Electronic Packaging and Manufacturing

Prof. Anandaroop Bhattacharya
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 06
1st Level Packaging – I

Welcome back and we will continue with our course on Electronic Packaging and Manufacturing. So, if you recall in the last class we had talked about semiconductors, we have got introduced to the concept of the pn-junction followed by a diode and then we also looked at some micro fabrication techniques by which you can which you can use to fabricate a diode. So, those micro fabrication techniques that we saw are used to you know to have all these components etcetera on a micro chip. So, microchip, die, integrated circuit these terms are going to be used interchangeably, throughout this course. So, please keep that in mind and if at any point you have any confusion these unless otherwise specified would mean more or less the same thing. So, with that what we now do is we will come to first level packaging, ok.

So, that is the topic of today's course. So, that is what we are going to start with and first level packaging is probably going to continue for a while definitely for one and half weeks and maybe even two weeks. So, because this is probably the most important where we are going to talk about how the signals from the integrated circuit is being carried out of that circuit through the motherboard into other components so on and so forth and what are the different designs and the different technologies that are used to have this what is called the IO or input output or interconnections, ok.

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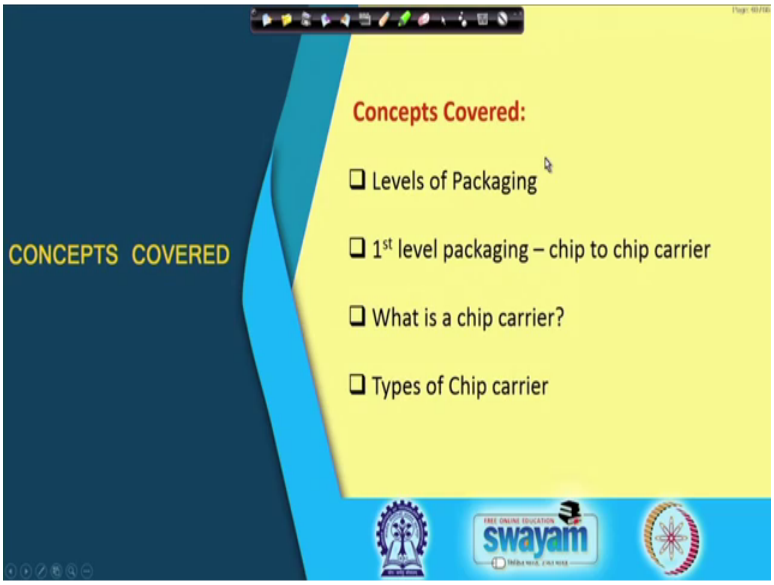

So, first level packaging; what we are going to discuss today we will just briefly discuss about the levels of packaging if you recall what we had studied or what we had mentioned earlier and then we will straight away go on to first level packaging. First level packaging we will see is something called chip to chip carrier and which typically which immediately brings the question as to what is a chip carrier and then what are the different types of chip carrier once we know what a chip carrier is, alright.

So, levels of packaging, let us recall what we had discussed earlier probably in the first lecture or and the second lecture as well in the introduction part. Level of packaging, the first level of packaging is when you get the silicon out from the wafer and connect it to the chip carrier or connect it basically to its substrate and have these interconnections come out that is first level of packaging.

The second level of packaging involves the chip with the chip carrier and with this interconnections coming out of that how is it put on a motherboard or a daughter card and how the signals are now being conducted through the motherboard and the third level is something that goes into from the motherboard to the overall system through connectors assemblies and so on. So, first level again is where the starting point is the piece of silicon with all the circuitries inside whether it is diodes, whether it is transistors and so on and so forth, ok.

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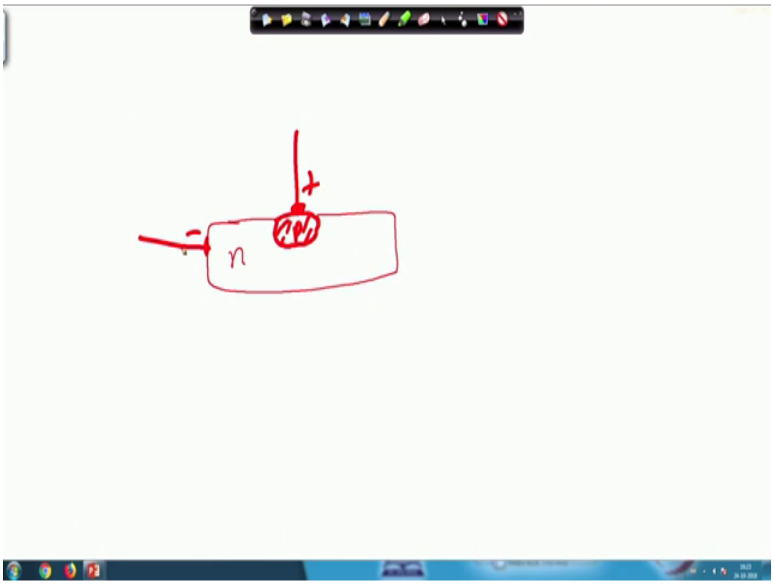

