Electronic Materilas, Devices and Fabrications.
Prof.Dr. S Parasuraman
Department of Matallurgical and Materials Engneering
Indian Institute of Technology, Madras

Module - 01
Lecture – 32
IC Circuit Logic and Packaging

Last class, we looked at the various elements in the IC circuit. So today, we going to look at how these elements come together to form a tupical integrated circuit.

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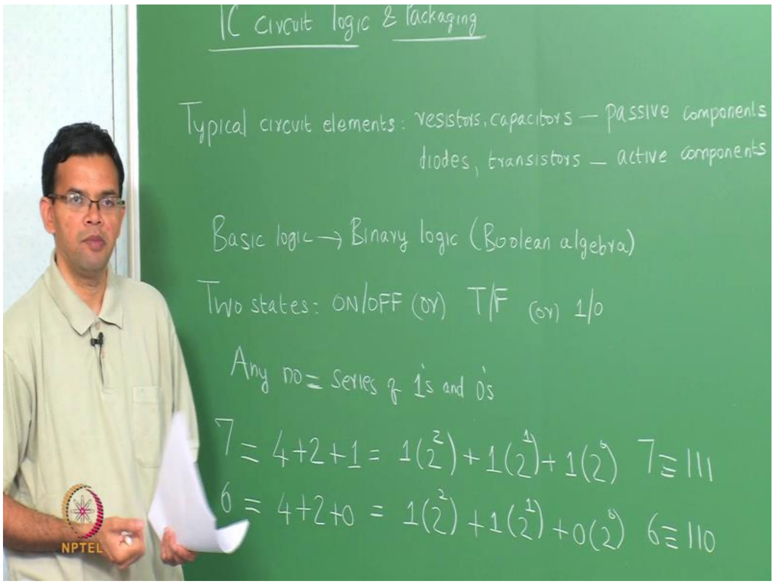

So, we are going to look at Ic circuit logic and we are also going to look at packaging. So, packaging refers the fact that, when have the final die or IC circuit made, how it is then integrated as part of your system. So, this system could be a laptop, to be a desktop, could be a mobile computing device any of those.

So, some of the circuit elements we saw in the last class. We look at resistors or conductors, capacitors, diodes and then transistors. So, these can be divided to 2 many types. So, resistors and capacitors are essentially called passive components, while diodes and transistors are called active componets. Both of these come together to form a final IC circuit. And VLSI design mainly deals with; how we arrange these diffrent elements to form your I circuit.

Now VLSI design in silicon micros architecture, by itself is a complete course. So;

obviously, we will not be covering that greatly in detail, but, what I want to do was show a flavour of how the various componets that we saw, come together in orer to form logical and arithmatic calculations. So, we think of computer, the basic logic behind it is called binary logic and other name for that is called boolean algebra. So, according to this, they are essentially 2 states in your system. So, these states are denote as on and off, or you can denote them as true or flase, or even 1 and 0.

So, the advantage of using boolean algebra is; especially when you think of on and off kind of state, you could have a high voltage being on state and low voltage being off state and this can be controlled by controling the voltage across the circuit. So, in the case of boolean algebra, any number can be represented as a series of 1 and 0. So, any number becomes a series of 1 and 0. To give you an example; you take the numbers 7, 7 can be written as 4 plus 2 plus 1. So, since boolean algebra has only 2 states, it is basically written in powers of 2. And 4 can be written as 1 2 square, 2 is 1 2 to the 1. And 1 is 1 times 2 to the 0. So, 7 essentially becomes 111.

If, you think of the number 6, 6 is again 4 plus 2 plus 0. So, 1 2 to the 2 plus 1 2 to the 1 plus 0 times 2 to the 0. So, 6 essentially becomes 110. If you think of a higher number, you may have to go with a longer string of these, but, essentially anything can be broken down into 1 and 0, which represents on and off states and these again can be represented by voltage fluctuations.

