Electronic Packaging and Manufacturing
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Lecture - 02
Introduction- II

Welcome back and we are going to continue our discussion on the Introduction section or the Introduction module on our course on Electronic Packaging and Manufacturing. So, we are in lecture number 2 today and if you recall last time we were discussing the electronic module or sorry the introduction module and what you see here is these were the different concepts or topics that we are going to be covered.

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So, what we have done is we were primarily still on the first one. This is more or less done and what we will now do is move on to the next topic which is the crux of this electronic of this introduction module is what is it that ok. What is electronic packaging?

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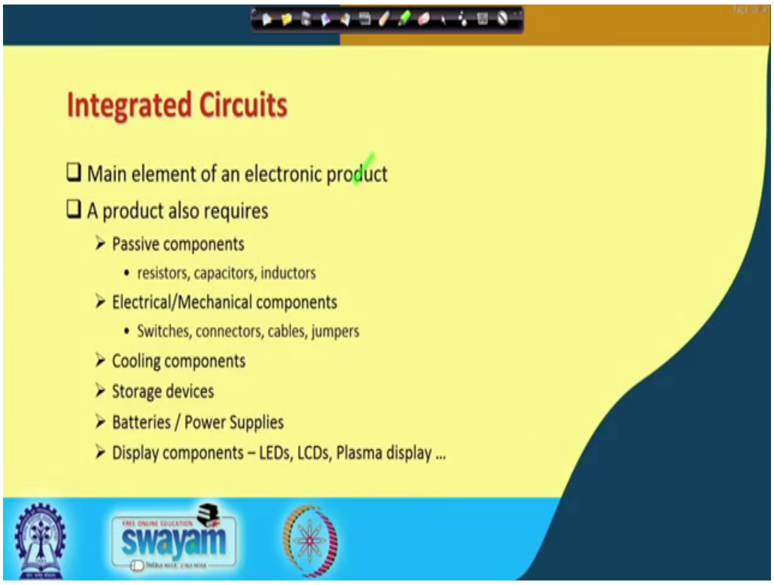

So, this is where we were before right and we were talking about the integrated circuit in the last lecture. Now, if you look at this, this is what we discussed and we say that electronic product apart from the VLSI chip or the integrate the microchip with the integrated circuits, it also has a lot of other components. All of which needs to come together to form the final product for end use right and this makes a (Refer Time: 01:44) to our discussion on electronic packaging ok. What is electronic packaging? So, this is a question that people ask ok. And one of the things that from the word packaging that we know we say that what is the electronic packaging.

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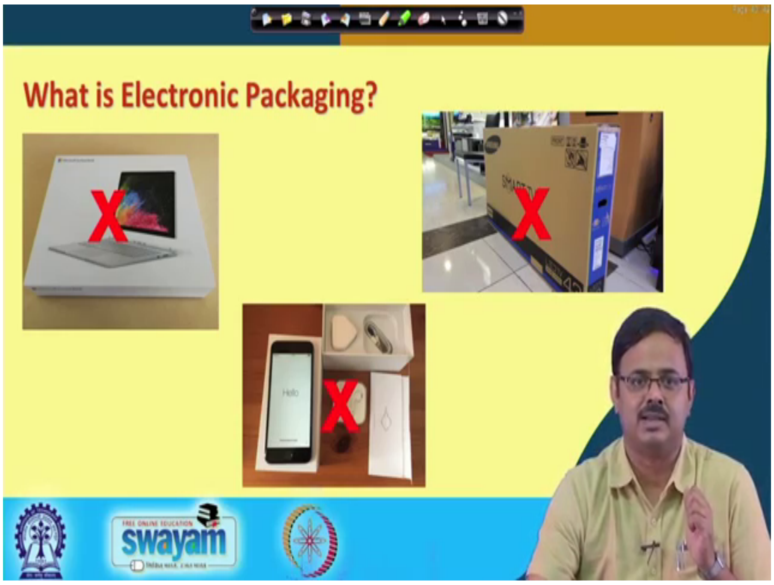

Is it one of these? Ok, at this the cardboard boxes in which electronic product has to go? So, that it can be shift safely from one place to another or can be stored safely. So, here we are saying all these ok. Is this what electronic packaging means, because what the word packaging can be a little confusing ok.

Now, the answer is of course, no and that is what I am showing here that no, the answer is not this. This is not electronic packaging ok. This way electronic packing it is a packing materials. It is important, but that is why when we talk about electronic packaging this is not what we mean ok. Then what is the electronic packaging?

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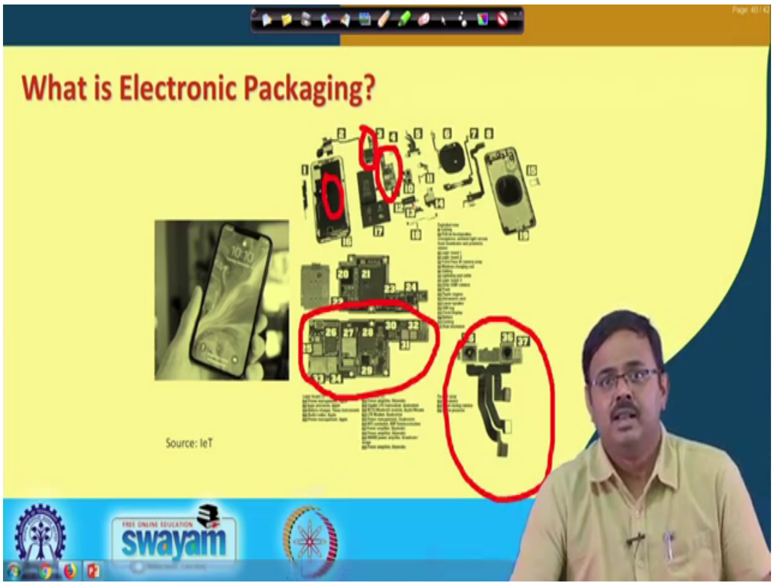

If you look at this picture and I would say this is electronic packaging and then you would ask me what. What is this? You are showing me the different components inside a certain electronic product and my answer to that, yes, exactly that is my point friends, my friends. This is exactly what I am talking about when I say when I when I use the word electronic packaging ok.