So, recall if we just go back yesterday to the sketch that we saw what did we have at the end. This was my n-semiconductor and then this was my p-semiconductor and what did we have we had of you know we had this connections or the or the junction between the p and n, but then the question comes is well we now need to have this external source of voltage connected to this pn junction. So, how am I going to do that?

So, definitely and from very simple point of view I need something coming here and something being attached here, right. So, this will be the plus this will be the minus, but it is not. So, simple the point I am trying to make is and let us say there are millions of these devices on us on a piece of silicon semiconductor chip and so, each of those would need these connections to come out. And finally, go to the pop the power supply that we have.

So, that is where the first level of packaging comes in. How do I get these connections out? So, that is where the concept of what is the chip carrier also comes into picture.

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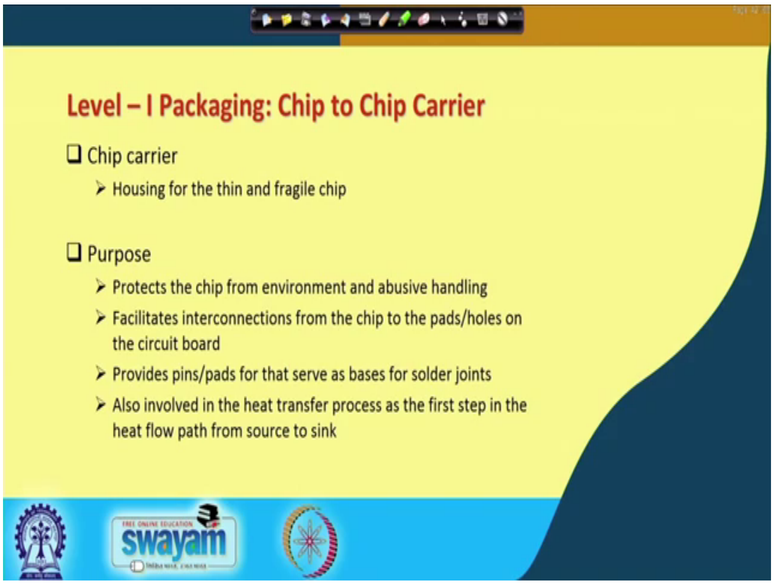

So, what is the chip carrier? The first question is what is the chip carrier. The chip carrier is the housing for the thin and fragile chip again the chip is this piece of silicon that I have you know diced or cut out from the wafer which is circular in shape. Now, what is the purpose of the chip carrier it protects the chip from in the environment and abusive handling. So, I cannot be firstly, from reliability point of view I cannot be carrying this very thin fragile delicate piece of silicon. So, I need to give it a protective housing and the chip carrier does that, ok.

The second one is what we are talking about it is facilitates the interconnections from the chip to the pads or holes on the circuit board. I need to take this piece of silicon and put it on the circuit board, now how do I make these connections to the wiring traces that are there in your motherboard? Correct. So, that is where these interconnections become very important the provides pins or pads that serve as basis for solder joints.

So, this actually ties into the previous point. So, these are the way connections are made we are going to see all these later. So, at this point even if you do not understand you can just assume that these pins or pads. So, many of these interconnections happen because of soldering and the chip carrier is the basis that forms the pins or pads that serve as that that serves or basically that facilitates these interconnections to happen.

