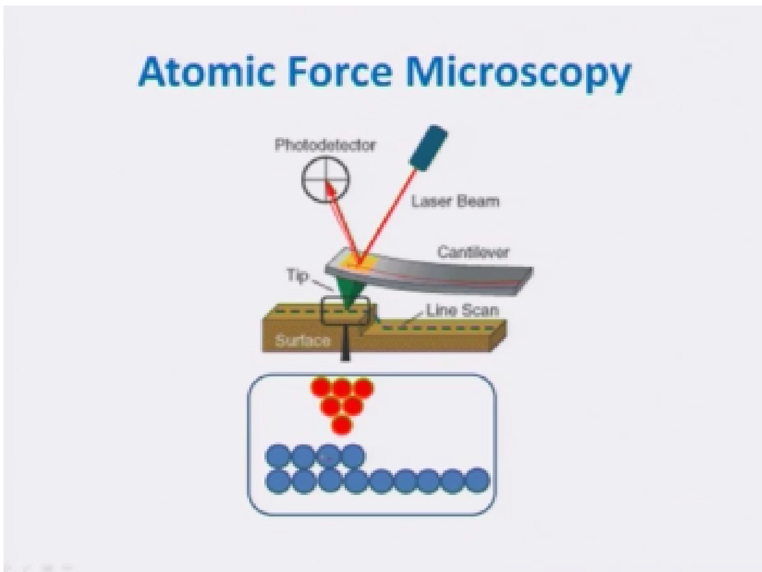

And this is again based on the principle that if we have a very fine tip attached with the cantilever beam and whenever this tip is bought close to the sample surface so they will be atomic force acting on the tip because of the atoms which are presence a sample surface. And depending on the force they are actually there can be repulsive or attractive forces which I will tell you depend the distance within tip and the sample surface.

So depending on the forces the tip can be going down or going up so if we measure the tip position by using a laser beam there is if I have a laser beam falling on the tip surface and reflected back on a four quadrant photo detector then I can preserve remain the tip height as a scan for the sample surface and then plot it just like it is STEM and we can get a better image.

Remember this does not require any vacuum system this does not require you know the sample to be contacting because it depends on the atomic forces and this kind of atomic forces between the tip atoms of the tip that is this red color atoms then the sample atoms they depend on the what is called distance with the tip and the atom it does not depend on whether sample is contacting non contacting insulating nothing. So this is the basically idea, now I will discuss you in detail how does it work?

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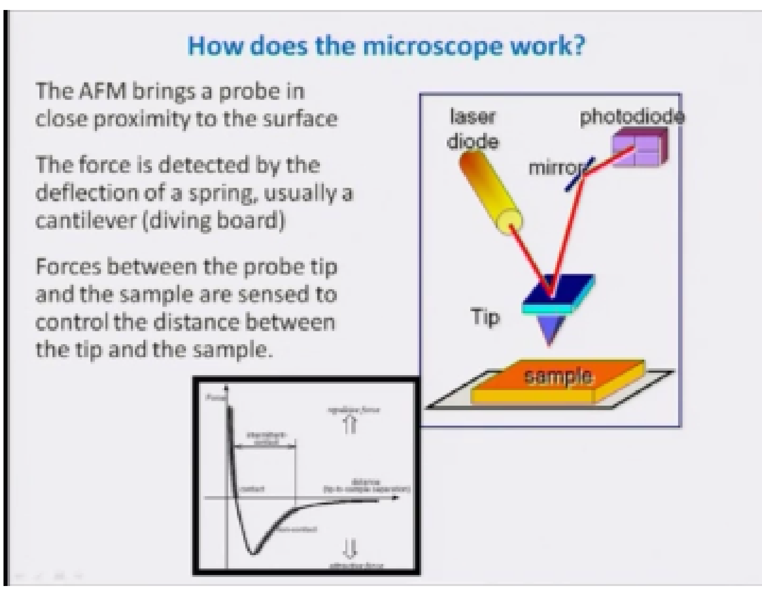

Well AFM brings a probe very close to proximity surface there is the tip and this force is then it detected by deflecting spring actually it is not a deflective cantilever you can see this is a big cantilever beam which is attach to the microscope and this force is detected. Now forces between the probe tip that is the tip and the sample are sensed to control a distance between the tip and the sample.

So as you know if you have two atoms suppose the force versus distance between the atom can be plotted like this and this is our force versus discovery, so whenever the atoms are very close to each other there will repulsive forces okay whenever atoms are far apart from each other there will attractive forces whole you know that. So therefore depending on the close of the tip to the sample surfaces the forces between the atoms of the tip and a sample well vary whether impulsive type are maybe attractive type and this can be used to operate this kind of microscope AFM in different modes.

So one of the mode is called contact mode other one is called non contact mode, so we will discuss one by one this contact mode and non contact mode but I hope you have understood what is the basic mechanism is the forces between the atoms and the surface and the tip atom in the tips. So that is those are the probes, now before that let me just tell you how it is.

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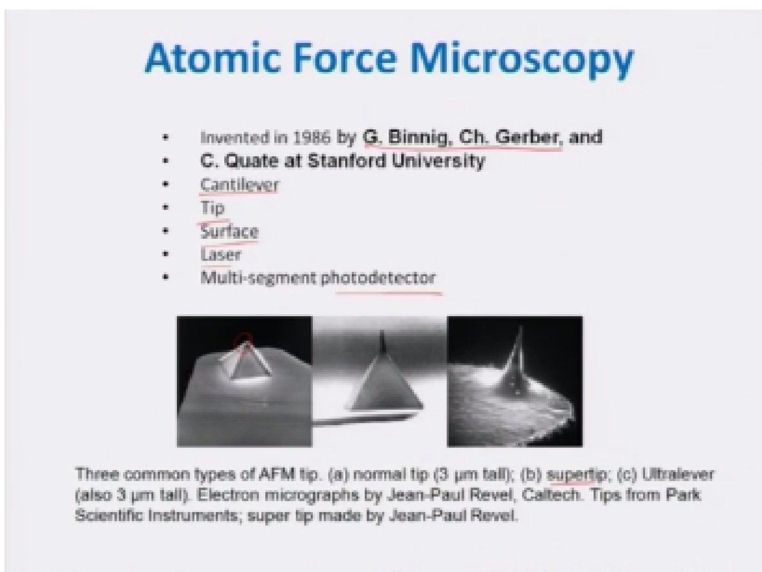

Which is again discovered by Binnig Gerber and the Quate at Stanford remember after discovery of STM Binnig move to the Stanford University and it requires a cantilever beam a tip sample surface laser beam and obviously we need a photo detector all of this I have shown you the first slide. And the tips actually can be different type this is a normal tip as we see just like a tetra

Haden or you can have a super tip again one tip and another one is set us to that or ultra lever tip which is three m tall.

