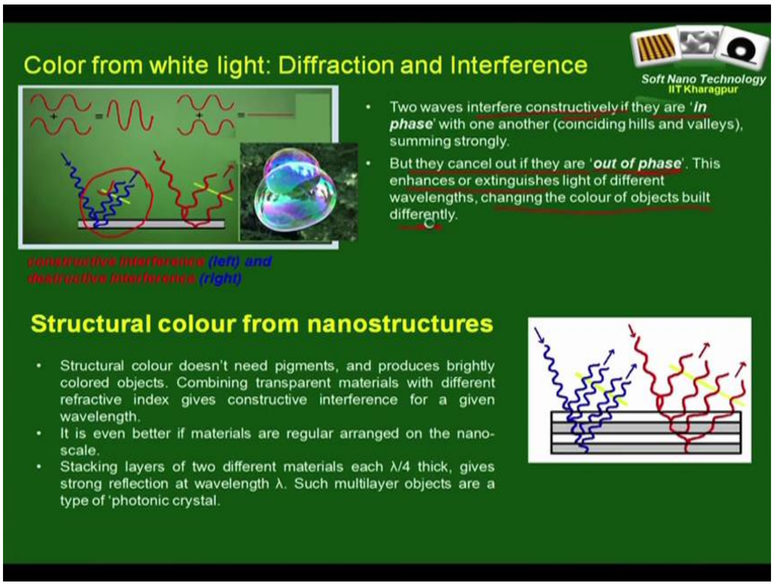
Soft Nano Technology

Prof. Rabibrata Mukherjee
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 03
Introduction – 3

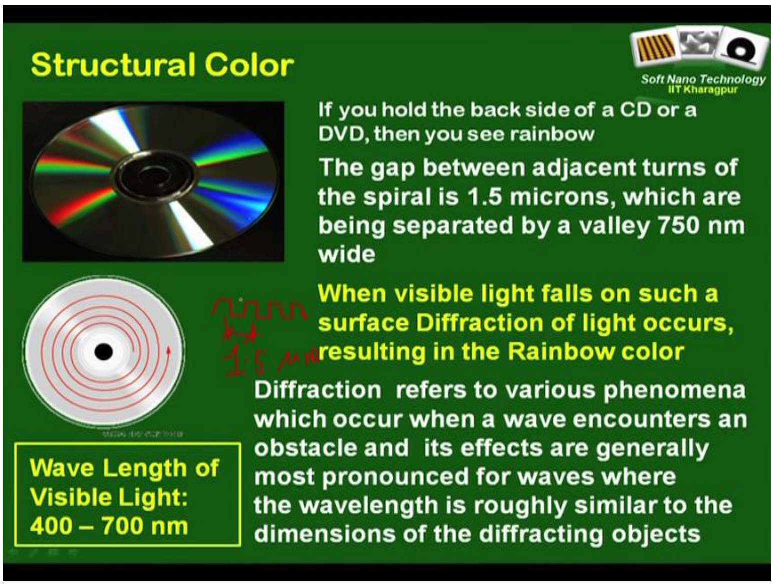
Welcome back to the 3rd Lecture. This is a last 1 on the Introduction and we will move on to topic.

(Refer Slide Time: 00:25)



I just briefly touched about the structural color in the time moments of the previous lecture. You can sort of have quick glimpse of what it is. So, they can either couple up in phase. They can interfere constructively this is the constructive interference in the in phase as you can see here. This in fact enhances the brightness or but they cancel out if they sort of interfere in out of phase. So, this sort of a enhances or extinguishes light of different wave 0lengths and changing the color of the object.

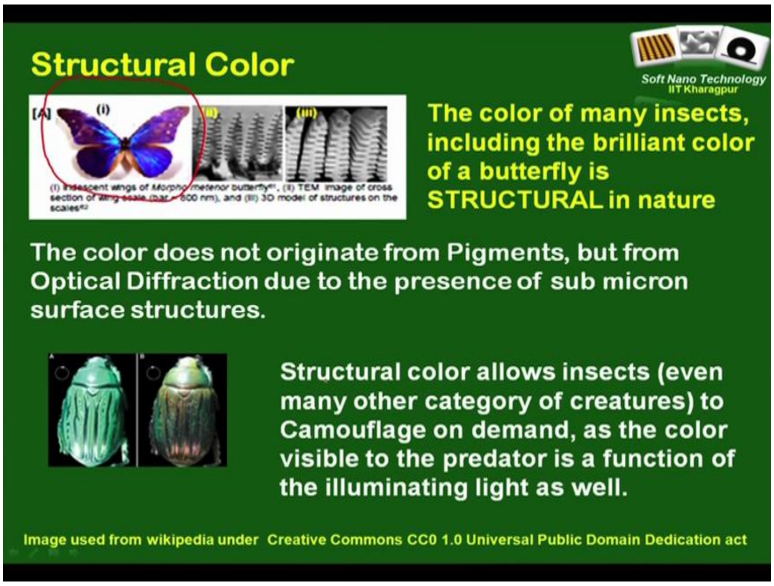
(Refer Slide Time: 01:11)