Still confused let us see. I am showing a nice mobile smartphone on the left hand side and then inside you see that these are the different components that goes into it, starting with the casing over here which you see, this is the casing, right. There is a battery there is cables and connectors this is the main motherboard with the different components on it ok. Then you have all these several separate small cards and boards dotted cards and dotted boards here ok you have a display. So, all these go into forming the smartphone that we see here.

So, in order to make the smartphone function as per our expectations, number one all of these components need to perform their individual functions number 1. Number 2, they need to perform their functions in perfect harmony which with each other, right. All of these functions have to happen in perfect coordination which means that each of these components and again thinking about our smart phone the main CPU that goes inside the graphics chip, the graphics device the memory the wireless chip or the wireless the controller all of the display all of these have to work in perfect harmony, right. I mean they cannot just be performing their own functions in isolation. So, which means there has to be perfect communication through exchange of signals between these various components inside ok.

So, connection, the different devices talking to each other through what we will learn later as interconnect technologies that is that forms an essential what should I say essential that is an essential requirement of a good electronic product. Along with that you would have a display, you have a casing, etcetera which protects this you know this device from external factors and ensures that it performs reliably over it is lifespan, ok. So, electronic packaging is where this all this come together ok. Electronic packaging comes into picture, it is the science and a bit of art which converts this microchip the individual micro devices which bring them together on a common platform and gives it the shape of an usable product ok. So, electronic packaging entails all of these ok so, again let us try again to define what is electronics packaging.

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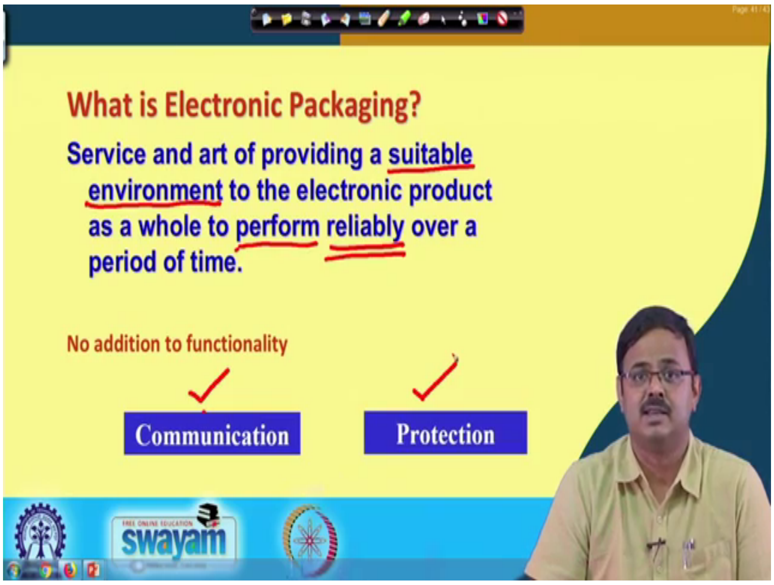

So, what is electronic packaging if I try to define, I am stating as it is a service and art of providing a suitable environment to the electronic product as a whole to perform reliably over a period of time. And that period of time is the individual expected lifespan of that product. So, what do I mean by that? And let us look at each of this term providing a suitable environment where and when I talk about suitable environment is within the product ok. It is within the product maintaining the conditions such that they perform each of them perform as per their expectations, which means they are able to talk and communicate with each other ok. They are able to exchange signals and the integrity of those signals is maintained signal integrity. The power is delivered at the right place at the right point of time from the power generating device. And perform reliably, very very important.

It is not enough for your smartphone or for your laptop to perform well today when I start using it. It should perform with the same effectiveness and efficiency and reliability 3 years from now when I am still using it. The de performance should not degrade with time or degrade as minimally as possible with time, ok. So, that is the reliable performance over it is lifespan ok. That is what I am talking about. And electronic packaging if it is not packaged properly then we are not going to ensure ok

So, electronic packaging does not add any functionality to the device ok, the functionalities are defined by the microarchitecture of the individual components that goes into your product. The CPU has it is own function, the function it is defined by the architecture the integrated circuits that goes into it same for memory, same for graphics, but ensuring that they perform as per the expected as per the expectations they perform as per the requirements at that point of time, that is what and in perfect harmony with each other that is where packaging comes into picture ok.

So, is this communication which is what I am trying to say here? It is communication between the different components in a product, packaging plays a big role in that and protection from extraneous factors, protection against from harsh environments or adverse environments to in it is operation. Protection from shocks and vibrations, protection from a water splash, protection from overheating, so these are the two, I mean if you think about it these are the two main contributions of electronics packaging. And these are both extremely important and the crux of converting a micro architecture or micro or a series or a series of microchips with their individual may be excellent micro-architectures converting them bringing them together and converting that into a system or a platform and finally, into an usable product that we use today, that is electronic packaging.