And these are all obtain from J. Paul Revel from Caltech, and all this image available in this website you can see that, so tip manufacturing is a big things it is normally done using a very complex process like dipping in electron and looking at in the microscope subsequently every time you dip it some all amount of the material is getting corroded this kind of tips and that why we can find it up to the atomic level remember the tip is very fine observe of few maybe 1nm or less so that there are very few number where atoms space in the tip.

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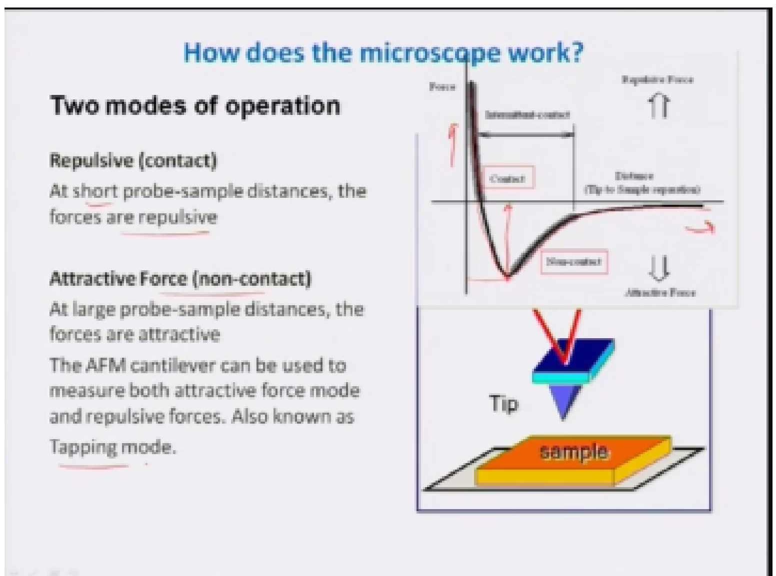

Well as I said there are two modes operation one is called contact other one is called non contact, contact mode is corresponded to repulsive and non contact repulsive call as attractive force use your macular from this plot force process distance whenever two atoms are bought close to each other and as you know that the force process distance if the atoms are even impinging on to each other will be very high and this course comes down and then there is optimum distance where force is the minimum and then if we move that on far effort from each other again force increases and it becomes constant after sometime.

And obviously we are going to sudden distance there will be no force of attraction repulsive and whatever between the two atoms, that is how the forces vary and this basically was this can be obtain from any physics or chemistry text book you can see that and so therefore whenever the probe or the tip is very close to the sample surface the distance are very short the forces will be repulsive in nature as you can see here repulsive in nature or whenever the distance will be large the force will be attractive in nature and KTM cantilever can be used to both measure the both the attractive force or the repulsive force in different modes.

So if you measure the repulsive force is call a contact mode we measure the repulsive attractive force is called non contact mode this is also known as tapping mode, I will discuss in deal.

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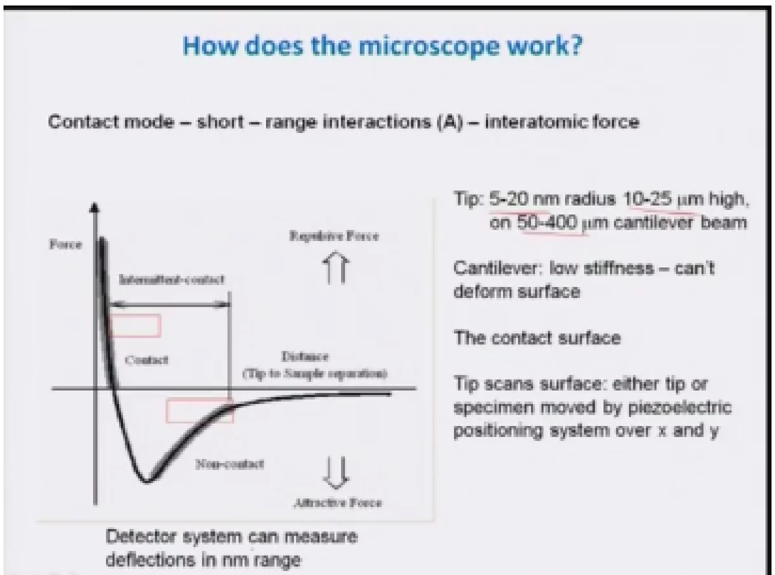

So in a contact mode where the short range interaction ofr between the interatomic forces are very important tip is normally 5 to 20nm diameter radius and if 10 to 25m height okay and the cantilever is approximately 50 to 400 m long and cantilevers are normally very low stiffness because they needs to be you know going up and down deform actually, but it cannot deform the sample surface because it feeds the sample surface in contact mode sample surface will get deform and then you do not actually detect exactly what is the sample surface.

Tip some scanner surface either the tip of the specimen can be moved by piezoelectric position system and detector system can measure the reflection of the tip as a contacts make a contact of the sample surface very close to the sample surface, so they will be contact and then it will be deflected and the deflected can be measure by laser beam. So as I said here also there are two ways of doing so.