Now, a compact disk in fact has some structures which are track where the data is stored and it turns out and show you fm picture later. It turns out that the track width over here is of the order of 1.5 micron the track periodicity. The track width is about 750 nanometers; the wave length of visible light is about 400 to 700 nanometer. So, if you sort of tilt a compact disk what happens is the theory is a destructive interference or diffraction and you see again more color. Where it is the structural color is not limited to compact disks or there are whole lot of example of structural color in the animal kingdom.

For example the beautiful color of butterfly is of an attributed to a combination of pigments and structures. There are some butterflies which sort of blue at night and then it is, but primarily because of these type of structures and these type of color does not originate from pigments, but they form due to diffraction and presence of microns strikers size structures as we have already told.

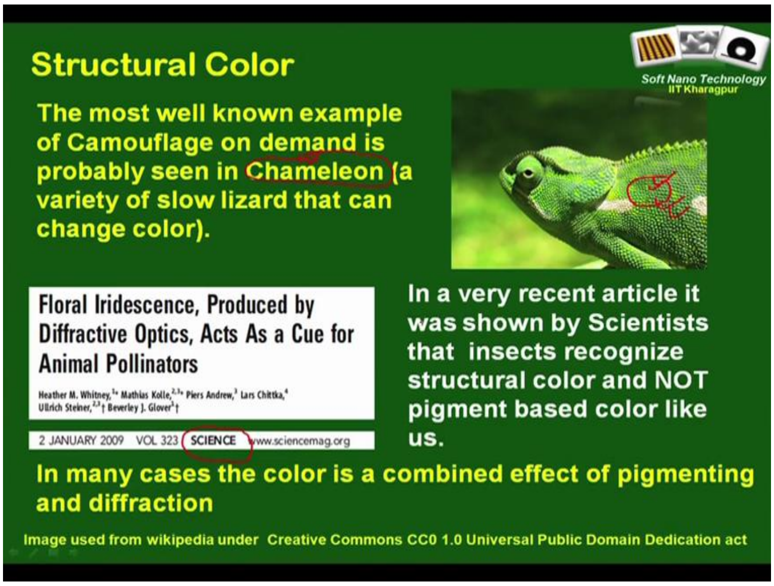
(Refer Slide Time: 02:00)



Again as I have told that in the animal kingdom or in the lower state of the life, many functionalities are attributed either in clocking so that you are not sort of a danger, you can hide from somebody if you is trying to eat you up or attack you or you can also hide in a h when you want to attack somebody and the structural color allows in 6, even many other category of creatures to camouflage on demand, as the color visible to the predator is a function of the illuminating light as well.

There is in fact a very fascinating lot of very fascinating research that goes on about the color in the in the animal kingdom and one quick example. I will pick is sort of a fantasy in many of us had as a child as children is can a chameleon actually change it is color and it is turns out that to a certain extent may not be all possible colors because a chameleon might be either staying close to bush or plants or leaves or may be close to the ground which is grey or dusty.

(Refer Slide Time: 03:08)



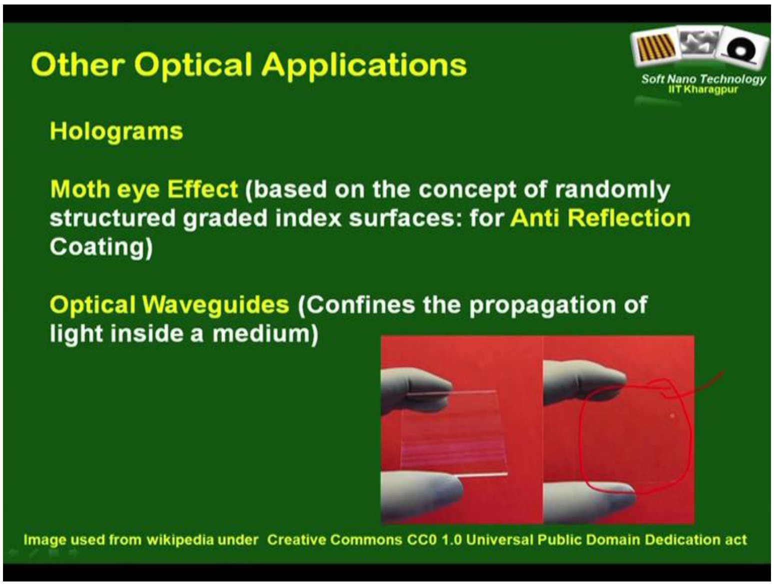
Within these 2 shades of color it in fact, can change it is color to a limited extent and what it can do as, you can see from this picture it has certain surface structures. So, depending on the excitement on the ambience they can sort of a erect from years or may be make this structures differ and as a consequence of that the interference changes and indeed they can partially change colors. There was another very interesting study about ten years back from a group of researchers in a Cambridge university and that in fact told that in 6 and many of us know studies in our school days biological science that insects have compound eye.