So, now think about it what does it mean, what does it entail? It entails that we use the right communication and exchange of signals. If you think of the motherboard with several layers of wiring traces inside that is all packaging and you need expertise from electrical engineering and electronics engineering to perform that ok.

You think of the motherboard again, what should be the material? If our 4 5 retardant motherboards, there are ceramic boards and packages and that is where we will go to material scientists ok. We have to ensure that that during it is operation the components are cooled adequately so that the temperature at the devices does not exceed their maximum allowable limit. And why just devices and components, just the product itself when I am holding a cell phone making a call like this, when I am holding the cell phone it should not be so hot that I cannot touch. So, I have to maintain that I am ensure that the temperature is maintained, not just at the component level but at the product level as well. So, who do I call upon for that? The thermal engineer.

I also have to ensure that if my laptop just falls on the floor there is minimal damage to that ok. So, what do I where do I need that? We, I need the mechanical engineer, the applied mechanics engineer, to do the kind of analysis the shock and vibration and the stresses and the deformation that it goes through. Even otherwise when I switching it on and off there are this, this whole system has different materials which are undergo expansion and contraction leading to stresses and strain in the product, you need an in depth knowledge of solid mechanics to characterize and to analyze and design such a product ok.

Other then that the corrosion in a moist environment in a hot and harsh environment do this products corrode, what should be the composition of the solder that goes into the into forming this various interconnects again material scientists and chemical engineers. So, electronic packaging the friends the message I am trying to say it is a very broad field, it is a truly multidisciplinary field requiring expertise from various domains ok. And that is a part of that that we are going to appreciate as we go through this course ok.

And there is one domain that I did not mention which is part of our course title which is manufacturing how do I make all these? How do I have all these tiny tiny transistors on a piece of silicon which is 1 centimeter by 1 centimeter, millions of transistors going into it? What are the techniques? What are the micro fabrication techniques? How do I make this interconnects? How do I manufacture a motherboard? The manufacturing is again the fab the fabrication and manufacturing a very very important part of the electronics industry ok.

So, electronic packaging, electronic manufacturing packaging they are all very interrelated with each other packaging design manufacturing and this is all the system level ok. Also the component level I should say. So, these are the technologies that meet that convert a microchip to an usable product. Just like the human body just having the brain is not enough, yes the brain; brain is like the CPU of a computer, but then the human body also needs a cardiovascular system, a nervous system, the muscles, the bones, the joints and the sensory organs, to process the signals that we that to accept and process the signals. So, same case if you think of an electronic product it also needs all these it is own systems and devices to ensure that it functions in a perfect manner, ok, all right.

So, that electronic packaging it is not about packing an electronic product into cardboard boxes it is much more than that. It is about bringing the different components together and making them perform as per our expectations and perform reliably by protecting them from degradation while it operates in hot in adverse conditions and environments clear ok. So, with that let us move on now to a little more and see what we are talking about here ok.

Let us move on to the next slide and let us see what electronic packaging means. So, this is from book by Professor Rao Tummala again microelectronics packaging. And here you see what I was talking about.

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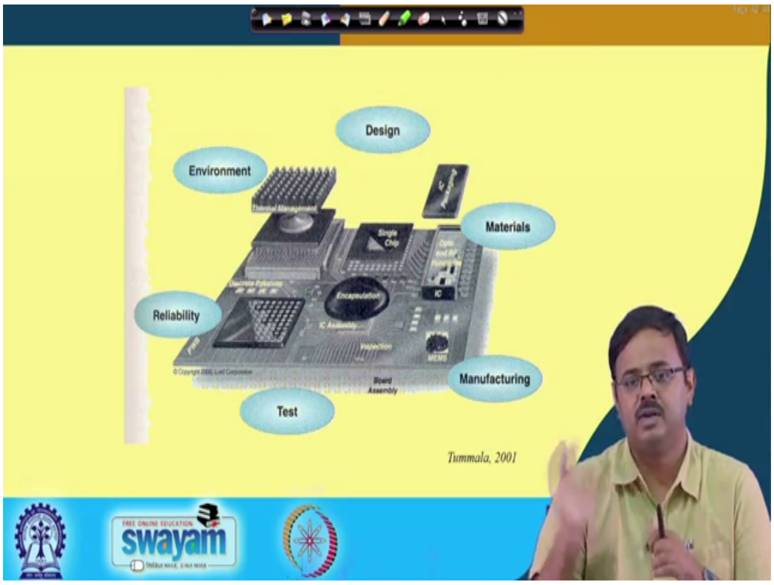

Reliability, if you look at the different components this kind of is a snapshot of the various domains and disciplines that goes into electronic packaging ok. Right over here you see thermal management ok passives, the PWB which is a printed wiring board, the IC assembly, encapsulation we are going to talk about that ok. They are plastic encapsulated chips, a single chip, there is IC packaging ok. So, all these things the board assembly, the materials, design environment reliability, manufacturing these are all part of electronic packaging, the broad field of electronic packaging, many a times also for electronic packaging and manufacturing which is what the title of our course is ok.

So, the truly multidisciplinary nature of electronic packaging probably is best captured in this slide or in this figure from Professor Tummala's book ok.