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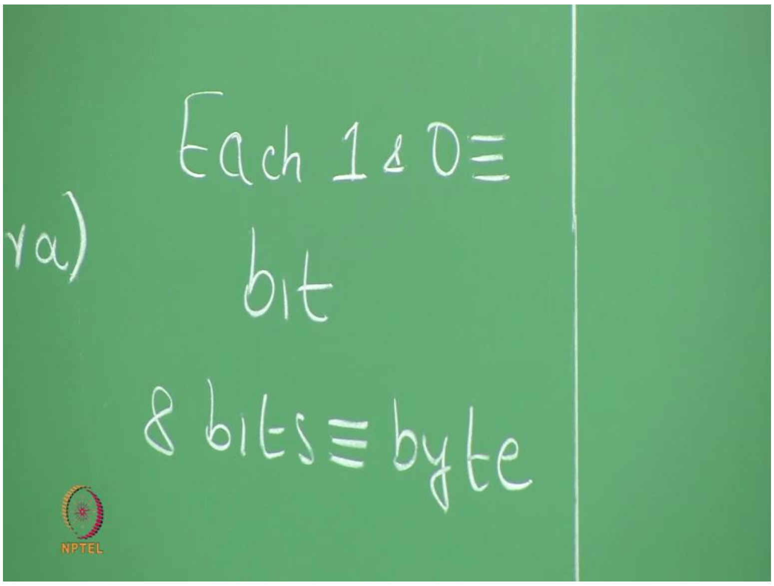

Each 1 and. 0 is called a bit. And 8 bits come together to make a byte. They are higher orders as well; they are kilobytes, megabytes, gegabytess and so on, which all represents higher order of these bits. So, using boolean algebra, you can do both arithmatic calculations and also logical operations.

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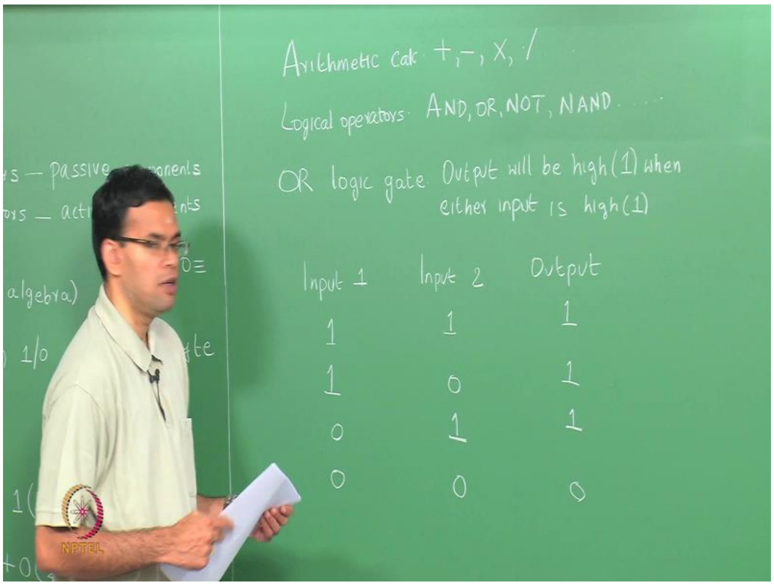

So, when you think of arithmatic calculations, you can do things like addition, substration, multiplication divition and so on. You can also do higer order arithmatic calculations, as just paste upon these. You also have various logical operators. So, typical logical opeartors are; AND gates, OR, NOT and then variations like; NAND, which is NOT and the AND gate and so on. So, these operations can basically be performared by using your diodes and transistors, which are your active components and the through these can be modulated by using resistors and capacitors, which are passive components.

So, we will look at 1 very simple example. We will consider an OR gate and we will see how we can execute this OR gate using simple diodes. So, we look at an OR logic gate. Just based on the name, we can see that the output will be high. And high we can represnted by 1, when either input is high. So, we have 2 inputs; 1 and 2 and then we have an output. So, both are 1 and output is 1. But, if either of them is 1, so if either is high, the output is also high. So, 1 0 gives you 1, 0 1 gives you 1, only when both are 0 is your output essentially 0.

So, it is possible to construct an OR gate, which displays this characteristics. This is essentially called a truth table, by just using 2 diodes.

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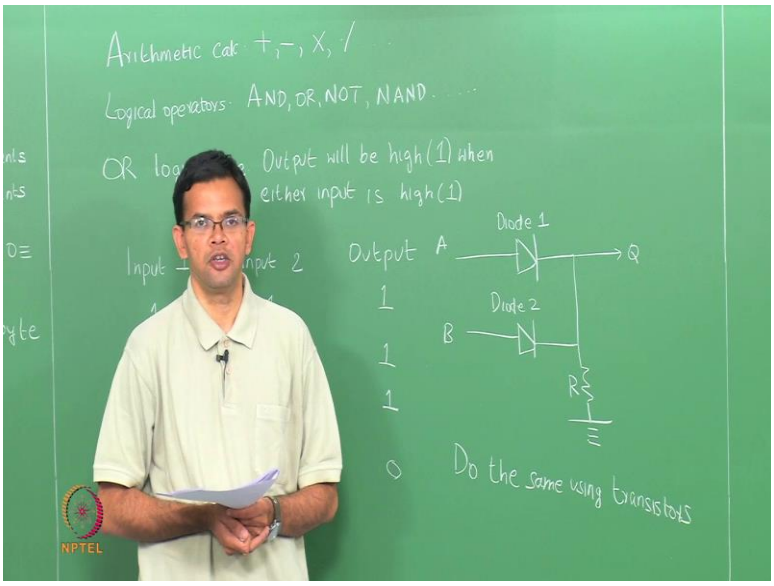