It was earlier believed that compound eye give in 6 roughly a 360 degree vision wide vision again. So, that they can see who is trying to attack them or they can identify if there is something which they can eat up. But there is something more to that. In fact, insect eyes double up as microscopes because it was shown in this landmark 2007 science paper by a group of researchers in a Cambridge university, that insects actually identify some structural color. They actually identify the structures. So, our perception of vision is like we identify something that is blue if it is appearing as blue, but because structure like a compact this will see only the rainbow colors, but insects it turns out actually can identify structures.

The experiments that was done in a very quick nut shell certain insects were trained to migrate to a particular variety of flower which has a red color and these structures on this flower were elute or replicated in some other material in something that you are going to learn in this course how to replicate these structures and then that replicated structures. Insects where seem migrated to the replicated structure because a structures on those flowers were identical to that it flower and most interestingly when this replicated structures were illuminated with some other color the insects were still found to migrate with them.

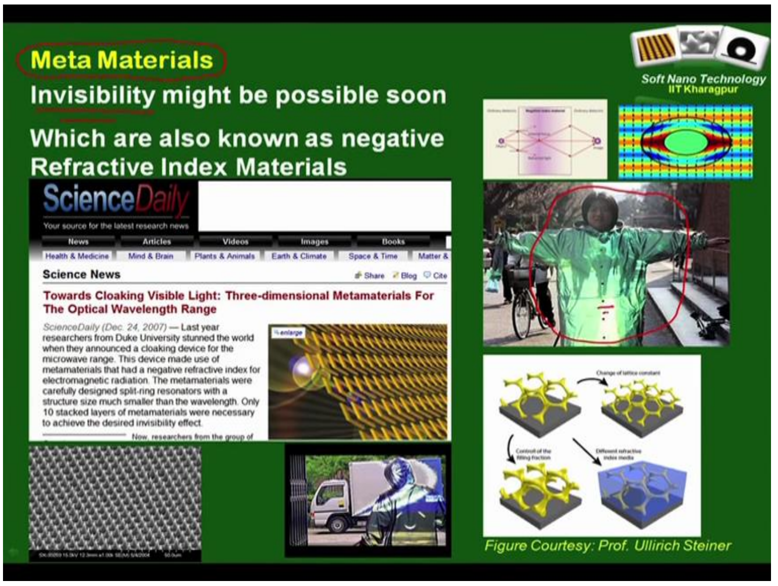
It is clearly shows that whether the structures, it clearly shows that it. In fact, is the structure that matters to them and not whether the object is illuminated to blue, red or green like the way you typically identify color?

(Refer Slide Time: 06:06)



There are many other applications. So, like holograms moth eye effect or anti reflection surfaces for example, you can see there is a glass quoted with anti reflections surface, you do not see the reflection of the tube light in your room, they actually have some nano and micro scale structures waveguides, but this anti reflections surface probably I will spend some time on making some of them because we make them routine in our lab any things like that.

(Refer Slide Time: 06:30)