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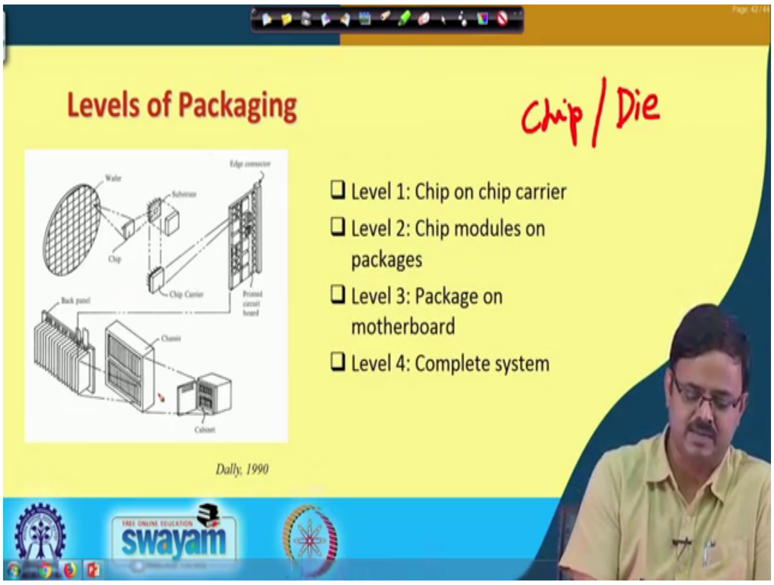

What else, so, if you now think about break it down to the various levels of electronic packaging I mean the definitions do vary from one school of thought to another, but I think level 1 and level 2 is pretty much what people kind of agree upon is the level 1 is the chip on a chip carrier. Now, what is the chip first? So, what you see here what I am showing in this cursor is what is known as the wafer, the silicon wafer. Inside the silicon wafer on the silicon wafer rather the various circuitries are kind of deposited and when I say deposited I am using that word in a little loose term and then it is diced into this square or rectangular chips or dies, die chip and die are often used interchangeably. So, let me write that down here, chip or die ok.

Then this chip comes, and then what happens is it goes into what is called a chip carrier, ok there is a substrate with various pins and what is called interconnects. And then the chip carrier now goes into a wiring board and then the wiring board goes into a chassis, and the chassis then has it is you know it is enclosures etcetera and forms a complete system. So, these are the different levels of packaging ok. And level 1, level 2, level 3, level 4 this is what we are going to follow, but again I want to put the disclaimer here, that if you go to two different books the various levels may be the nomenclature may vary a little bit, but these are essentially the steps.

So, this figure from professor Dally's book it is an old book, but one of the very first and comprehensive ones in electronic packaging; that is Professor James Dally it is called packaging of electronic system. So, this figure is taken from there. And you will see this very very widely used by many professors and teachers who teach electronic packaging across the world ok. The same one is being shown a little in a little more exploded form here that to show the different levels of packaging ok.

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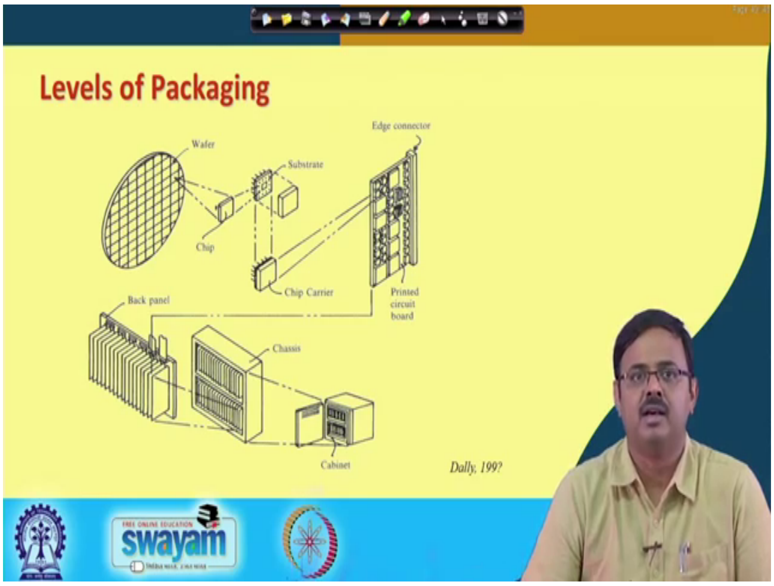

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Now, mechanical design aspects of packaging are all these things. So, in our course we are not going to talk a lot about the electronics part, when we talk about electronic packaging and manufacturing. The focus of this course are primarily going to be on the mechanical and manufacturing sides because unfortunately these aspects are often neglected. Now, no more, but for a long time these were often done later. They were not considered at the design phase and later on these were found to be bottlenecks ok. So, if these are neglected the initial stages you are going to you probably can get into catastrophic consequences where your products may fail, much earlier than it is predicted lifespan ok.

So, all these become very important connections we are going to talk a lot about this what are the different kinds of connections that happen from the device to the substrate to the motherboard at to between devices and so on and so forth. Manufacturing, how do you manufacture all these connectors how do you manufacture these printed wiring boards and various other components. Thermal management which is where I have done some work and thermal management is very important, because 70 percent of failures of electronic products can be attributed to overheating ok.

Maintenance, shock and vibration ergonomics; the product may not fail, but if you cannot use it because it is so hot especially for handled products then it is a non ergonomic design, clear. If the fan noise in your desktop computer is so loud that you cannot even sit next to it is so irritating and so disturbing then it is not an ergonomic design and environment is designed based on environment, ok.

