Electronic Packaging and Manufacturing
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Lecture – 12
1st Level Interconnections- I

Welcome back friends to the next lecture of Electronic Packaging and Manufacturing. In the last class, we had just started the discussion on wire bonding, we just introduced we saw a definition and we said we are going to elaborate on that in the next lecture which is this one ok. So, the concepts that will be covered today is our wire bonding and tape automated bonding, these are the two concepts that, we are going to talk about in today's lecture as is shown in this slide ok.

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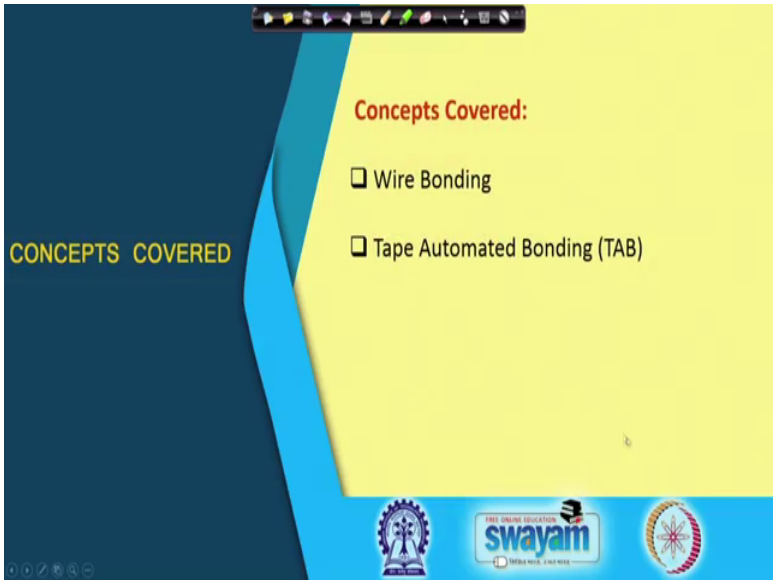

So, let us move on to the first topic which is wire bonding ok.

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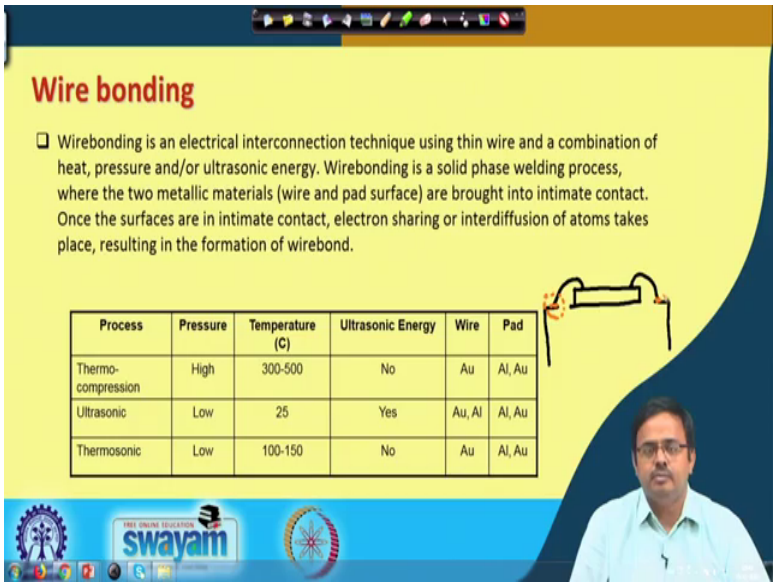

So, this is a definition we saw in the last class, it is an electrical interconnection technique using a thin wire ok. So, this wire bonding these are typically made of gold is most common aluminum is also used, but gold of definitely has better conduction characteristics, conduction properties. So, therefore gold is most popular, but it is also very expensive. So, quite exact quite evident and quite obvious.

So, using a thin wire and a combination of heat pressure and ultrasonic energy, why let us look at that. It is a solid phase welding process unlike melting, it is a solid phase welding process, where two metallic materials. What are those metalic materials? One is the wire that comes out and the other is this pad surface landing pad surface, on the chip carrier where the connection has to be made right. So, again if I draw directly on this slide remember, this is my silicon and then this was my interconnect, remember and then this wire bonding was happening like this.