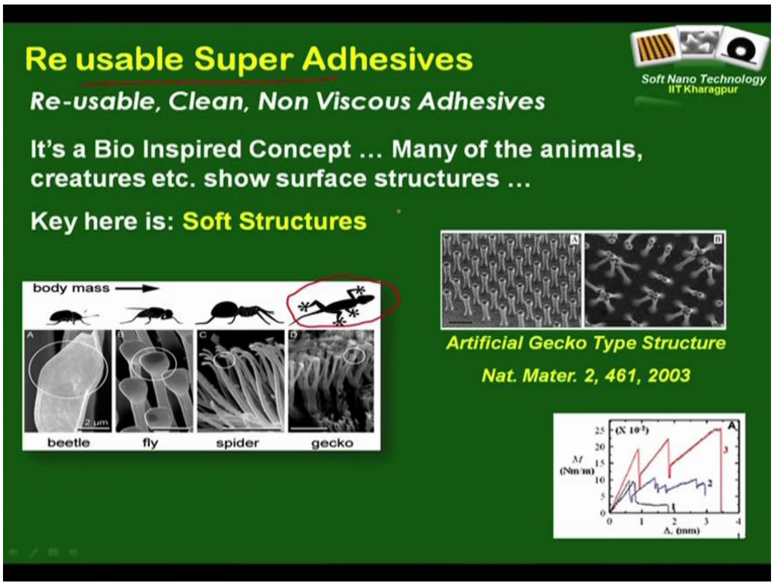


There is another very fascinating application that is a research is still going on, it is not fully realized, but it is a good key word for all of you to learn at this stage is the so called Meta materials. I do not know how many of you know about this meta materials or they are also called the Negative Refractive Index Material, but if they are realized they are artificial materials, you do not see these type of meta material signature, but if they are realized that will in fact lead to invisibility or cloaking that is exactly what it is. So, you can look into this image, which I have downloaded, but it is a bit controversial. So, people say is a mort image or whatever. So this might not be very far away possibility that, you can in fact come up with Meta material, which makes cloaking or invisibility possible.

In fact, the latest state of art in Meta material is that looking in the microwave wave lengths has already been achieved with some structures, specific structures, but when one goes down to the optical wave length there are certain scaling issues and the classical approach is failing. So one the latest development that is taking from Prof. Ullirich Steiner lab in Switzerland is that they are using some block copolymers, a special type of a block copolymers, then they back fail it with it metal and things like that which is very close to achieving this desired property and this block copolymers has in one of the introductory slides we already pointed out that they are in fact related to this internally structure nano structure materials.

Now you see that I think I have given a few examples, which sort of convinces you that there are many cases where a it is possible to sort of have a extraordinary properties arising out of nano structures present on let say the surface of a material right. So, we will look into one of them in somewhat detail and that is this effect of Hydrophobicity because that is also very important for our other understandings.

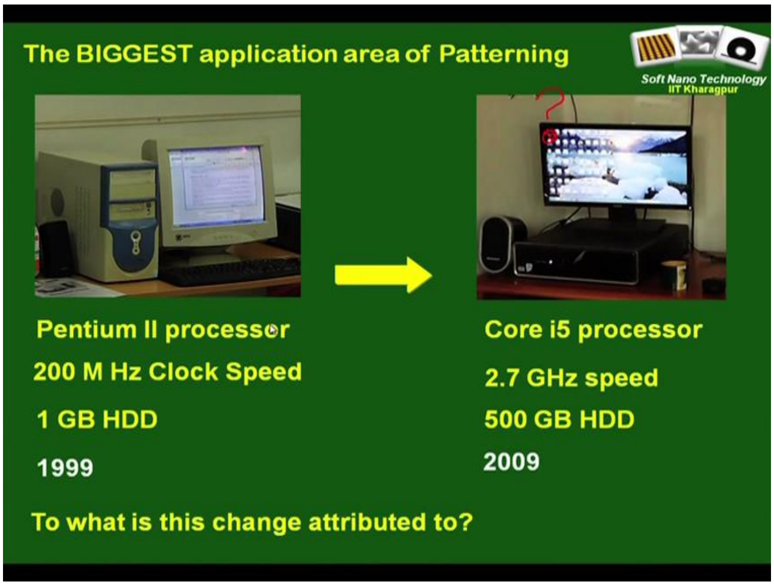
(Refer Slide Time: 08:50)



That is something we will learned and there are other examples also for example, re usable super adhesives, which is known as the Gecko effect because a house lizard or Gecko can sort of defy the gravity and climb along the wall which you cannot. So, their legs have super adhesive property, but there is something more. This super adhesives is they can also detached very easily because if you really stick something with a very high quality glue like fevi quick you yourself need a lot energy to detach this fingers. But this small animal does not have it is metabolism own sustain or give provide him to so much energy to detach.

Not only their pad legs or feet come with super adhesive pads, but there are capabilities that allow them to detached very easily and they are clean, if you take a sellotape for example, and stick it on to a surface well first time it will stick. If you peal it off from there try to stick it the second time it may stick, third time onwards it will definitely not stick. Why? Because some dust or something might have attached to it and it has spoiled, but this is not the case with let say these animals were they go on using their legs again and again. So, they are reusable clean super adhesive with easy detachment and this is attribute to again with the presence of some structures on their feet.