So, if I have to give you a very simple example simple and a simple example let us say is which is analogous to what I am talking about if you take your simple plug point, what is the plug point have whether depending on 2-pin or 3-pin? It has these 3-pins that come out and then you have a socket on the wall where it goes in, right. So, that is how I am powering up my system. What happens inside the socket there are these metalized connections and when this pins go in, they form an electrical joint. So, these through these holes through the pins or the holes the pins when they go in inside the hole there is a metalized connection,

So, similarly that is one example that we see in everyday life. So, you can think of a similar arrangement for a chip carrier carrying the chip with these pins coming out and on the motherboard their corresponding holes into which it goes and plugs in and that is where the connections are made, ok. We will see all these later ok, but I am this is pin in whole arrangement that is what it is called and it is very similar to what you have in the regular plug points that we see in our everyday life. So, the purpose is to provide those pins or pads that serve as the basis for solder joints and solder joints basically are these connections.

The last point as you see in this slide is that is very important is it also provides a means for heat transfer. See all this circuitry when they are powered on is going to generate heat. Why? Because of joule heating I squared r everything is the resistor as current flows there will be heat that is generated, and if this heat cannot be dissipated efficiently the temperature of these circuits are going to rise and reach a threshold where it can just burn or and it can lead to failure temperature induced failures.

So, therefore, the chip carrier also has this additional function of providing the first step in the heat flow path from the source which is the source is the circuitry where it is generated to the sink which is where it is dissipated whether it is air cooled, water cooled, whatever it is. So, the chip carrier has many functions as we can see, alright.

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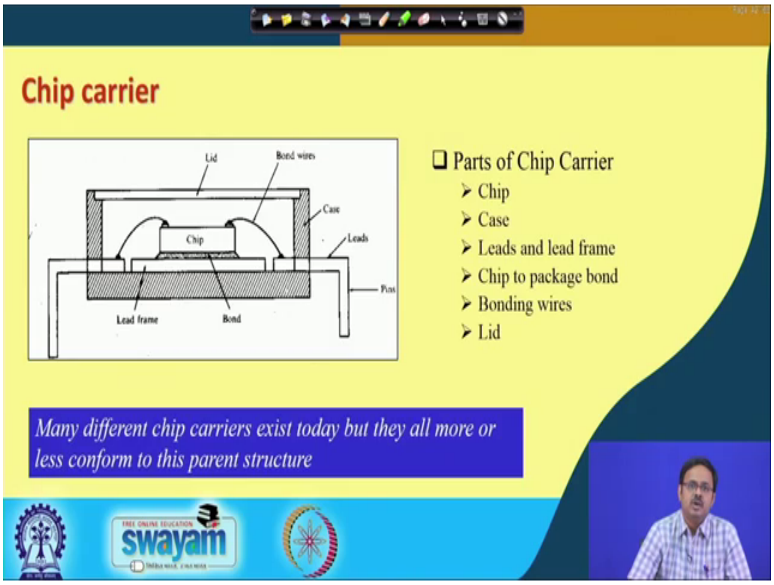

So, now, let us look into a picture of a chip carrier, ok. This is a very simple picture as we see here. But I can tell you that there are many different types of chief carriers that exist today, but more or less they all confirm to this parent structure. So, let us first understand what are the different parts of this diagram are.

So, first what we have is this chip, ok; then there is something called a case, ok. So, what I am showing you over here is a cross section, alright. So, if I take a cross section this is how it looks. The chip is a piece of silicon and there is a lot of circuitry over here. If I want to draw this, so, there is going to be circuitry over here sorry this is going to be some circuitry over here, some circuitry over here and many more. So, these are the points from where I have to take connections out, alright. So, how is that going to be done? As you can see there are these wires that are connecting that are basically joined or yeah basically that are basically joined to these points.

So, these are called the bonding wires, ok. Now, what happens if you look at this these bonding wires finally, bring I connected to another metalized structure which are known as leads or pins, and this leads by the way you are seeing only two of them. And if you consider several of them in the third direction in the depth of in the direction of the depth of this screen, then they are all part of something called a lead frame which you cannot see over here, but what you can see the just the cross section part is over here, this is my lead frame.

And, then this whole thing is encapsulated inside a case which can be made of ceramic, which can be made of plastic and sometimes some other exotic materials as well. So, this is this is a configuration of a chip inside a chip carrier, and then this whole thing is has a cover or a lid, ok. So, keep in mind there are two very similar sounding words; one is called a lid – l i d the other is called a lead which is l e a d.

The lead is the one which connects to you know which forms a connections and the lid is definitely you know a cover, alright. And, then the chip is connected to the lead frame by some kind of an adhesive which is a and that is the bonding structure it has a bonding material alright. So, then what am I seeing over here I had some points on the piece of silicon and then once this piece of silicon or the chip is connected to the chip carrier, what are the connections now? The connections are in the form of these pins.