So the bond, what is the bond area? The bond area is over here, where this wire this is a wire and this pad surface, they are brought into intimate contact ok. So, when they are brought into intimate contact, then what happens? Then somehow the contact has to be so, good that the two need to get attached. And how will that done? The two will need to will get attached, if there is a diffusion of atoms from one to the other and that is how the bonding is formed right.

So, that is where the electrical path will get completed, will get shorted and that is how the connection the in current will flow so, that is the point so that is wire bonding. So, the next question is how do you do this ok, let us say I have some means of drawing the wire from the connection point on the on this chip to the lead, or the interconnection point to the pad, then what happens? How does this diffusion of atoms inter diffusion of atoms take place? So, that is where this term what I said in the first line combination of heat, pressure or ultrasonic energy ok.

So, now depending on the process used, it can be a combination of all these, so, the first process we talked about is thermo compression. So, thermo compression bonding is where you bring the two surfaces in close contact and then you press them while heating both surfaces to a high temperature. So, there is high pressure at the same time simultaneously, you heat it up to a temperature in the range of 300 to 500 degrees C ok.

So, the wire typically in such thermo compression bonding is gold and the pad can be gold can be aluminum ok. So, once again thermo compression as a name itself such as thermo means heat, compression is definitely application of pressure. So, thermo compression bonding wire bonding is when the wire and the pad come in contact with each other and the attachment happens due to a combination of heat and pressure ok. So, you press the too tightly and then you heat it up as well all right.

The next one is ultrasonic bonding. In ultrasonic; however, you do not need heat or pressure you need a little bit of pressure of course, that you have to be in contact with each other, but you really do not have to press them ok. Just bring them in contact reasonable pressure and that is it. And then what you do is you subject or the entire combination or this you know this combination of the chip and the chip carrier to an ultrasonic energy source.

So, therefore, what happens? There is an ultrasonic energy source. So, there is this rubbing at ultrasonic frequencies and as a result the connection takes place ok, whether you can read about all of these and also look up for videos in YouTube ok. Ultrasonic bonding, the temperature you do not need heat as I said is room temperature 25 degrees ok, I mean can be 30 degrees also depending on summer day.

But you really do not need a thermal energy source ok, that localized probably there is some localized heating, because of this energy ultrasound energy source, but that is good

enough pressure also you really do not as I said before you really do not have to press hard, just press them together and apply this ultrasonic energy source ok.

So, this is more versatile because the wire as well as the pad can both be gold or aluminum ok. The next thing is thermosonic bonding so, which is that ultrasound is not easy ok. So, you do not need ultrasound energy source, but you need some kind of vibrations ok, at reasonable frequencies all right. And you need to simultaneously apply some heat and heat it up not to the range of thermo compression bonding, but around 100 to 150 degree C. So, under such situations what happens is so, you do not need to put pressure, because you know putting pressure, I mean the it calls for the chip and their whole connection to be robust and all so it is not easy.

And later on when we see this it is not easy, because we will see these automated processes, but thermosonic bonding on the other hand you do not need pressure, you need the heat. And then it is again these vibrations and the rubbing that forms this bond, this also is not possible with aluminum wires, gold wires are required the pad can be gold or aluminum ok. So, once again summarizing this stable, we are talking about the three methods of wire bonding in terms of how this bonding happens at the pad and wire interface, how do we do this what kind of energy? What kind of conditions are required?

So, that is where you have thermo compression which is a combination of heat and pressure high pressure ultrasonic, where you need a specialized energy source emitting you know vibrations at ultrasonic frequencies or thermosonic, where you do not need an ultrasonic energy source, but you need some vibrations and you need also some heating ok.

So, the names actually the names are pretty self explanatory that way, once you have understood what these mean thus names now are self explanatory which is what all right. Now, this is in terms of a classification in terms of how this bonding happens and what is the method that is used.

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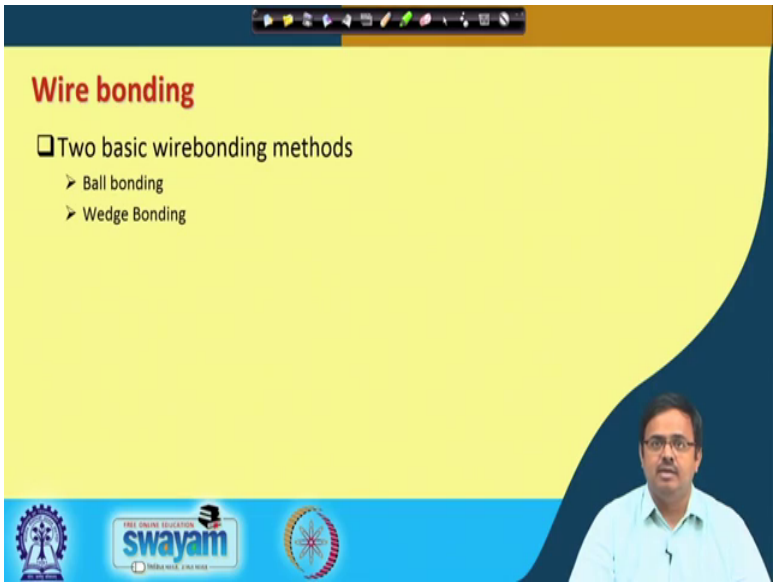