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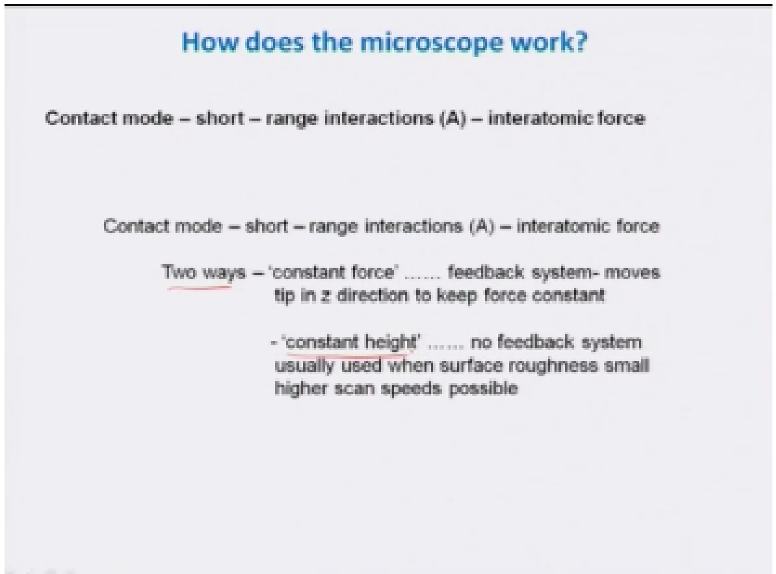

One is called constant force that means if you suppose want to have the constant force between the sample surface and the tip to be maintained then there will be feedback loop which will keep this constant force of during the sample and the tip but to keep this constant force the sample till has to deflect more when the distance is higher between the tip and the sample surface but distance is smaller that attractive force will sorry whenever distance here are attractive forces where repulsive force will be little less and when the distance is close impulsive force will by high.

So depending on that you can detect the tip deflection and in z directions and then plot it later on to get an image, or you can actually have the constant height so no feedbacks system usually used when the sample roughness is small higher scan that is possible here also and in this case tip is keep it is constant height from sample surface and force actually varies and that force can be lead to deflection the tip and that can be measure to plot.

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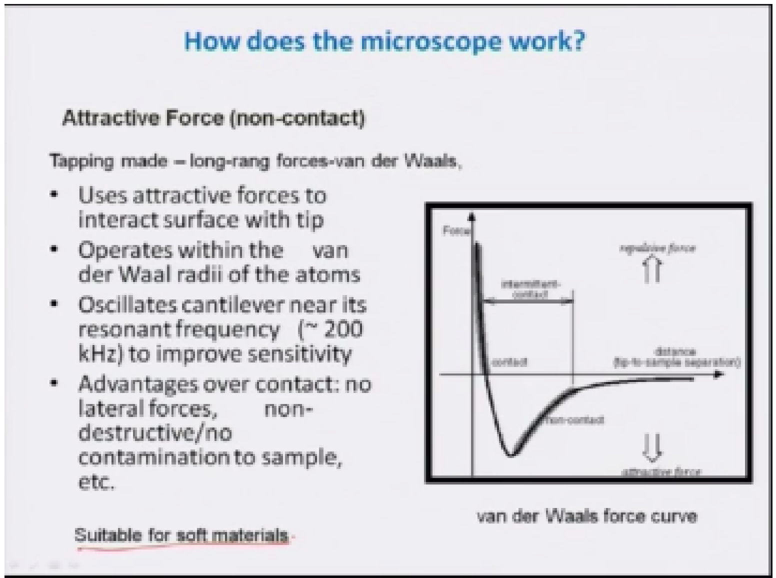

Well in attractive mode there is a non contact mode is called also tapping mode this used for the interact normally attractive force to interact a sample is a tip it is operates with in the vender Waal radii of the atoms, we know there is a vender Waal course of attractions and this attractions happen when the radii of the atoms is within the vender Waal force of attractions limits and in this case actually the cantilever is zone acts cantilever actually oscillates near resonant frequency normally 200kw to improve this seasons.

Basically if I have tip like this I just keep a tap so that it resonant or it is do like this and once it does it measure the long reforces, that is why that is go a tapping mode it has many advantage then the contact mode no lateral forces will act on the tip because whenever tip is very close this sample surface there will be lateral forces which can act also have then the this vertical forces, I have the force the distances higher this is non contact so non distractive so it does not lead to any contamination of sample it does not lead to deformation of the sample also.

So this is basically suitable for all kind of soft material. And the other mode which is contact mode is basically suitable for the hard materials because even the sample set tip heat the sample surface there will be no deformation activities and sample surface which will not change the material surface or the chemistries surface because of contamination or the change on atoms on the sample surface.

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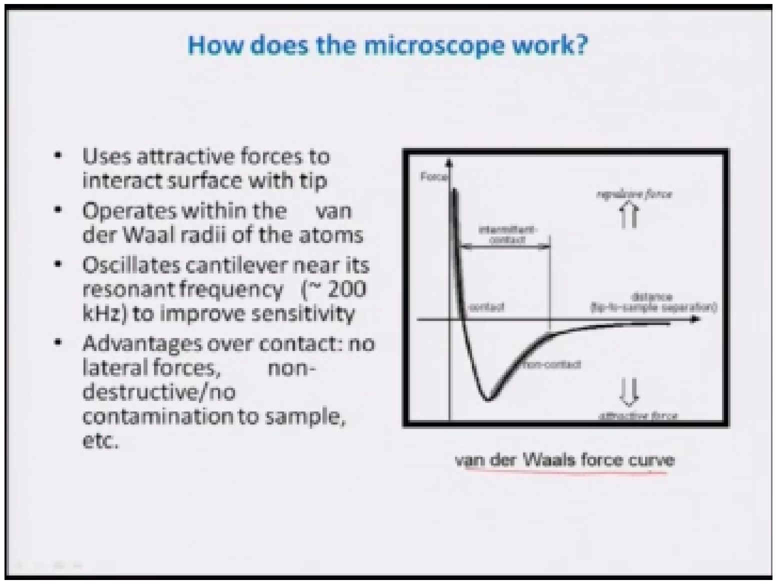

So the attractive force is basically as I just now said is basically depends on the Waals force so the distance should be maintained such that forces ready of the atoms actually becomes comparable with the tip distance.