So, let me draw the circuit diodes. A diodes is nothing, but, a p n junction. And last we saw, how we can fabricates this p n junctions. So, I have 2 diodes and 2 inputs A and B. So, this is my diode 1, this my diodes 2. Both are connected together and there is is an external resistor R to module the current in the circuit. Then you measure the output Q. So, either A and B are high, which means your idode is in your forward bias conditions, you will be able to measure current or you will be able to measure voltage drop across Q. So, your output is 1 only when both A and B are turned off. So, can think of this as reverse bias condition, there is no current in the circuit and then the output is 0.

So, just like an OR gate, you also have other gates like AND, NOT etcetera, which can be implemented by using simply diodes. You could do the same using transistors. We will not talk about the ciruit implementation using tansistors, but something similar can also be done. And since all of these are essentially fabricated devices, we can essentially fabricate the simple logic gates on 2 year before. And if you think about it, an integrated circuit consistes of whole bunch of these active and passive elements. So, all of these can be fabricated on to wafer, to give the decide logic.

Similarly, arithmatic operations. So, your simple addition, substration, multiplication and divition, you can also be performed by using these diodes and transistors. And how they come together, in order to give the final result. Another importnt component of any intergrated circuit is the memory element.

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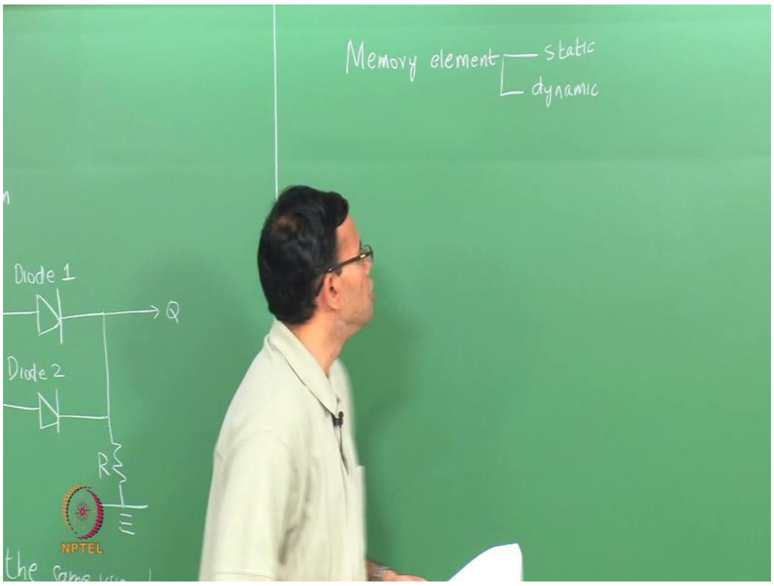

So, memory element essentialy either static or dynamic. A static memory element is 1, which 1 it is written, can be stored. On the other hand, a dymanic memory has to be constantly refreshed, in order to store the particular value.

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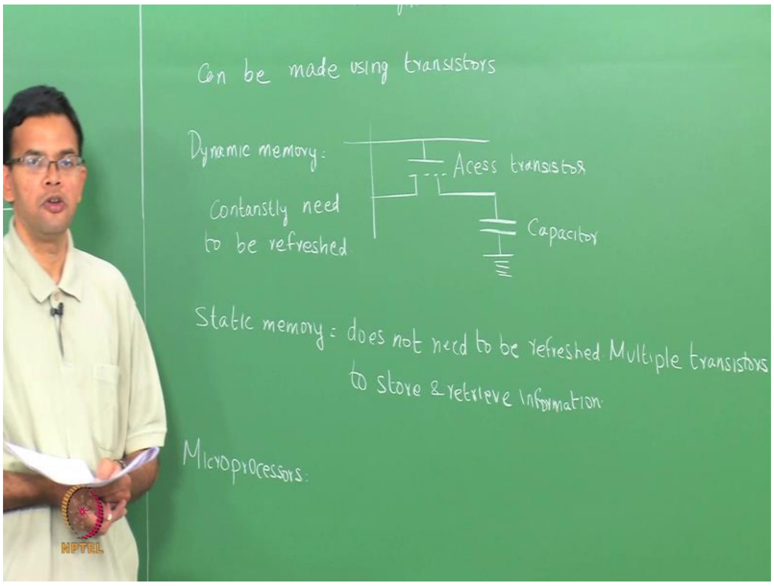