A desktop computer probably functions in my office or in the air conditioned lab in the department or in the school. Whereas, the military electronic products operate probably in the desert at 50 degree scorching sun or maybe in the Siachen Glacier at the border ok. So, the design for products for these conditions will be different than the design for a product that is for operation in an indoor controlled environment ok. So, designing for the environment is very very important ok. So, I hope you understand that you appreciate that part ok. So, let us now end this lecture with a little bit of a discussion on the formation of a wafer.

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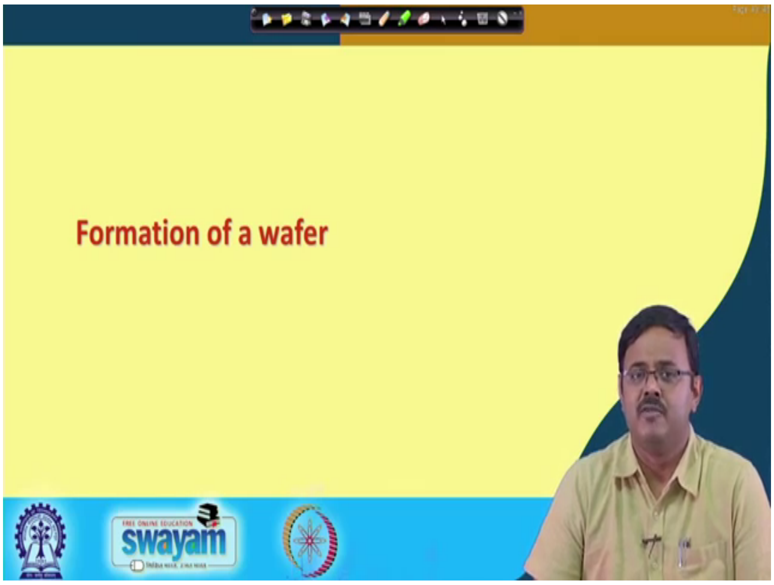

Which is the first one; the wafer was that circular disk if you recall made of silicon. How is it made in the first place? This is still not packaging, but definitely part of manufacturing electronic manufacturing where we are talking about the most elemental starting point when we talk about electronic product. How is the wafer formed?

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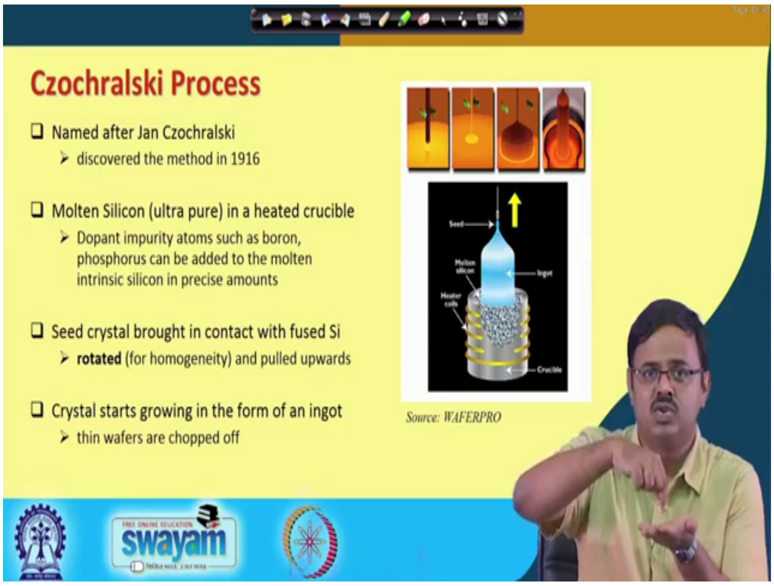

The wafer the silicon wafer forms or is formed the one of the most common methods is known as the I think the pronunciation can be very different I mean I still do not know what is the correct pronunciation it is a Czochralski scientist Jan Czochralski what I know, but if a Czochralski pronounce it will be little different. So, it is named after Jan Yan Czochralski and discovered in 1916. It is a pretty old method that way ok.

So, how does it work? It works if you take ultra pure silicon in a crucible and if it is a dope silicon if you want a p type or n type doping if you recall that you add a group 3 or a group 5 element to the silicon which is the dopant impurity atoms in precise amount, ok. The doping has to be in precise amount you put it in that crucible and then you melt it by some heating mechanism it is a crucible hot crucible you have to really heat it to very high temperature ok.

After that what happens is the seed crystal comes close to this crucible and this seed crystal when it comes in touch it rotates, and as it is rotated it is also pulled upwards, and during this motion the molten silicon kind of attaches and this can be analyzed using fluid mechanics it attaches to this rising crystal and forms what is known as the ingot in this manner. So, you see these pictures ok. This is how the ingot is formed and you slowly pull it out ok.