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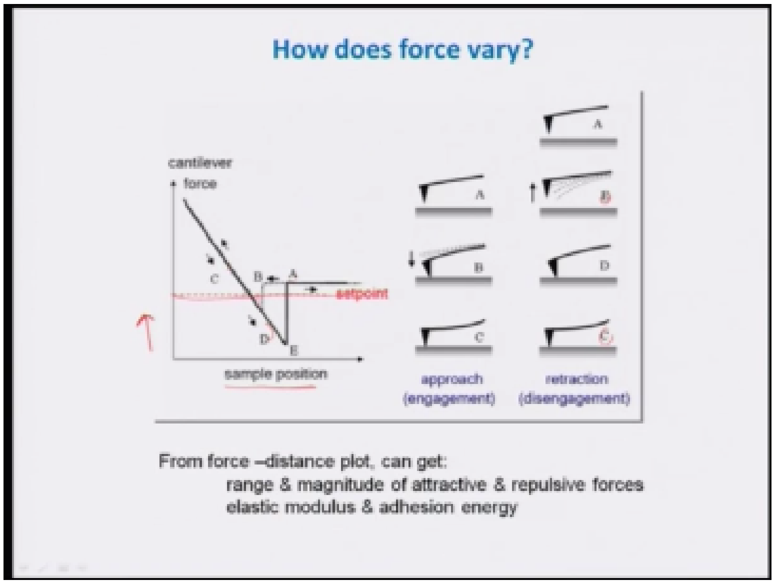

Now as the force actually vary let me just tell you in a sample slide like this, so how do you actually measure, as you know AFM one can measure the force % distance plot also. So this is the sample position this is the force, and these are the different position ABCDE and I am showing the position tip.

As you see the tip is close to sample surface at the position A but not at course, therefore the force is very constant and whenever the tip is touching this sample surface tip gets bend so the force started dropping or rather it will be sticking on the rising at position C force is very high and whenever this is what happens whenever tip comes down and basically hit the smaple surface.

If you want retraction that is disengagement on the sample surface then again it will be going CDE say EDCBA, so this is the position C which is exactly at the contact point. D is basically it has again gone down, so gone up so the force as decrease, the E as decreased A means it has got up and this is set point here. So that would depend the kind of disengagement engagement the forces varies. How the forces are measure? This is obviously very important aspect suppose this is.

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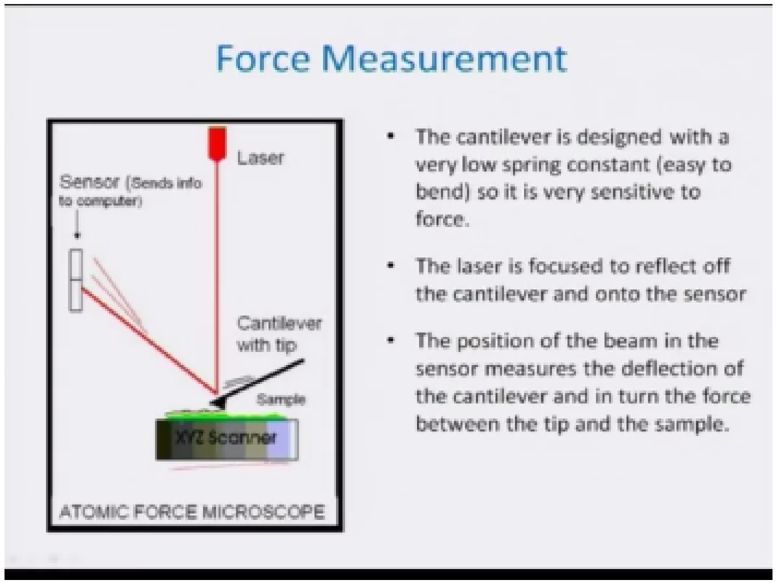

X y scanner and this is the sample that means sample scans tip does not move but sample scans and as tips basically goes down as a sample surface as okay this is the tip directory forces acting on the tip will be varying, so therefore that the deflection at the tip will also vary and if you have the laser beam for the sample at tip surface and depending on the position of the with tip it is deflected more or less because of attraction whatever force attractive with the sample surface.

And this will go dip back to the censor constitutes of pro system is just like this ABCD, so if the laser beam hits ABCD any positions it can be easy to detect very precisely so the cantilever beam is designed with a very low as I said, so that it is easy to built and laser is focused to reflect this cantilever beam whether to focus on cantilever surface and so that it can be reflected back at the censor.

And position of the bema is sense whether the reflection of the cantilever beam and this is turn can give us the value of the force.

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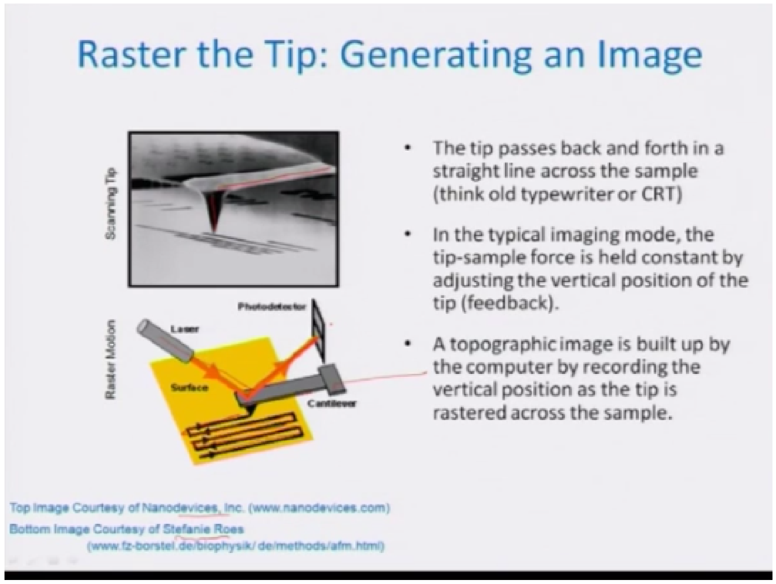

Obviously this has to be doing the rastering just like STEM and these are the images taken from the nano device which are making this instruments another one is taken from Stefanie rose bio physics department in Germany. As you see here this is the tip which I told you that I will show you and here you are showing the same thing this is the tip and this is attached to microscope laser will fall on the tip.