So, the memory elements can be made using transistors. So, to give you an example; consider a dynamic memory element. A simple schemeatic of this shown here. So, you hve a capacitor that basically stores charge. So, the capacitor can act as a storage of memory. So, when the capacitor is charge, you could have certain value written to it. For example it could be 1. When the capacitor is discharged, then the value goes back to 0, but, the capacitor essentially 10 to lead charged. So, they constantly need to be refreshed, which is why this is dymanic memory. Whenever you have a memory element, the memory element also need to be red and this is done by using your transistor. So, this is called acess transistor.

You could also have a static memory elements. So, this just not need to be refreshed. So, these are formed by using multiple transistors, in order to store and tetriew the information multiple transistors. So, it is possible to built both the operative part of your IC circuit; so logical opeartions and arithmatic operations. It is also possible to build memory element, again using your transistors and capacitors and again your active and passive componets. All of these come together to form your integrated circuit.

So, micro processors; if you think about it, our circuits that combine both the logical and the memory units. So, the logical refers to that part of the circuit, that has both the logical and the arithmatic calculation. And the memory units correspondance to that part of the circuit, that basically stores the input and also the result and that can be retrived whenever needed. So, the first micro processor was built in 1972.

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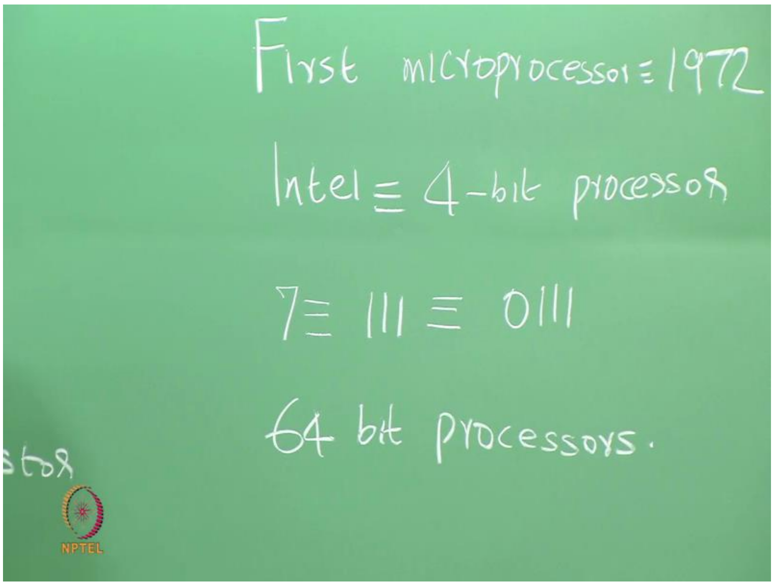

So, the first micro processor was built in 1972. Basically built by Intel, was essentially a

4 bit processor, which meant each elemnt was essentially built with 4 bits. So, earlier we looked at the number 7 and we reprsented the 7 as 111. So, we trying to do the same using the 4 bit processors, then just becomes 0111. So, this was the first micro processor that was built. Now we have processors that are essentially 64 bit long. So, the same number 7 can be written as 64 bit number, but, the essentially all the leading elements would be 0, followed by last 3 11 and 1.

So, we have look briefly at the IC circuit logic. The next thing i am going to look at his packaging. So, how we take the final die and then package it so that, it can become the part of an external circuit.

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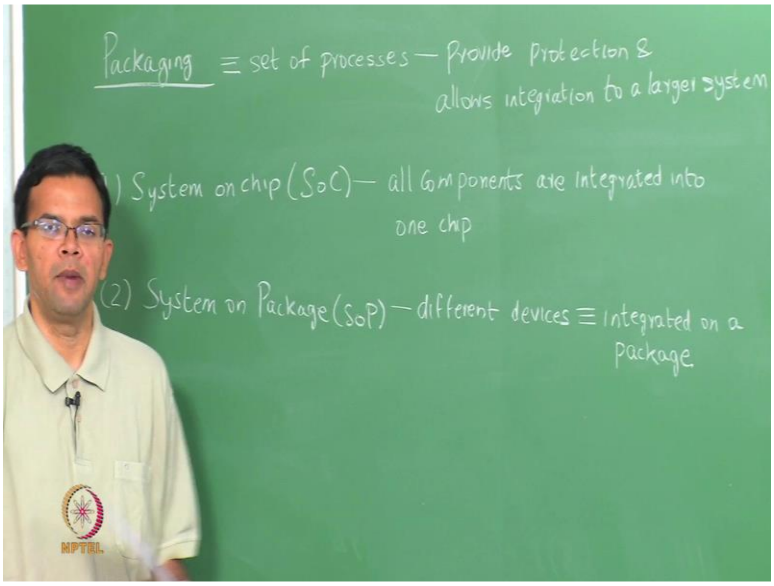