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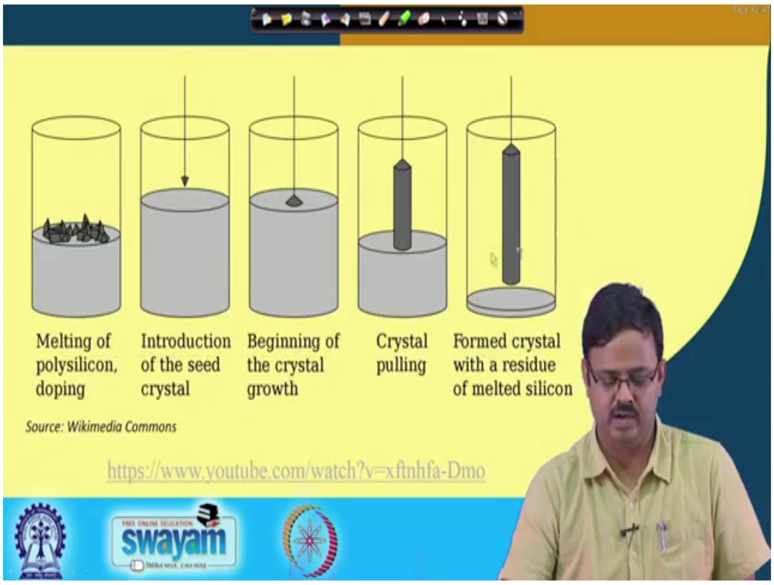

So, I am going to show you again a schematic from Wikimedia and this is how it is. But I think this video will make it more clear. So, let me play this video.

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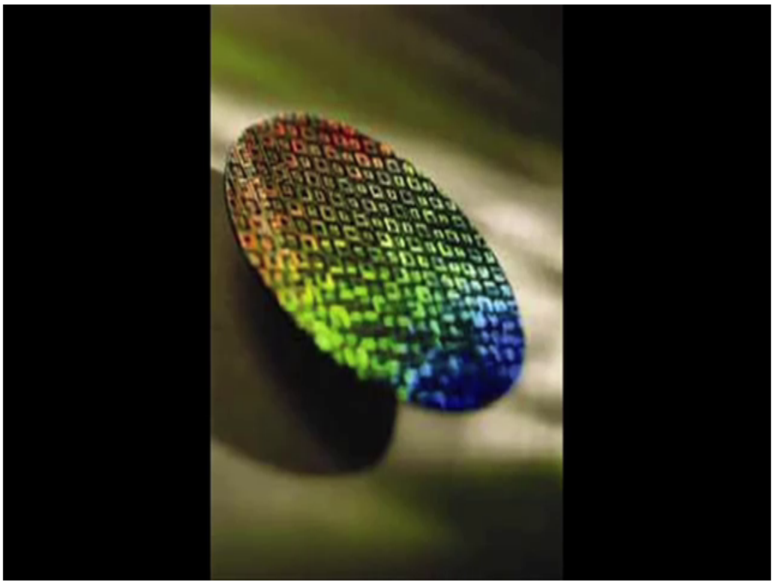

A silicon wafer is a thin piece of semiconductor material which used in fabrication process in integrated circuit.

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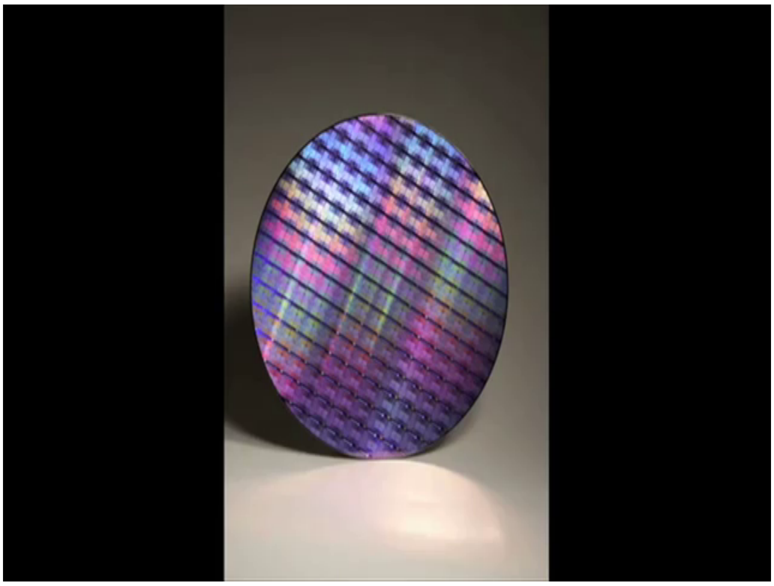

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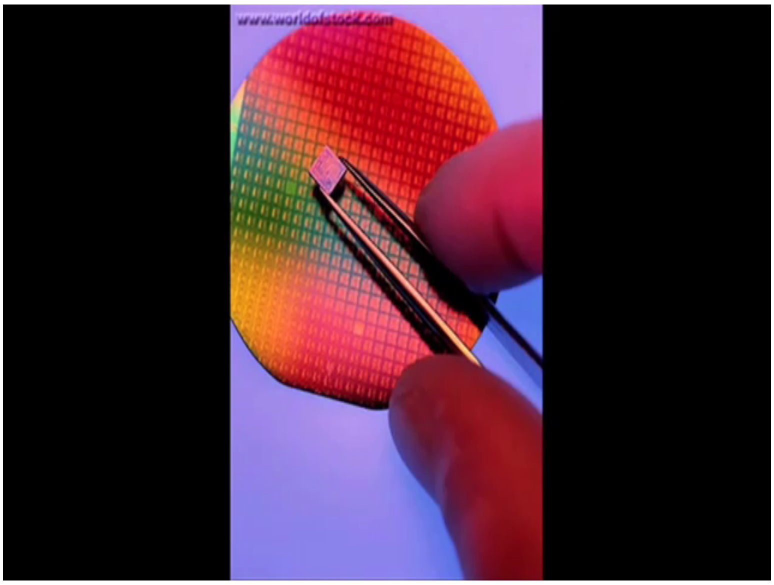

There are two different methods can be used to grow and ingot of single crystal silicon which are known as Czochralski and float zone method.