And as the tip deflects more it is positions of the tip by using that and this is how it is done and tip make a rastering here just like this and every time it is position can be determined by using a device and the tip position can also be deducted by this. If you store all the data in the computer electronic and plot the position of tip as a function of the distance or the special codeine and get the image.

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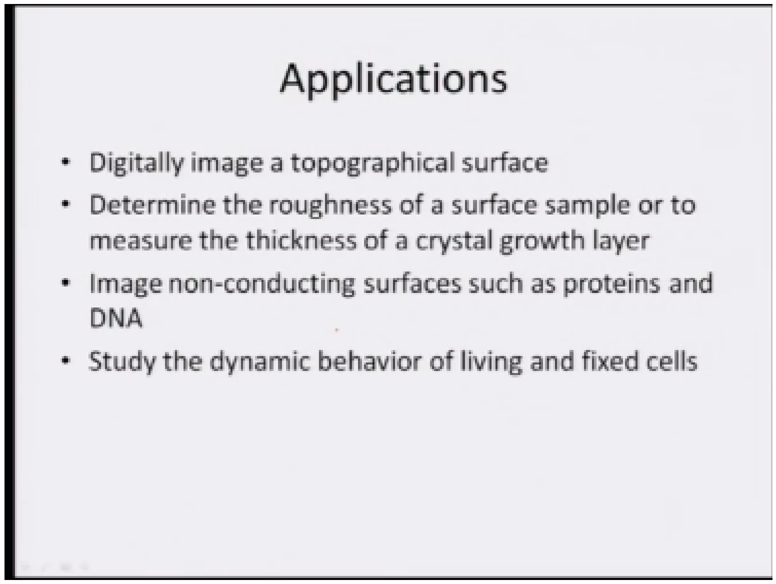

This is used in many purposes like digital image for the topographical surface or this can be used to determine the roughness of the surface sample or to measure the thickness of the growth layer. In fact this is mostly done to measure topographical sample surface this can be done to that is Armstrong level. So people are able to get relation of the order of one Armstrong, so you can see that which I have shown you and I have shown you in case of the STEM.

Now this can be also used for non conducting surfaces like proteins and DNA as I showed you this can also be used to study the dynamical behavior of living and fixed cells. Remember this is not exhaustive application are keep on coming as the technique is getting used more and more, so therefore if you really want to know about the real application you have to look at the literature available in the different journals. Topographic is obviously done this is again.

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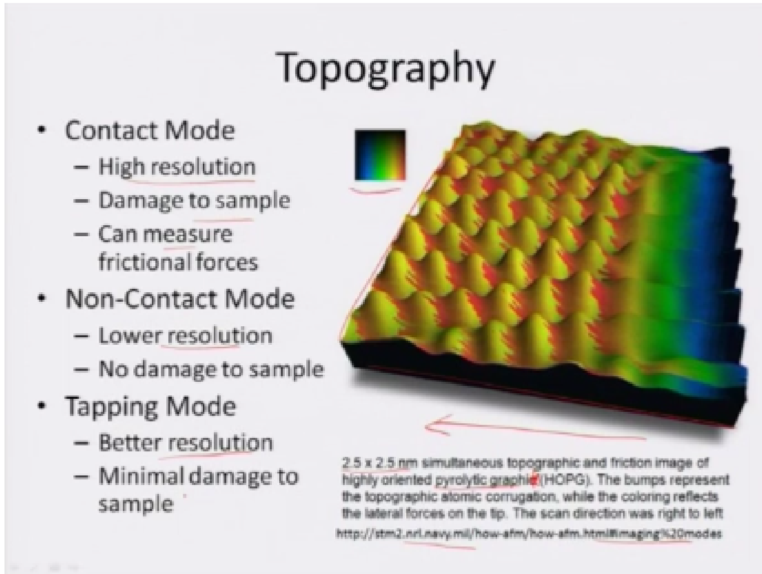

Right side of the topography image 2.5 nanometer distance of pyrolytic graphite okay, in fact you know the graphite is basically prepared for the pyrolytic graphite this is the graphite and bumps are represented Topographic atomic configuration okay these are the ones while coloring later force of the tip okay there is the coloring scheme these are the force varies and scan direction was right to left this is the way.

This is taken again from the laboratory of US they have obtained this images, so this can be used for the high resolution imagining for the contact mode actually will lead to very good resolution but it can damage and also measure basically friction also. A non conduct mode has low resolutions but no resistance taping mode as I said the tip can be tapped better solution but minimal damage to the sample surface.

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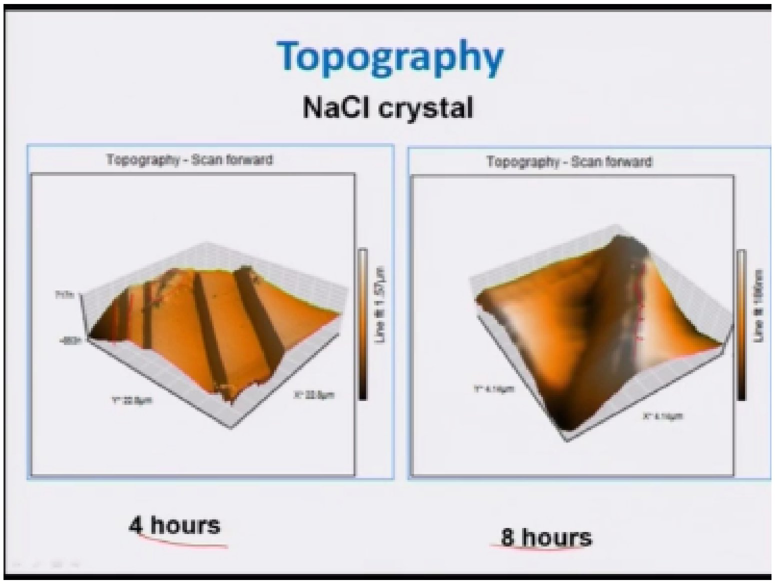

Again to show you some of the images which we taken for energy crystals which were basically to see the defect structure on the sample surface these are not to the atomic resolution images but it will really tell us the images on the sample surface okay. so as you here this is the initially NCl sample with the clear steps which can be seen on the topographic plot if you deform it by 4 hours and 8 hours.