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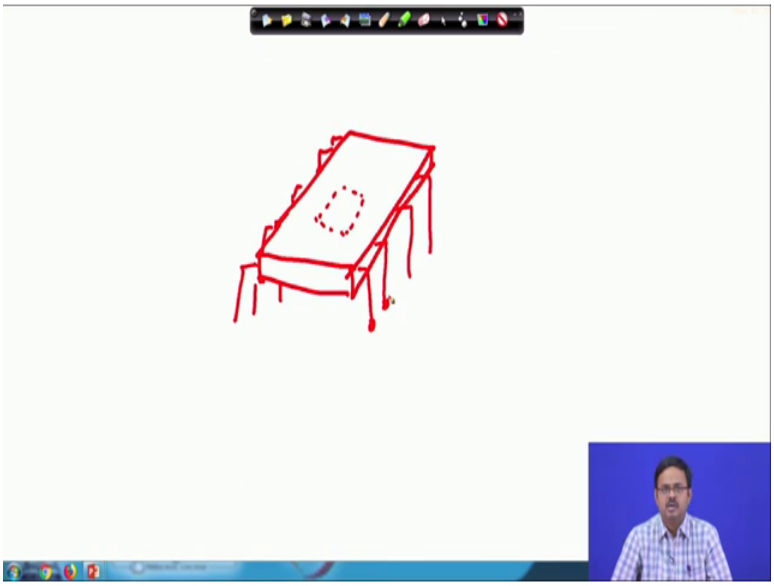

If I now, draw something, sorry; so what I will be able to see is if I look at it in a from outside, this is how it is going to be. I cannot see because this is the case and the lid. So, what is inside somewhere inside probably the silicon is setting over here, but then what I see over here is are these leads that are coming out and so, these are the ones that now from this or enable me to do these connections to the motherboard clear.

So, I am sorry for the quality of drawing it is not very nice, but I hope you get an idea. If you just repeat it from outside now once it is covered I am unable to see this chip. And this wire bonds inside I cannot see this chip and the wire bonds inside, but what I am going to see is this outside cover and these leads coming out. So, as I say there are many different kinds of structures or chip carriers that exist today, but they all more or less conform to this parent structure.

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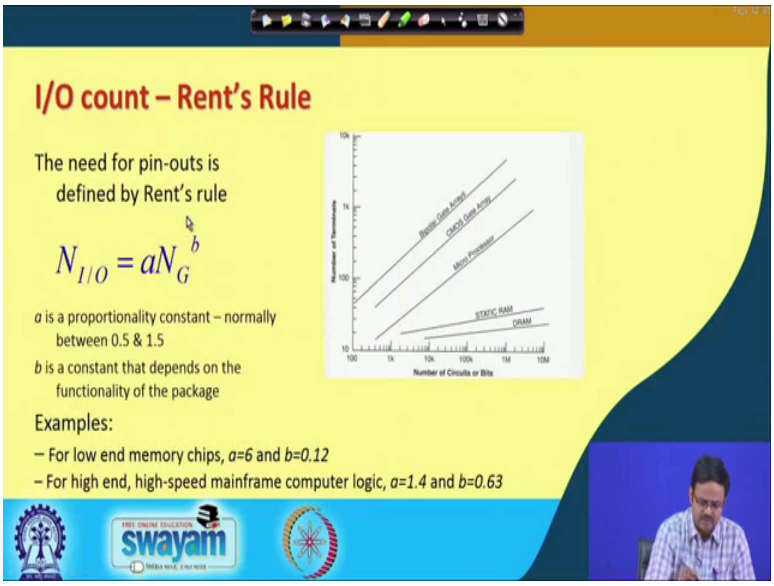

Now, the next thing that I am going to talk about is something called a Rent's rule, that determines that how many of these leads or pins do I need from a certain piece of silicon, ok. So, deed for the pin-outs is defined by Rent's rule, ok. So, the number of this interconnects or IOs is given in this form a times N G times a times N G to the power b, ok. What is N G? N G is the number of gates or terminals inside your silicon, and IO is a number of these pins or terminals or this interconnects that we need, alright.