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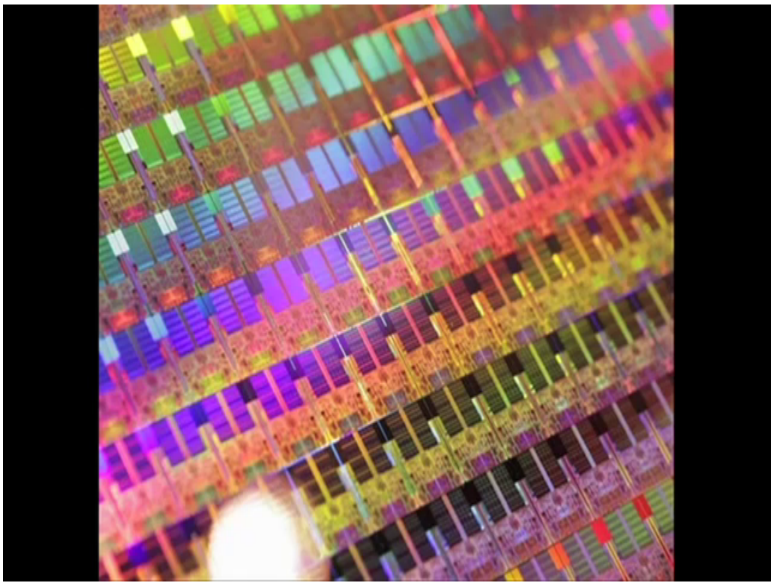

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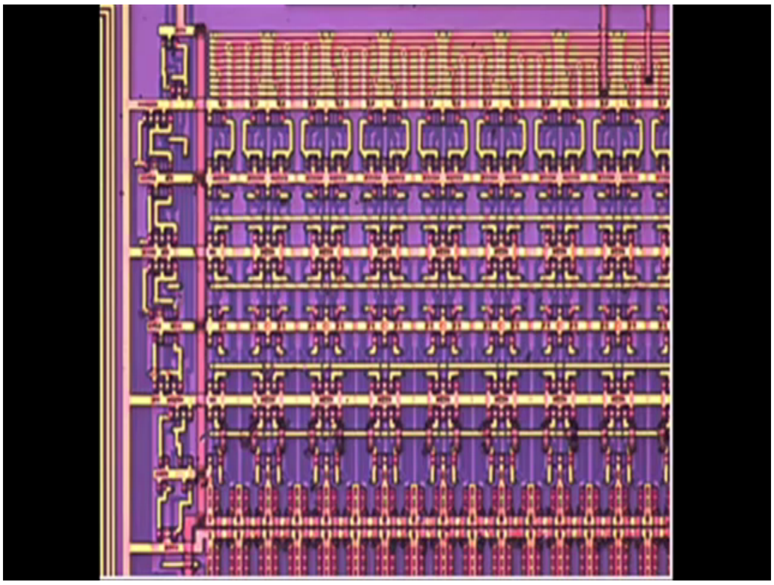

The following is a summary of the steps in Czochralski process of silicon wafers manufacturing.

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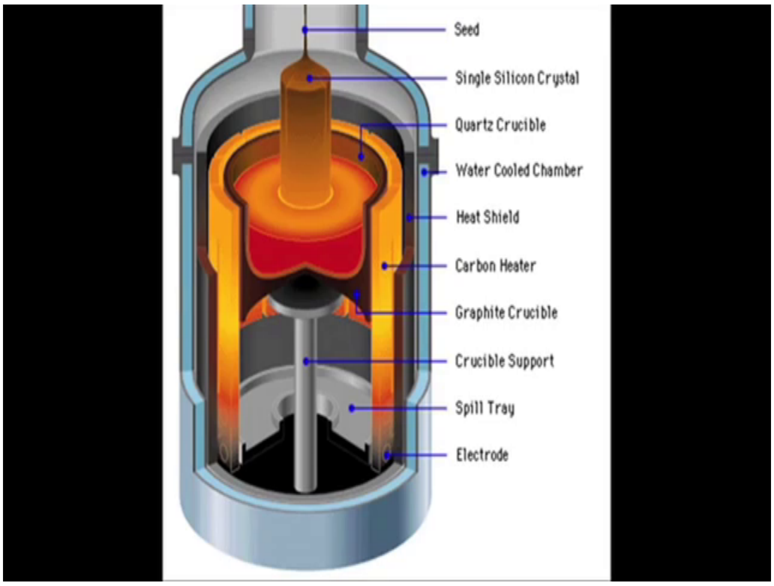

Step 1, preparation of high purity of molten silicon. In Czochralski process high purity of silicon is encouraged to be used as molten to form single crystal silicon. Silicon dioxide can be used to prepare high purity molten silicon then the substance will be heated to it is melting point into a crucible made of quartz. The supersaturated molten solution will become the source of silicon wafer.

Step 2, dipping seed crystal a small piece of single crystal material known as seed crystal will be dipped into the saturated molten silicon solution. Seed crystal is the equipment used to grow a large crystal of the same material. The large crystal will grow when the seed crystal dipped into the molten which will then be cooled.

Step 3, pulling the seed upwards the seed crystal will extract from the molten silicon pool and the rod will be pulled upward and rotated at the same time. During this time the rod and the crucible rotate in opposite directions to minimize the effects of convection in the melt. In manufacturing single crystal silicon the temperature gradient cooling rate and rotation speed influences the size of the single crystal as the seed crystal is slowly raised upward the molten silicon will solidify as same as the seed. That is why this process is known as growing which is producing a new rod of single crystal silicon from molten silicon. The large cylindrical crystal silicon is called ingot a bowl which can be grown to 300 millimeter to 400 millimeter in diameter.