(Refer Slide Time: 10:17)



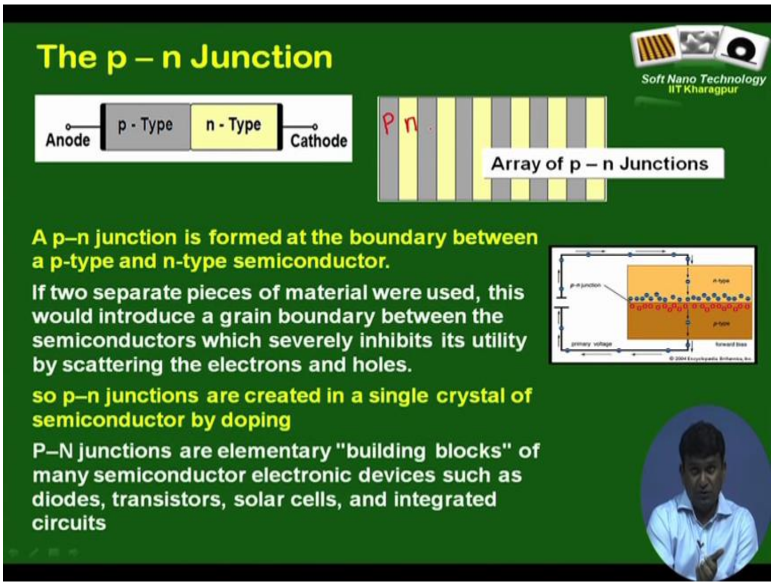
A whole lot of application in the biological world animal kingdom everywhere, but if I ask you a question what is the biggest application area of patterning? Take a minute to guess, well I am sure all of you will agree to this transformation probably has kids at home even 15 years back you have seen stuff like this where as the Pentium 2 processor or something like that and now you have core i7 processors any things like that and this is also an old picture about 5, 6 years old picture.

(Refer Slide Time: 11:05)

What has led to this transformation, and this transformation this rapid faster processors higher capacity memories or storage devices. They are all attributed to nothing, but patterning technique and that is the application of patterning in micro electronics and the progress it is not an over statement that the progress in micro electronics is significantly attributed to progress in a patterning technique which is known as photolithography. Why it is so? Because as we all know that these are semi conductor devices.

You have what is a semi conductor? It is essentially a junction between p type and n type material of it is silicone dope with p and n, but one particular junction p n junction is not going to serve the purpose of a high speed computers.

(Refer Slide Time: 11:28)

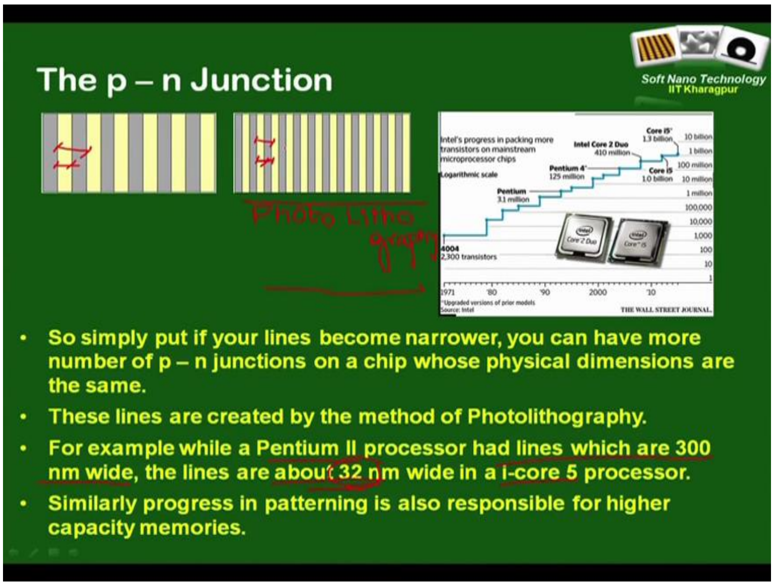


What you need to do? You need to have arrays of this p-n junction's right and as you have a larger number of these junctions, of course the processor speed sort of shoots. So, at heart of a computer processor you have these p-n junctions right o they are all silicone, but you have areas which are p type dope and areas which are n type drop. That is something that we will not go, we will just learn how the system works, but we will not go into all the details, but they are they are sort of seamless it is on the same block because if you bringing blocks of p type drop material and n type drop material and try to sort of stitch them together there is going to be a lot of loss at the interfaces and your performances will drop. These are the details that that are beyond the requirement of this course, but the then what we are going to talk you can understand very easily.