So, what you can see is if you look at over here in this picture what you see is there is the number of terminals for a same number of circuits or bits depends on the type of the microprocessor that you are using ok, but this is how it is shown and the point I am trying to make is the number of terminals that come out of the chip carrier is not equal to does not is not necessarily equal to the number of gates or circuits or that is there inside your chip rather it is much lesser. If you look at the number of gates is like 1000 depending on the type of microprocessor we are talking about it can be as low as 10 to about 30 or 40 to about 100.

So, orders of magnitude less so, again let me try to give you the an analogy same analogy of the plug point. If you take your computer desktop or even a server laptop or any other thing TV, microwave, there is a lot of intense circuitry inside. But finally, what is the final number of interconnections that we are getting number of pins that is coming out it is either two or three. If it is three, one of them is ground and that is what is finally, going into the wall socket. So, you are powering up your computer the number of input output that finally, comes out of the system is just three and then once it goes inside the system it fans out etcetera, etcetera and give it grows in number probably go into your microprocessor which has probably one million circuits inside.

So, this is just to give you an analogy that finally, just two points is powering up everything all the complex circuitry inside your computing product. So, if you scale it down and just concentrate on the microprocessor, then the piece of silicon has millions of circuits, but once comes what comes out probably are a few thousands, ok. So, the number of interconnections that is coming out of your microprocessor is probably definitely orders of magnitude less compared to the number of circuitry or the number of transistors that you have inside your piece of silicon, ok. So, that is what Rent's rule give us, ok. It is a N to the power b and if you look at some of these examples for memory low end memory chips, the power b is 0.12, but as high end mainframe computer logic circuits the b is 0.63. So, that kinds of gives you the field, ok. It is never to the power 1, alright.

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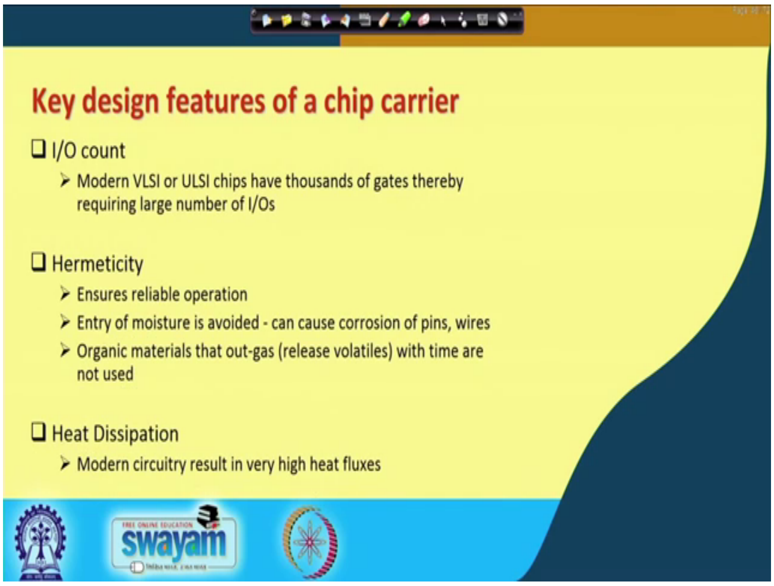

So, now that we know what is the chip carrier and what it is supposed to do, what are the key design features of a chip carrier in that case, ok. The first is the IO count. See the modern VLSI chips have thousands of gates thereby requiring large number of IOs, not just thousands I would say today there is millions of gates. So, there is large number of IOs probably sometime sometimes ordering to thousands, ok. So, the chip carrier should have that kind of capability to have to be able to accommodate this high number of interconnections.

The second one is hermeticity: sealing it, protecting it from outside factors, moisture, it is a killer. That is why we have if you if you need if you if you are talking about you know circuit or devices that are operating in hot and harsh environments. So, packaging for that is very very essential. Moisture is a very very big enemy of electronic circuits. So, it has to be sealed and protected from these kinds of extraneous or environmental factors. To ensure reliable operations, to ensure that moisture does not get in it does not get in to corrode the pins wires your circuit will be gone, ok.

Just to give you an example I mean again from real life my very recent personal example my washing machine; for a long time my washing machine was stationed outside in the in the backyard of my house it was it was covered and all that, but what happens is especially during the rainy season. Now that we are it is October-November here we are just coming to the end of the rainy we have just come to the end of the rainy season and suddenly actually they were it was giving indications. Suddenly one day we would see that if you power on the body switch it is not powering on and then after a few attempts it will be powering on and slowly that became worse. And finally, one day it stopped working and the whole idea was moisture content.