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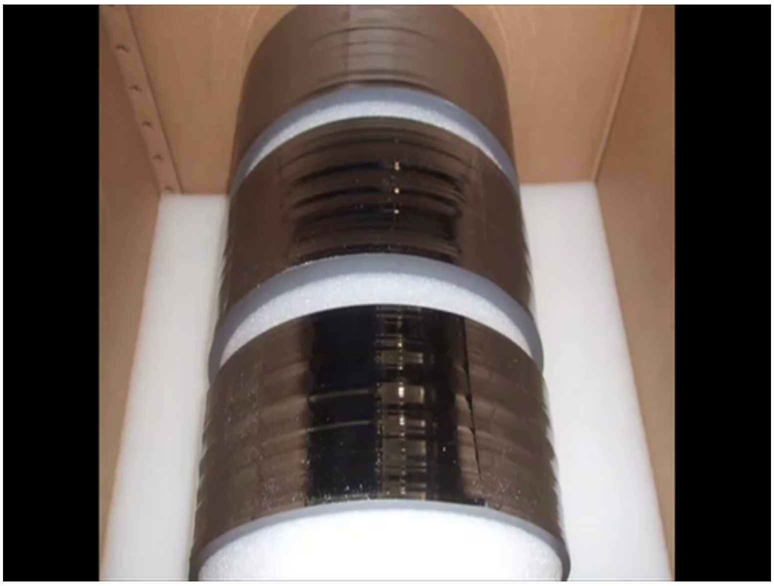

So, I believe that that was an educational video and it nicely showed how this Czochralski process of this growth of this silicon ingot happens, right so, this is very important. And you know when I first learnt about this Czochralski process the analogy that was given to me by my teacher and which still stays with me till today. I do not know if you are seen in this you know some sometimes is in villages even in cities also in some of these fairs you have this candy floss and if you see the way it works the principle of operation is still is the same as that of Czochralski process.

You will see there is a wooden stick with a little bit of sugary crystals at the tip and then this whole crucible is rotated. So, here the difference over there in this candy flosses is the crucible with that with the candy floss and the sugar thing that sugary thing that rotates and instead of the stick. But, otherwise there is a relative rotational motion between the stick and the crucible and then as a result what happens is this whole this cotton like cotton candy flux, cotton candy floss kind of deposits on this stick using that small seed of sugar particles that are you know smeared on that stick to start with.

So, here is the same thing except that the rotating piece is this stick, which contains a seed crystal instead of the crucible, ok all right. So, what is done is this ingot once it comes out see how big it can be.

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This is actually a person standing over there and this can be long this can be like 2 meters, 2 and half meters long and the diameter can be very wide I have a at least I when I used to work for Intel or when I started at that time they still had a 1 foot wafer, 12 inches. That was the largest wafer that they were talking about and the other was the 8 inches. So, 12 and 8 were the standards ok.

And then as we know that this cylindrical ingot that you see this is diced, this is diced into small thin disks of few 100 microns on which you have, you deposit the circuitry on one end and then you dice it of to give or to generate those square or rectangular microchips ok.

So, once again let me go back a little bit to this picture over here. So, once you take that ingot and slice it into this circular disks this is how it looks that is the wafer. Then, you deposit the circuitry and then you again using some laser cutting tool you kind of dice it into these smaller chips which is kitchen with circular or rectangular ok. And after that the level 1 packaging comes into picture where the chip goes on a chip carrier then it goes on a substrate to a motherboard which is what we are going to discuss quite a bit as part of this electronic packaging course, especially the first half ok.

So, let me move down to this one and this is the last slide that I had today. And so in summary that brings us also to the end of the introduction module. So, if you what did we do at part of the introduction module we started with a discussion on the electronics industry we saw how wide and in through various segments how electronics has proliferated whether it is our daily lives, whether it is military, whether it is aviation, spacecraft so on and so forth ok.

After that we spend some time discussing that what is electronic packaging? What is the definition of an electronic packaging? But more importantly what does electronic packaging involve and through some discussions we were able to appreciate that it is an extremely, it is a highly multidisciplinary field of activity that requires expertise from various fields of science and technology, right.

And then we looked at the various levels of packaging and the 1st one was to first of all was to generate this dye from a wafer and to start with you have to go back and find out how a wafer is made and that lead us to the discussion on Czochralski process by which a silicon ingot is grown from pure or precisely doped silicon. And then from there you slice the ingot to give rise to these wafers and from the wafer you further dice it using laser cutting to give rise to these individual dies ok. So, that kind of brings us to the end of this introduction module.

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These are two references to two books that I refer to. Both quite old now, the James Dally's book is actually very good and comprehensive. It is a one of the first texts in packaging, but still very good, unfortunately it is out of production to the best of my knowledge it is out of print now. And fundamentals of microelectronics packaging by Professor Tummala, first edition is where I took the figures from and which is what I have referred, but I think there has been subsequent additions that has come out thereafter. And this is also a good book this is an edited book by the way it is not by a single author Professor Tummala is the editor and he has written quite a few chapters in that book, but again a very comprehensive volume of knowledge ok.

So, with that I would like to come to the end. And thank you very much for your attention. I hope you are able to learn and appreciate what electronics packaging is and in the next lecture we will move on to the next topic under electronic packaging.

Thank you very much.