1 of the treats of enhancing the processor speed, of course would be to add more and more number of these p-n junctions, but as you go on increasing the number of these p n junctions your device size and everything goes up and that is not what you would like to achieve and that is not where the development is taking place because you see now you had 10 years or 15 years back you had big boxes as species and now you have almost everything in your cell phone or mobile or small size laptops were which perform as good as your regular office desktop.

How can it be done? Certainly it is a technological requirement to add own number of this p-n junctions, but certainly increase in size is against the general trend. So, if this is sort of an array of these p-n junctions, let say this grey array corresponds to p and this yellow array corresponds to n type domains. One way you can increase the number density of these junctions there by increasing the processor speed and not increase the size. If you can make this domain smaller and smaller and that is exactly what has been done right. And how this is done, is something that you are going to learn and this is in fact done by photolithography, and you can just Google with photolithography.

(Refer Slide Time: 14:01)



Photolithography is something that we will probably take up after 2 or 3 lectures may be a little later, this is what is known as Photolithography, but it is extremely important from the stand point of micro electronics industry and this is sort of a silicon electronics as it is called photolithography is the industry standard or the only technique for creating these semiconductors or these basic this p-n junctions, which are absolutely essential for making the computer chips or the processors.

For example the Pentium 2 processor had lines which were 300 nanometers wide right. So, let us say these are the domains and each of the domains is sort of 300 nanometers wide and this i5 core. In fact, the present state of that is some were around 20 or 16 to 20 nanometer i5 core has 32 nanometer wide lines. So, here the line width has gone down to 32 nanometers.

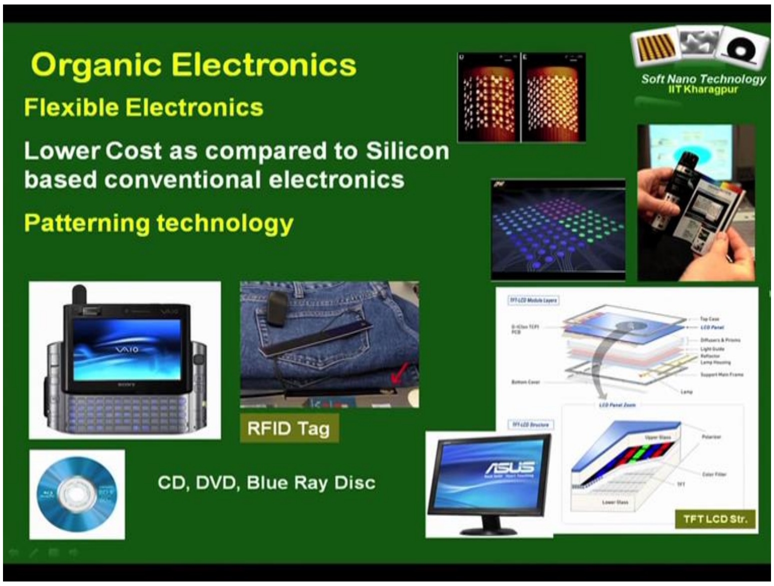
1 p-n junction let say in a older processor could have a taken a six hundred nanometer of space right because each one is about three hundred nanometer wide and now you can

understand this is thirty two. So, one two adjacent domains we will have a width of about 64 nanometer that is like roughly around 60 nanometer this is 600 nanometer. So, in place where there was only one p-n junction.

Now in fact, there are 10 number of p-n junctions backed in that same location. So now, you can see why the processor speeds up and these tremendous progress in micro electronics is something that is related to or it is attributed to entirely to nano patterning that is something that you are going to learn as a part of this course because if you remember the first lecture where I introduce to you into the contents photolithography is one of the major things, where we are going to spend at least four where 3 to 4 lectures or photolithography. So, that at least you learn the basic.