So, we are going to look at packaging. We can define a packagin as a set of processes, that provide protection to the chip, there is 1 of the functionalities. But, more importantly, it allows the chip to be integrated to a larger system. So, there are essentially 2 main paradims, by how this is implemented. The first 1 is called a system on chip, short form is SoC. So, in this case, all the various components are integrated on to 1 chip. So, essentially becomes a fabrication issue, how you fabricate the different components on to the single chip. To give you an example; desktops usually have things like an intergrated video card. So, this would be an example of sysem on chip, where the video card is integrated along with the main micro processor.

The other paradian is called sysem on packaging. In this case, you have different divices with specific functionalities, which are intergrated on a package. For example, you could have a micro processor, you could have a video card which could be an external video card, you could have audio devices or input output audio devices, all of this having specific functionalities, coming together on to the package to form you final system. So, when we look at the packaging process, the chip characteristics basically affect the packaging.

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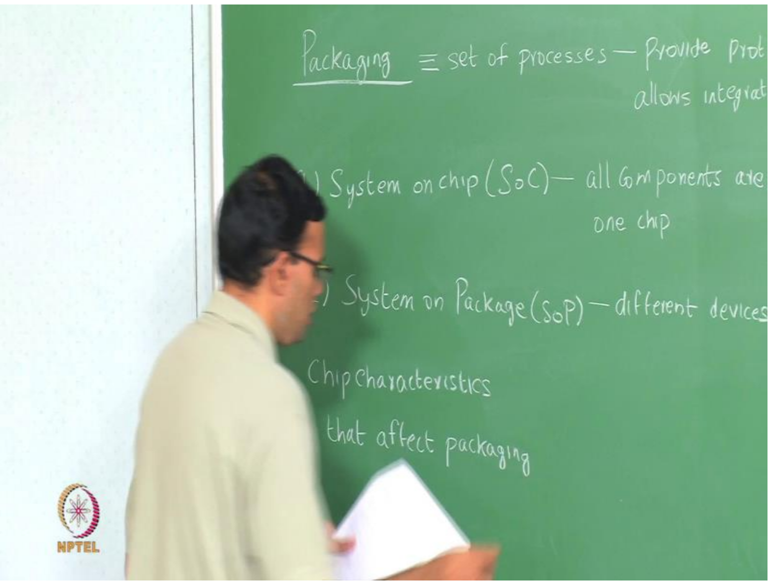

So, when we look at the packaging process, the chip characteristics basically affect the packaging. So, the first 1 is integrated level.

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So, this refers to whether you have a system on chip or a syste on package. And also define things like how many leads you have and how many connections have to be made and so on the way for thickness. So, later we will look at the various steps in the packaging process. And 1 of them is actually thin the way for down so that, when you start with the wafer the restifically, 700 microns thick, it is thin down to the few 100 micros. So, that packaging become the easier. Then the dimensions. So, the dimensions again refer to how many leads you can have, how closely space these are. So, this is related to the die size, is again related to type of chip you have.

Then environmental sensitivity. So, this is related to the fact that, the original solder that we used, where all led based because, led is essentially a low melting point. But, led is also poisones so that, the process is also itself highly hazardness. So, now, new methods are being developed, in order to have led free package. The other 1 is physcical vulburability. So, its refers to; what are the physical conditions, that are encountered by the system during operation. For example, you could have a micro processor being embedded in a machine, that is under constant use so that, both stress and strains and vibrations would all play a role. Some of the other characteristics are heat generation and heat sensitivity.

So, the last two are essentially imporant because, we find that, as we go with the higher levels of integration, so that, we have more and more transitors, that have been packed smaller and smaller areas. It basically tense to generate a lot of heat. Simple way to think about heating is that, if you have a resistor and pass cuttent through it, you have something to call juel heating, which is directly proportional to the square of the current and also directly porportionl to the resistors. So, more the circuit elemts there are, more the heat will be generated and this intern can affect device performance.

So, the amount of heat generated and the sensitivity of the device to heat is also essential, in detarmining how we package it. So, usually there are waste provided, in order to despate the heat, to minimise any affect on the wafer itself. So, we look next the some of the functions and designs of the packages and then we look at the series of steps, that going to packaging process. So, there is 4 basic functions for a package.