In 4 hours you see the steps created and the sample surface damages are done in 8 hours even the steps are matched final and you can see this scan of small sample surfaces.

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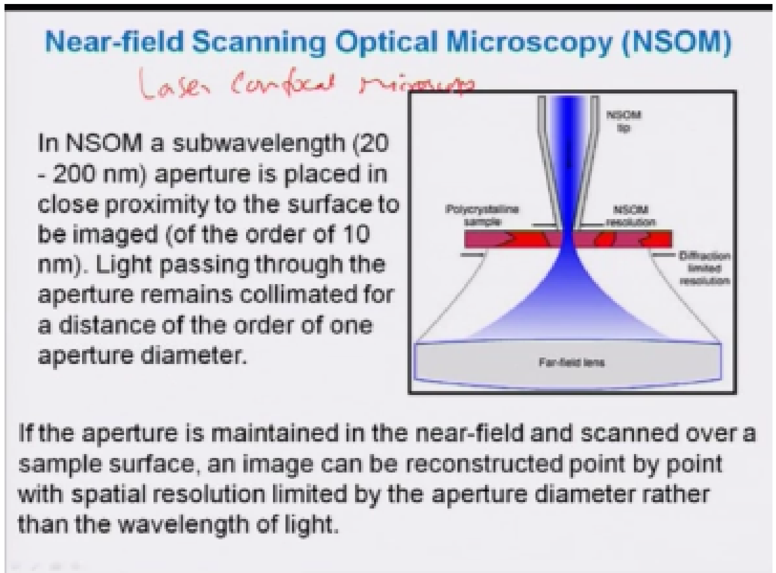

Important one laser co focal microscopic but let me tell you the basic principle first all of you know that in optical microscope the resolution is basically governed by the wavelength. And as you know the resolution is 300 nanometers and it is very difficult to go down because the optical microscope uses this as light, normal light. And not only that we can scan the surfaces, we can look at the internal surfaces of medical or biological research one can image the inside structure vein by using this microscopes.

I will show you some example how it can be used or there are lot of potential for this technique to be used for the material and applications. This technique are actually is called NSOM near filed scanning optical microscope is we use a sub wavelength aperture. Normally as I told or even in the other microscopic techniques that scanning also use apertures and aperture is nothing but the plate in which a small hole is present and it can be used to select the particular beam in a transmission electron microscope in this case you uses a slab wavelength aperture and this is about 200

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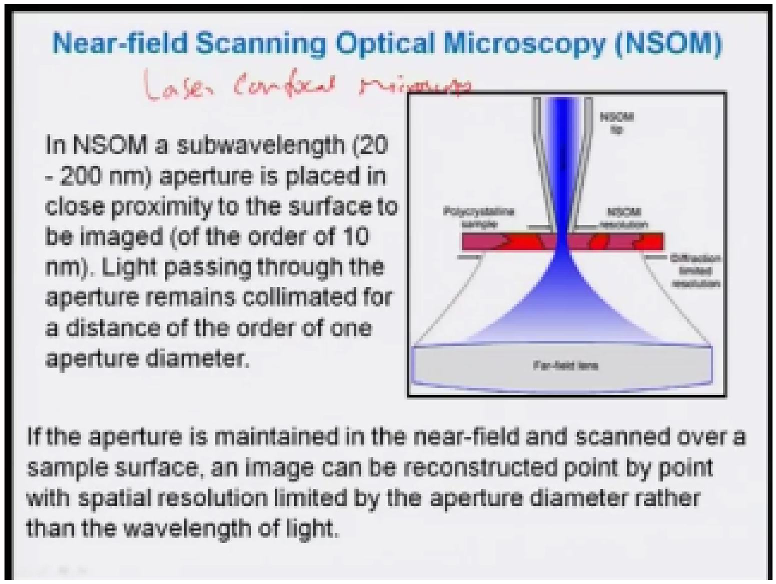

To 20 nanometers is the diameter and this can be placed very close to the sample surface that is the actually challenge actually it can be placed very close means 10 nanometer like 10, 20 nanometers and then if we allow the light to pass through this aperture light passing through the aperture will remain collimated.

Because it is very small size for the distance of the order of one at aperture diameter is of the order of 10 to 200 nanometers and the aperture diameter is minted in the near field position and then it is scan of surface so image can be replaced by point to point with the spatial resolution limited by the aperture not by the wavelength of the light because the aperture is smaller than the wavelength of the light here aperture normally in the light of the microscope optical microscope wavelength of the light is couple of 100 nanometers that is 300 to 400 nanometers.

But here aperture is less than size of that so if you keep the aperture in the near field is here that is very near to close to the samples surface the actually resolution of this microscope independent aperture size not on the wavelength that is how we bet the resolution determined by the law wavelength of the light so this has increased this are the lead to the rapid change of the you know study of the different kind of the material by using the optimal microscope just by using an near field aperture.

I hope this is clear from this picture. So why this here you actually have a tap aperture as you see here which is kept closed to the sample surface and then this is a polyester sample obviously and you pass a light beam to that and then this aperture can be actually scanned over the sample surface and if you scan the aperture light beam will also scanning on the sample surface and then this is the constricted image which is deflected limited resolution image basically and this can be obtained in a far filled lens and then plotted nowadays all is done digitally obviously because one can use more construct the image using computers.