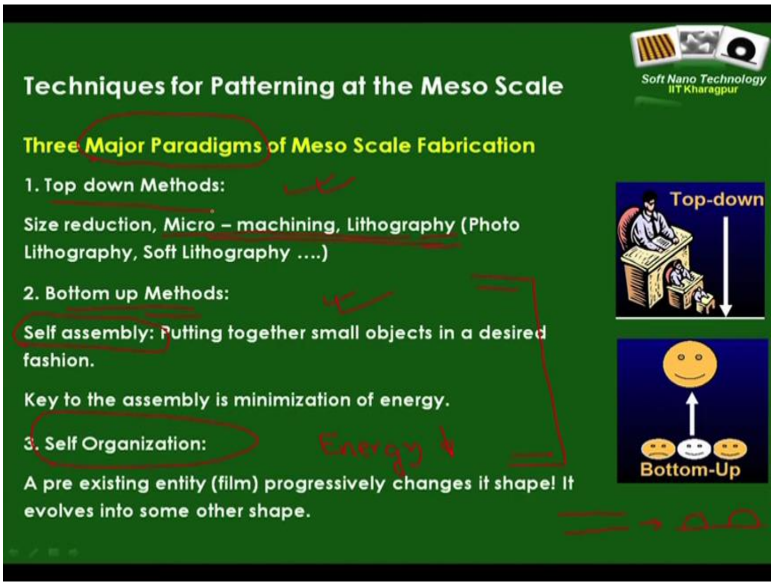
Almost similar those higher capacity memories are also attributed to something like that, but there are certain additional issues and therefore I will avoid a detailed description.

(Refer Slide Time: 16:55)



But classical micro electronics use as we all know it is silicon electronics, but with advancement of a technology you now have things like a flexible display and stuff like that. Silicon is a very rigid material. So, you cannot really have a big flexible electronics out of it therefore lot of emphasis is now also going on polymer electronics, polymer based electronics or plastic electronics for making things that are flexible. And they are also technologies; patterning technologies compatible to flexible objects or conformal with flexible devices are coming up. So, here also you can see that nano patterning plays a very important role.

(Refer Slide Time: 17:47)



Before moving on, I would just like to highlight one aspect of this so called nano fabrication and this is the slide we will revisit later again and what I would like to say is this is valid for any fabrication technique also even in the macro scale; that what are the major paradigms or major approaches in nano fabrication or meso scale fabrication. Now one of the approaches is can be like the top down approaches, top down approaches as you will find is that in micro or nano fabrication with the lithography based approaches are the top down approaches.

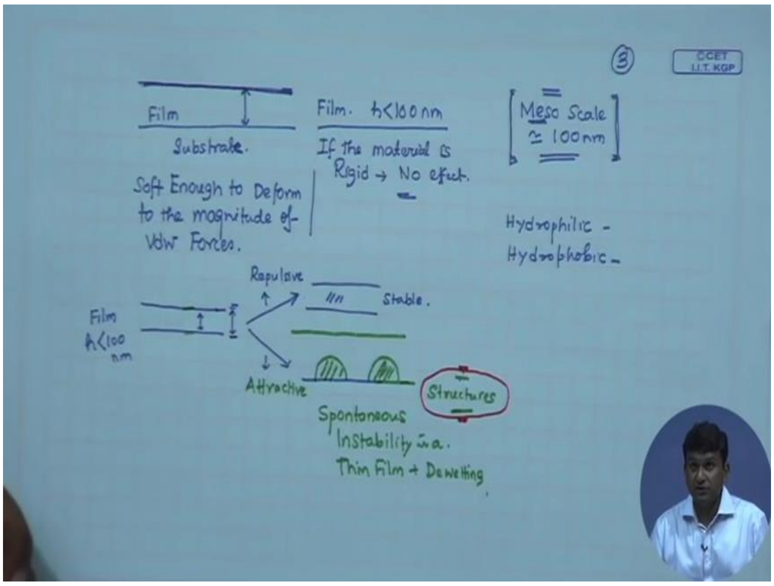
A better example of top down approach is let say curving out a cave in a mountain. So, you had a chunk of rock and you cut out things to achieve something desire the other approach can of course, be the bottom up approach where you start from individual building blocks. At the nano scale the individual building blocks can be even molecules and you sort of assemble them in a specific order to come up with something desire. Lego bricks or Lego blocks with which the children play or the way you build your home with bricks, they are all examples of bottom up fabrication technique right.

However there is a critical problem at the nano scale and that is whatever be the individual building blocks you do not have your hands at the nano scale or even a tweezers does not work. So, question becomes how do you assemble these individual blocks to achieve something desirable and it is in this contexts I will talk about surfactants, which show extraordinary self organization based on in fact wettability contrast and that something that is going to come up next.

The third approach. So, these are the 2 very well established approaches for the different approaches for nano fabrication and the top down and bottom up. As you are learning this particular course you should be aware of a third fabrication approach and that is becoming popular slowly is a very novel and recent concept and that is what is known as self organization and I have drawn a cartoon here, which should be assemble you something that we talk I think in the previous lecture and that is continuous in stability in a thin film.