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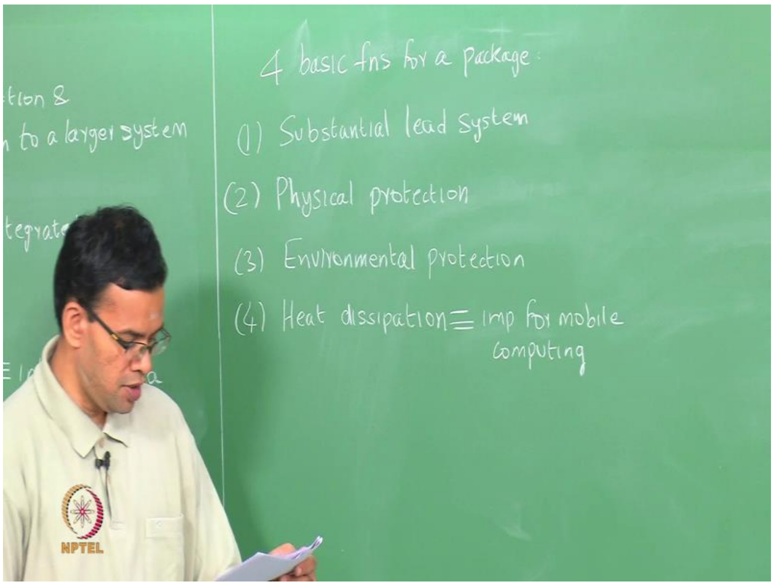

So, there is 4 basic functions for a package. So, the first 1 is to provide substantial lead system. So, these leads are electrical leads, which are used to make connections to the rest of the package. Physical protection; ragidness of the packaging process, environmental proptection and then finnaly heat dissipation. Heat dissipation is especially imporatnt, we have mobile computing. So, think of the fact, that you have tablets and cell phones. So, all of these again have micro processors. So, heat dissipation is very important in these because, these again can lead to heating up of the device, which something we all do not want. This is specially important for mobile computing. So, there are various ways of implementing this.

So, 1 way is at the fabrication level itself, to come with a micro architecture, that essentially uses low power so that, amount of heat generated is small. But, you can also adress this at the packaging side so that, you have proper heat dissipation in your system. So, eralier when we saw the fabrication process, we figureded as a series of processes, interms of a assmbly line, we saw the wafers go 1 step to the next, in sort of a assembly line faction. So, similarly, we can look at pacakging as a series of steps so that, the final wafers dies, go through the series of steps in assembly line. And at the end we have the final package.

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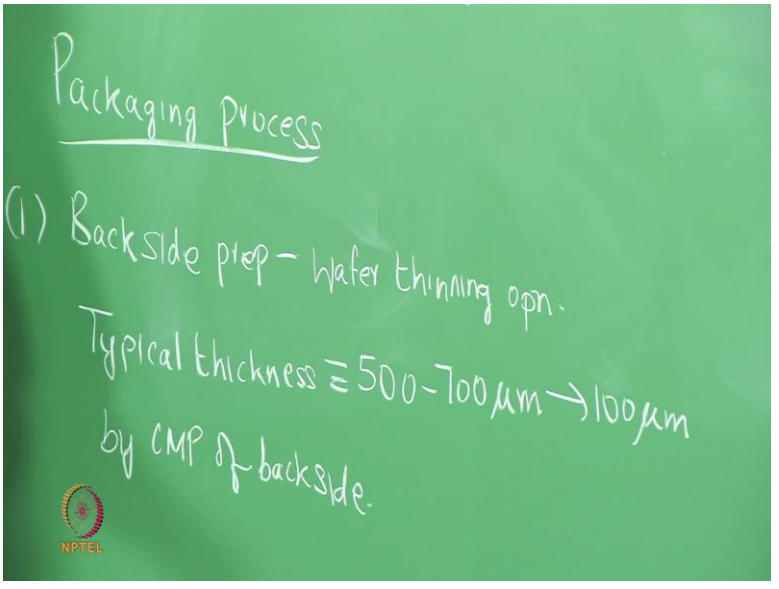

So, the first step in the packaging process is your back side preparation. So, this is typically a wafer thinning operation. So, if you look at it; a typical wafer demension has thicknesses somewhere around 500 to 700 micro meteres, depending upon the wafer diameter. So, the typical thickness somewhere around 500 to 700 micro meteres. This is thinned to aproximately 100 micro meters, by some sort of chemical, mechanical polishing of the back side. So, the front of the wafer is protected usually by applying some sort of coating. And then the back side is thin so that, the over all thickness comes to an around 100 micro meters. So, this is helpful because, it can then be used to easily separate the differeny dies from the wafer and then package them individually.