But however, there is another way by which we can classify this wire bonding and that is in terms of the bonding method ok. Well the previous ones were also methods that way, but here it is, but we will see what these mean. So, one is called the ball bonding the other is called the wedge bonding. Now what do each of these mean? Let us look at that.

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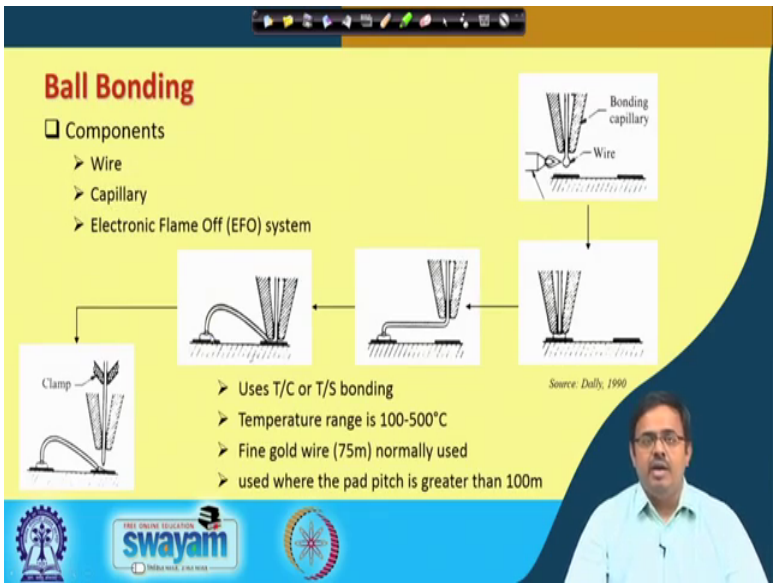

In ball bonding, these are pictures from the Wlectronic Packaging textbook by James Dally. So, for ball bonding the components that you require is definitely the wire, you need a capillary and an electronic flame off system ok. What happens? You have a

bonding capillary through which this wire is fed and right, where it comes out the wire comes out as you see in the top picture over here, there is a flame which locally melts it. So, for example so if these are the two you know connection points maybe so, in this case one should be on the chip the other will be on the interconnect. So, this is how it happens. This capillary comes in it is heated and then, you press it on the first connection point so, the bond is made ok.

So, think about it this is kind of a thermo compression bond I agree, because I have put heat and I am also putting pressure by pressing it ok. So, once that is pressed then what happens the capillary lifts up so, as it lifts up and then travels you can see these thin wire typically made of gold can be aluminum as well comes out. And then this capillary moves to the next connection point and then presses it ok. So, once it presses and again over here, you can use either thermo compression or thermosonic bonding ok.

So, you still need heat either, you compress it or you apply some kind of a vibration source and that is how the temperature range can be 100 to 500 y depending .If it is thermo compression, you really need to go very high temperatures; you need to go to like 300 to 500 as we saw in the previous slide. If it is thermosonic, you do not need to go that far 100 to 150 is good enough ok. So, fine gold wire or that would that should be 75 microns not 75 meters, I will correct that, but I once again want to say that this is 75 microns not meters ok.

So, I think the symbol got converted to the roman letter ok, but that is what it is so, fine gold wire is used and is used when pad pitch is greater than hundred microns again; if this is microns, but clear the whole process. So, once the second bond is made over here, then there is a clamp that kind of holds our wire and pulls it upward and so, the wire snaps over here and you see this nice wire bond that has happened, why is it called ball bonding we will see this in the next slide.