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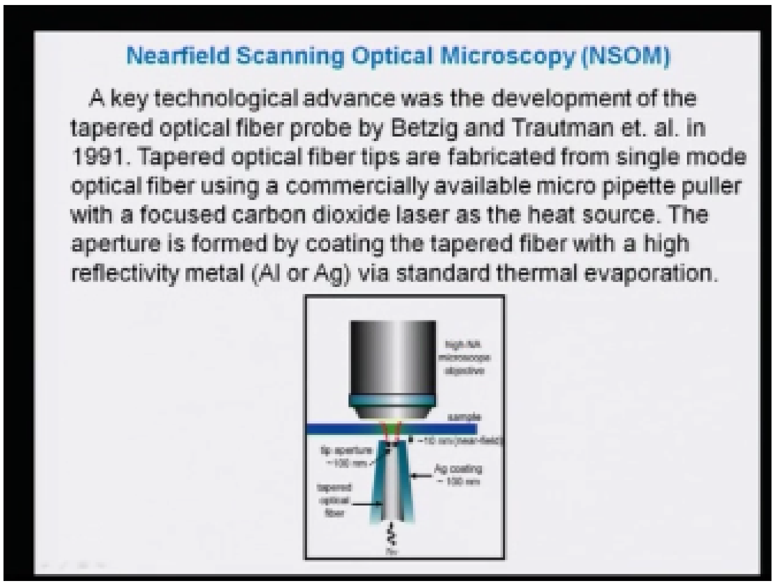

This has been possible because of one major discovery so as you see here in the earlier picture this tip of the tapper of the tip of the new the tip of the NSM is basically what is detect resolution so this was done by developed by tapper optical fiber probe was developed by Betzig and Trautman in 1991 and Tapered optical fibers are fabricated from single mode optical fiber using commercially available micro pipette puller with a focused carbon dioxide laser as the heat source.

These aperture is found by coating the tapered fiber with a high reflectivity material that is aluminum or silver while standard thermal evaporation so you can see there actually this is the educated on a tapper optical fiber and the edge actually increases reflectivity should be very high because using optical light and then this is actually high numerical aperture optimal microscope objective so this is detected whatever is after this light beam passes through the samples of this.

And that is what is done in a linear fill optical microscope of instead of a light one can lesser beam as you can understand there are optical lasers have lesser beam which come under optical wavelengths and that can used that is why it is called lesser configure microscopic and because aperture is near field that is why called focal.

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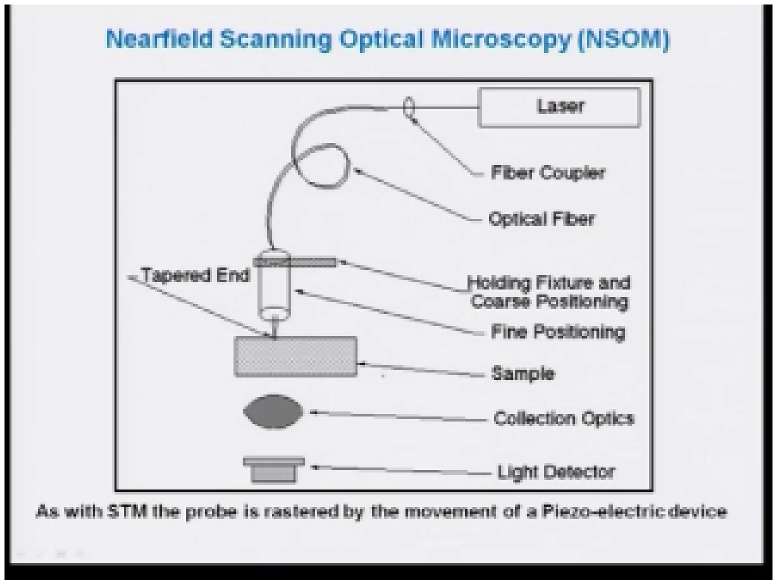

And this is how this is done really there is a lesser beam which comes a fiber optics and then this is the real aperture which is tapered one sample and the collection of thick and as you test probe is this also is rather using a piezo electric device this is means this probe is nothing but tapper optical fiber that is lasted using piezo electric device moment is to be controlled very.

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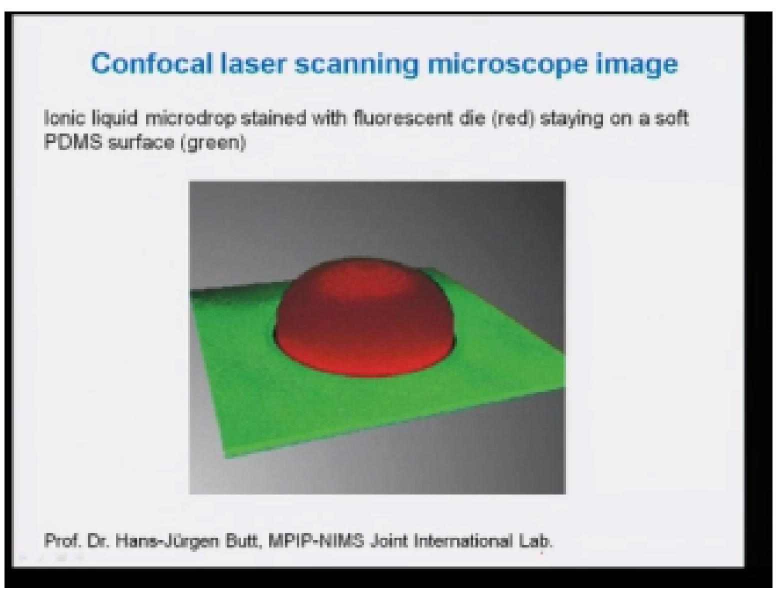

To give a some idea how it can be used this are all taken from different literature this is again from professor Dr.Hans Jurgen but from the MPIP this is institute NIMS joint international lab this is basically ironing liquid micro drop strain with fusion die red color staying on them soft PDMS surface which is green color we can clearly see the clarity of the image and when one can see the tampered nature hair of these of the liquid drop that is actually increases our capability to image event small liquid drops personally surface or many material.