The orginal high thickness is 500 and 700 microns is essential because, during fabrication, the wafers growth go through whole series of processes. So, they should be mechanical reboost, which is why they are originally thick, but, when comes to packaging the thinner the better.

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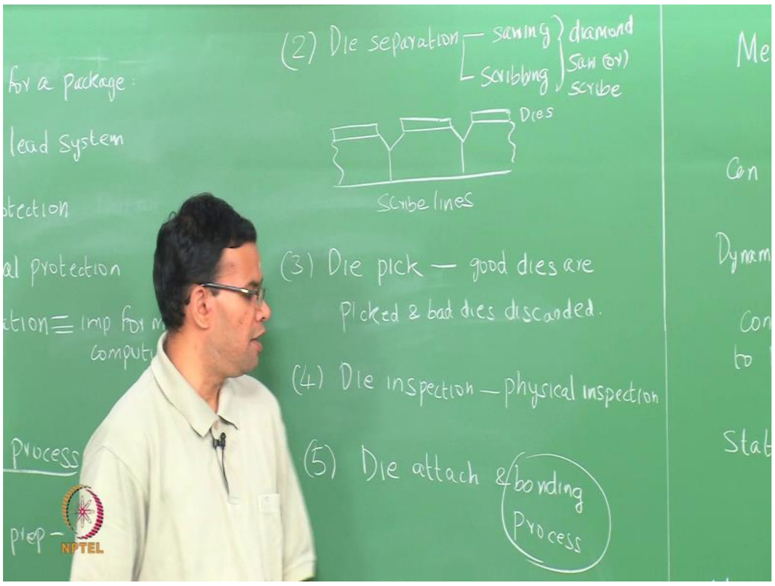

So, after back side preparation, the next step is die separation. So, in this; the individual dies are separated from your wafers. So, typically this is done by a saning process or a scribbing process. Usually you use a diamond base system, so you have a diamond saw or scribe. So, this is used in order to separe the wafers. So, just to give you a schemematic, this represents your wafers. We have seen the concept of scribe line earlier. So, scribe line basically separate the different componets of a die.

So, sometimes the scribe lines are blanked, but, usually have some circuits for electrical testing. So, these are scribe lines and then the dies are fabricated on top. So, the wafers are separated along the scribe lines, again by using a diamond saw or a diamond scribe so that, you get the individual dies out. This is the die separation process. After that, we have die pick. Again after die separation, the good dies are essentially pick and the bad dies are discardered. So, we saw this earlier. So, this goes into the yield of the process. So, more good dies we have, the higher is the yield.

Then we have die inspection. This is more of a physical inspection, to check for any craks or defects because, during the packaging process, there will be further stresses on the dies, so we want to make sure that dies donot fail. So, these dies are those that have passed the pick process. So, they have passed the electrical inspection, but this is essentially a physical inspection. The next process is the die attach process because, the die has now to be integrated along with your chip. So, you have a die attach and then a bonding process. So, this is essentially the most important part in the packaging process bonding. So, here the die is bondered to the package and also the leds are attached to make the electrical connections.

So, there are different ways in which bonding occurs. So, you will see that next. So, we look at the bonding process.

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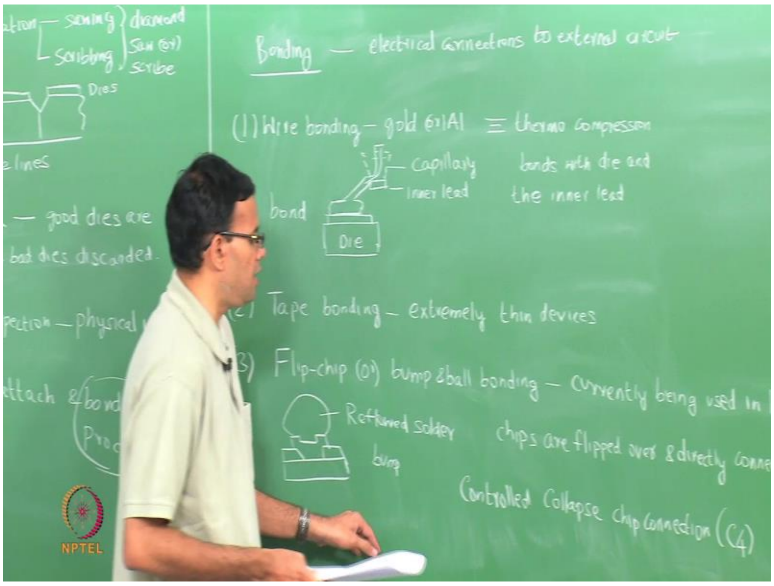

1 method is called the wire bonding. So, in this case, either gold or aluminium is used. So, if you recall, the bonding is done to mainly form the electrical connections to the external service. So, in this case, either gold or aluminium is used to form the electrical connections. To give a schemematic of this, here is your die, there is a pad for essentially making the electrical connection. So, that goes to how the matalization occurs. So, when we look at the metalization, we saw they were different levels of metalization.