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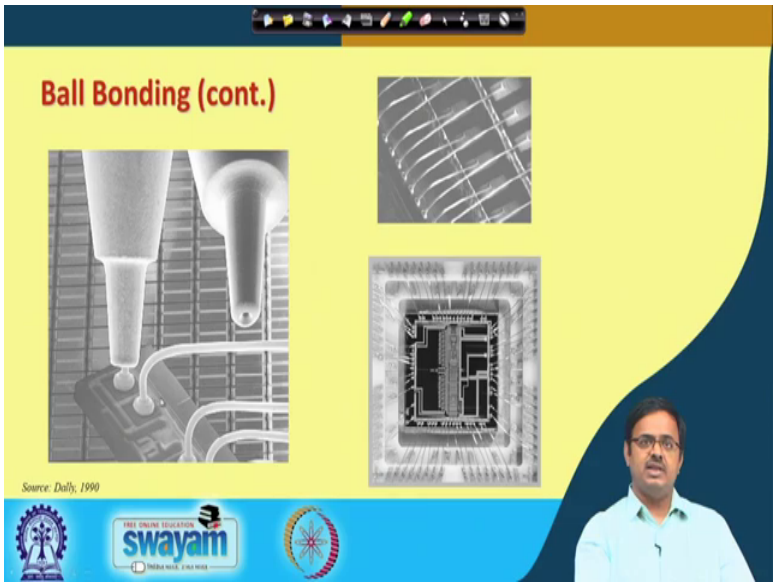

Look at this. These are actual pictures, this is actual capillary and you see how this is happening as the capillary rises this wire can be seen clear and it is called ball bonding because of the shape of this connection. Look at this shape or this shape, so that is why it is called a ball bonding ok. The previous one was a schematic previous slide pictures were schematics; these are real pictures, you can see this.

You can see pictures of these wire bonds that have taken place two rows of interconnections, you see these leads one two this is one row, this is another row ok. And from the top view you can see these wire bonds ok.These are the connection points on the periphery of the silicon or the chip and then these are the connection points on the chip carrier or the substrate connected to the interconnect leads yeah. So, this is ball bonding.

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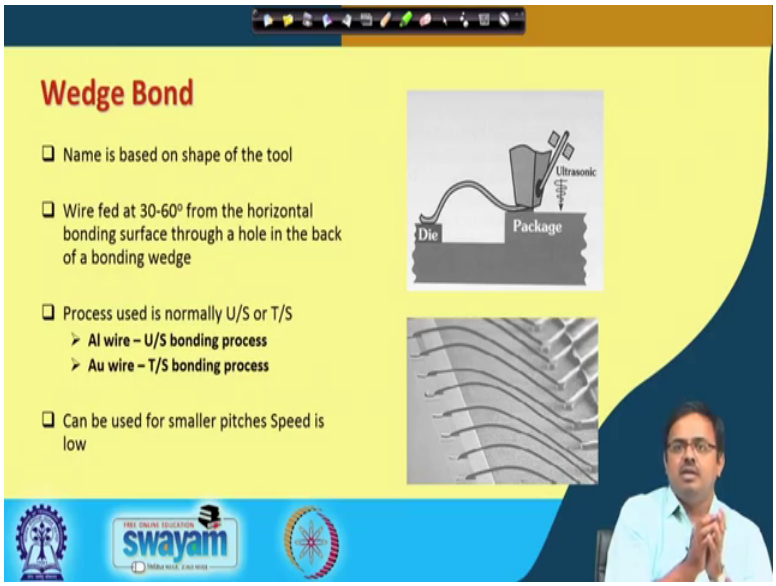

So, similarly there is something called a wedge bonding, where instead of a capillary the wedge bonding is called so, because based on the shape of the tool. So, instead of a capillary which when rises and falls, because of surface tension forces and all it gives rise to the connection or it gives rise to the shape of a like a spherical ball not exactly spherical, but it is a ball right at the connection point. In wedge bonding, what happens is you have this tool through which the wire is fed.

And as it comes close from the die to the package so, this is on the silicon and this is on the inter connect side, then works happens is there is an ultrasonic or thermosonic there is no heat by the way here. It needs an ultrasonic sound and because of this rubbing, you know the tool kind of presses and rubs it on the on the substrate and then the bond is formed ok. So, here instead of you know rising like this coming and then dropping almost at right angles the wire is fed at 30 to 60 degrees from the horizontal bonding surface.