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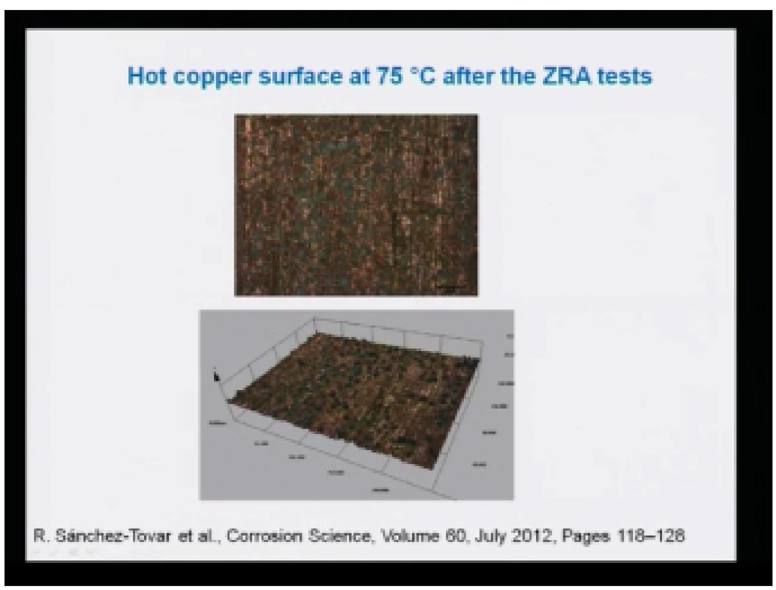

Another example of this is corrosion surface which is very new established just few months back by Sanchez Tovar at al at corrosion science and as you see is that this is actually copper surface at 75 degrees after the certain kind of corrosion called ZRA and you can see in fact that the corroded resumes and samples are base the black color regions are the samples of best this is an optimal microscope image using conformal microscope.

It is known as scanning of microscopic so the clarity and this actually micron distance is 40, 56 and this is the large scale and the resolution is much better than the normal optical microscopic image so one can actually probe this kind of effects and as I said in the lecture that the dew new application are coming into pictures as people started learning this techniques so one can use it more and more

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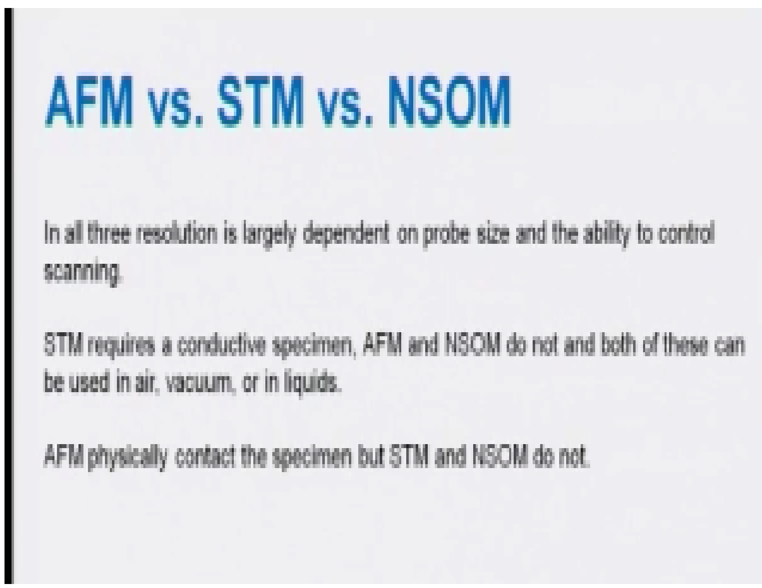

To compare this three define techniques AFM, STM and the NSOM I like to tell you three things in all this three techniques resolution is largely dependent on probe size okay that is tip size and in case of AFM, STM the tip size in case of NSOM this is the aperture size STM requires a contact specimen AFM does not require and both of this can be used in the air vacuum or in liquids but STM needs to be used only in the vacuum AFM physically contact the specimen by contact more but STM and NSOM does not so AFM in the contact mode can damage the specimen surface but STM in the same long.

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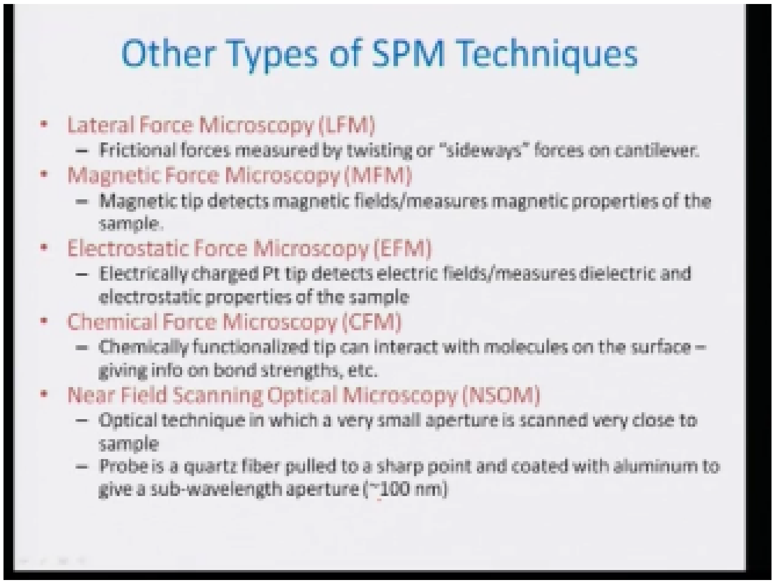

Well there are many other techniques in this world has come up also I will just try to tell you several once but I will not discuss each of this techniques first one is lateral force microscopy is called LFM in this case frictional force can be measured by twisting or sideways forces on the cantilever again in basically type of AFM you can also magnetic force microscopy MFM and this is again popular for the magnetic material if the tip is magnetic it detects.

The magnetic fields or whether the magnetic properties are sample or we can also have electrostatic force microscopy is called EFM in which electrically charge PT tip the platinum tip detects the relative fields or measure the dielectric and the electrostatic properties of samples in fact people can do chemical force microscopy also the chemically functioned tip in FM can interact to the molecules surface giving information about the bond stems.

And I have just discussed about the near field optical microscopy I discussed about all the technique lesser configure there are many other several level so in this technique also prove technique you know it is small aperture are scanned way to sample and through this quartz fiber a major discovery I made in 1991 pulled to SR point and coated to the aluminum or silver to give us sub wavelength aperture and there are many such interesting application of each technique level which one can actually get from literature.

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