So, some of the newer transistors or newer IC circuits have essentially 11 levels of metalization. The connection is made to the top most level. So, these intern feedback to the transistors and other components of IC. So, you have a bond that being found. So, the wire is fed through the some sort of a capillary system. So, this is the capillary, this is the inner lead and this refers to the bond. So, in this case, if gold is fed through the capillary and by thermo compression, it basically forms a bonds with both to the die, with both the die and the led and the inner lead. In the case of aluminium, you could use a similar process.

Sometimes ultrasonic agitation is also used to form a bond, in that case it is called as a veg bond, but, similar bond can occur. You also have something called a tape bond. It is mainly used for extremly thin devices. So, appear your bonding is usually in the form of a tape, which are again bondered to the lead and your die. But, recently when we have these ic circuits with the large number of leads, where large number of connections have to be made and the leads are also closely face to 1 another, a newer method of bonding is been developed. This is called a flip chip or a bump or a ball bonding. So, this is currently being used in the IC industry, due to the last number of leads. And they have to be closely spaced to 1 another.

So, in this particular idea, no wires are used. This is the schematic of die. So, in this case solder material is melted and then fload on to the conenction. So, this you refold solder bump. So, all the different connections, are all the diffrent leads that have to be made. The soder material is essentially melted and then fload onto it. The entire chip is then flip, which is why it is called flip chip and then the leads are directly bonded to your package.

So, the chips are flip over and directly connected to the die. So, the another name for this process is called the control collapsed chip connection or C 4. So, there is no separate die attach in the bonding process, both the bonding and die attached is done in 1 step, by using these refload solder bumps, which are inverted and then directly bonded to your die. So, after making the bond, there are few final steps. The 1 is your presed inspection. So, the bonding process is number 6, your presed inspection is 7.

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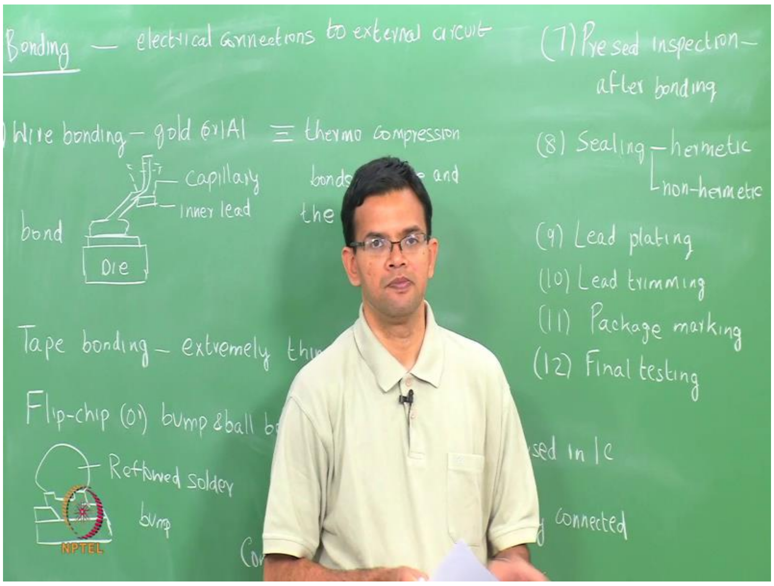

So, this again looks at the electical functonality and the reliability of the bond, once the bonding is done. So, this is after bonding, then the package is sealed. So, you have sealing process sealing, being either be a hemeting seal. So, in this case, you make sure that there is no external atmosphere, that come into the package. This is essentially important for environmental protection, you can also have non hemetical seals. So, selaing can be hemetic and non hemetic.

So, then you have the lead plating, lead trimming, package marking and then the final testing. At the end of the final testing, the package is ready and it can then be integrated either onto your system. So, it could be a part of your system on a package deal or it could be a package, where all the components are already integrated into with it, then it becomes a system on chip. So, these are the various steps, that go into the packaging process.

So, once again you can think about it as a assembly line, where the final dies go through the series of steps, in order to give the final package.