Sometimes we also saw that when one day did not power on the next state did not rain it was sunny the whole day was more or less dry and then it was powering up, ok, but slowly what happened was with time it degraded further and further and finally, it stopped working, ok. We brought it indoors etcetera, but by that time the damage was already done and just as of today morning I had to get that just that small circuit card replaced it cost me a few thousand rupees. Definitely much lesser than buying a much cheaper than buying a whole new washing machine, but the main culprit that led to this failure was moisture and I am responsible for that because unknowingly or knowingly, well I should have known better I had subjected this whole equipment to a moist environment to a level of moisture which it was not designed to handle, alright. So, that is was from my personal experience as current as today morning the Samsung guy came and he replaced my that small motherboard that that is over there in the circuit that that is inside your washing machine.

What is the third one? The hermeticity the organic materials that release volatize with time are not used. So, we do not use materials in chip carriers that are made of organic materials that can be later on I mean we do not use such organic materials in our chip carrier that can out gas and release volatiles with time because these are also going to lead to you know degradation of this circuitry inside. Look I mean especially the picture that we saw before we are talking about very very thin fragile delicate wire bonds.

And, the final part is heat dissipation. So, now, if I go back to the previous this picture you say this chip is going to generate heat, how can I dissipate that the main path for heat transfer is going to be through the bottom. It is going to go through this bond to the lead frame and then to this casing and sometimes through these pins as well and that is how it is going to be conducted away. Sometimes this portion inside which I am showing as hollow is also completely encapsulated by some by a plastic let us say or an epoxy and that also helps in some conduction of heat from the chip in the upward direction, ok.

So, heat dissipation is important and the chip carrier that is one of the functions of the chip carrier. And when you look at when you are trying to design a chip carrier these are all the things that need to be taken into account.

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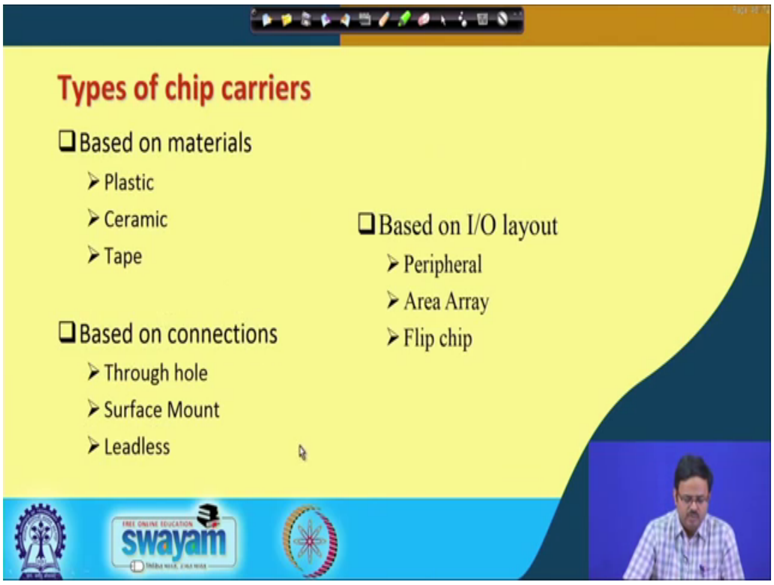

So, let us now go into the types of chip carriers. What are the different types of chip carriers? Now, types of chip carriers chip carriers can be classified based on several parameters, ok, I mean there are several types of classifications. Based on materials the chip carrier can be plastic if it is a plastic chip carrier then we call it we will we will look into all those. The next one is it can be made of ceramic, the third one is a tape type of chip carrier we will briefly touch upon that that is based on that type of material that is being used.

Based on connections, how are these connections, are this pins that go into holes then that is through holes then there is something called surface mount and there are also something called led less lead less, sorry. So, there are no leads there are some kind of a direct contact we will see all these. So, based on connections also there are some kind of there are some types of classifications. And, finally, based on the layout of interconnects is it peripheral, is it area array, is it flip chip, we will see all these; what all these mean. So, these are the different types of chip if the classifications are chip carriers depending on the parameters that we choose whether it is material whether it is type of connection or it is the layout.

So, that brings us to the end of this lecture. And what we will do is in the next lecture we are going to pick up from here and talk about both ceramic and plastic chip carriers, ok.

Thank you very much.