If we can quickly recapitulate what is the thing we argued? We argued that if you take film which is thin, there is a possibility that there might be active interfacial Van Der Waals interaction between the 2 interfaces right and depending on the nature of these interaction, the film might remains the stable nothing happens to it which is stable or if one can now add more detail to it the net interaction between the two interfaces has to be repulsive. Why? If you understand it is fine; even if you do not understand, does not matter this is something you will do in a great detail; however, if the net interaction between the 2 interfaces is attractive, there is a possibility that the film might be sink it. In fact, what will happen is these two separate interfaces might merge. This is the fundamental physics of spontaneous instability in a thin film and dewetting.

(Refer Slide Time: 20:34)

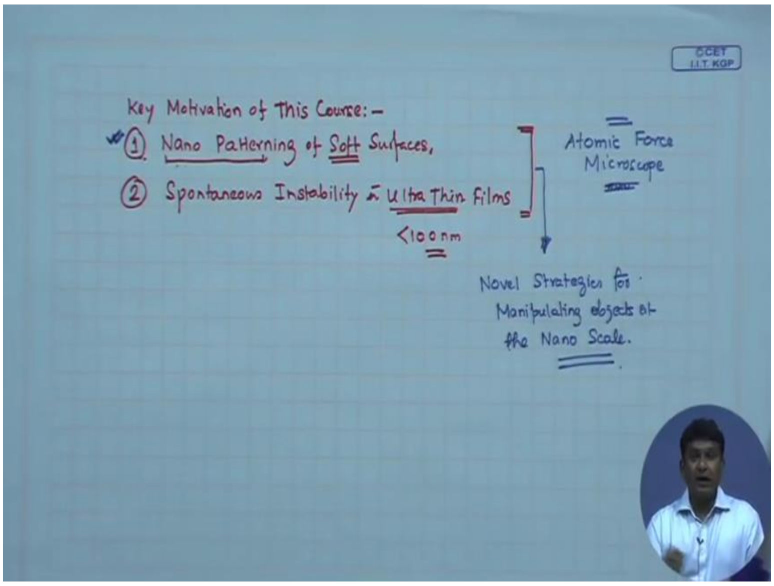


As I told in that cartoon that these leads to structures and these structures are often very small in lateral dimension, here is the new concept, new approach. Well if your thin film is unstable due to whatever reason, the reason for which you are going to learn, it is not a good it is not a good for the coating application it fails as a coating which is very bad news because in many applications you actually need coating and we also argued that you in fact often tend to enhance the thickness of the coating like you ask the painter to coat two layers of a paint.

So that you avoid this type of a possible catastrophic failure due to spontaneous instability right, but even if your film becomes unstable, that is also not a bad news because an unstable film as you can see is often leading to some sort of a nano structures and since we are already are good that at the nano scale we do not have hands or tools which is difficult to fabricate structures. So, this is this can be novel approach and in fact, this is what is known as a Self Organization, which is and as you will understand when I going to bit of detail. In fact, for both bottom up and top down approach sorry bottom up as well as self organization approaches, this bottom up approaches often refer to as a self assembly approaches. It is they are driven by a desire for energy minimization.

You all know that in from thermodynamics that a natural process always works towards energy minimization of course, in a top down approach you apply energy from outside to achieve your desire structures. So, with that I think we are quite comfortable now with the motivation of the course. We understand that nano patterns have phases whole lot of applications, it is responsible for certain properties which are not related to the bulk property of the material, but are related to the surface structures and therefore we also sort of understand the key motivation of this particular course we are going to look into 2 apparently different aspects and which are going to eventually towards the end of the course we will realize that they sort of seamlessly merge with each other.

(Refer Slide Time: 24:34)



1 of the aspects is nano patterning of soft surfaces. I emphasis this word Soft Surfaces because we will stick mostly to polymers any things like that and the second one is Spontaneous Instability in ultra thin films. So, where is nano here? This ultra thin is like less than 100 nanometer and these are sort of structures which are nano and the meso scale. So, these are sort of the 2 key things, which to start with there were look slightly decoupled to you which we will focus on.

In fact this is easier. So, we will start up with this one after we will done up with certain basic concepts and then we also need in fact in the both the cases we will be needing the atomic force microscope because you may feel, that you have made some nano patterns, but it is extremely important for you to see how the patterns actually look and that is where your AFM will help you significantly, but you will yourself see towards the end how beautifully these 2 things merge seamlessly in some sort of a coming up, particularly with what we just discussed in self organized nano fabrication techniques or in other words they merge to come up or lead to know novel strategies for manipulating objects at the nano scale.

With that I will stop here this lecture. This lecture I will stop here and we start off with some Fundamental Aspects Related to Surface and Interfaces in the next lecture.

Thank You.