Through a hole in the backs on the backside of a bonding wedge so, this is the bonding wedge clear. And the process is used for either ultrasonic or thermosonic not thermo compression, because we do not put that much of pressure ok. The aluminum wire is used if it is an aluminum wire is typically ultrasonic if it is a gold wire, it is thermosonic ok. It can be used for smaller pitches, but the speed of this is lower compared to a wire bond we will see some videos, where the ball bonding can happen very quickly it is still

an automated process with robotic arms, but it can happen very quickly wedge on the other hand, because of ultrasound this angle etcetera it cannot happen so, quickly all right. So, this is a wedge bond ok.

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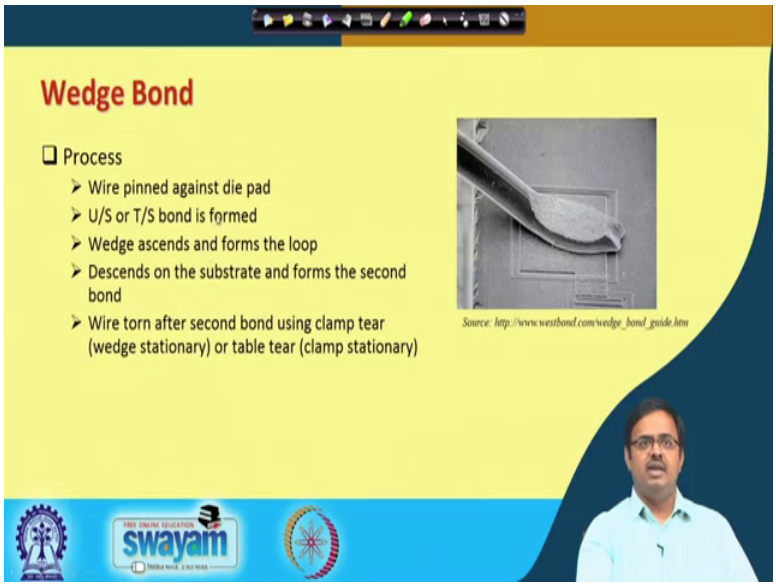

Again the process is over the wire is strong after the second bond using a clamp tear ok. And this is a picture of a wedge bond, you see it is not like a wire its first of all coming at an angle and this is how it is formed, nicely formed clear. So, this is how it is so, now what we will do is I have a couple of videos that I want to show you.

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So, to this end what I will do is, I will play these videos over here starting with the first one.

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And this is a gold wire bonding technique, I do not think we need the sound the sound is just music.

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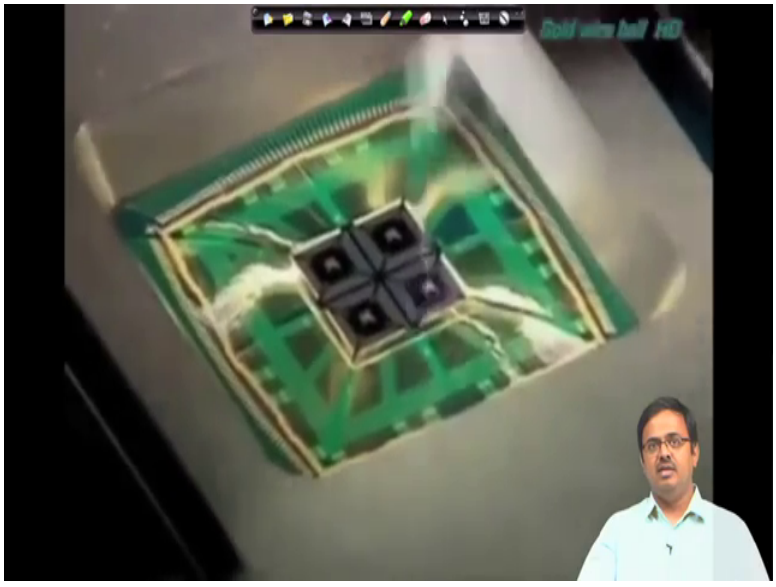

So, I will leave it and you see how this is still slowed down by the way this is actual speed, you have this tool completely automated look at how fast it goes you cannot even see and the wire bond is formed. On the periphery of the chip, it is which is what you are

seeing right now and on the periphery of the package, or the substrate which is the green color; see how these wire bonds are happening. There are four pieces of silicon actually as you can see, on the single chip carrier in the in the picture that we are seeing now ok. And you see how this is happening, the gold wires can be seen an extremely fast process.

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Now, in the slow motion see what happens, this is that capillary see how the bond happens ok.

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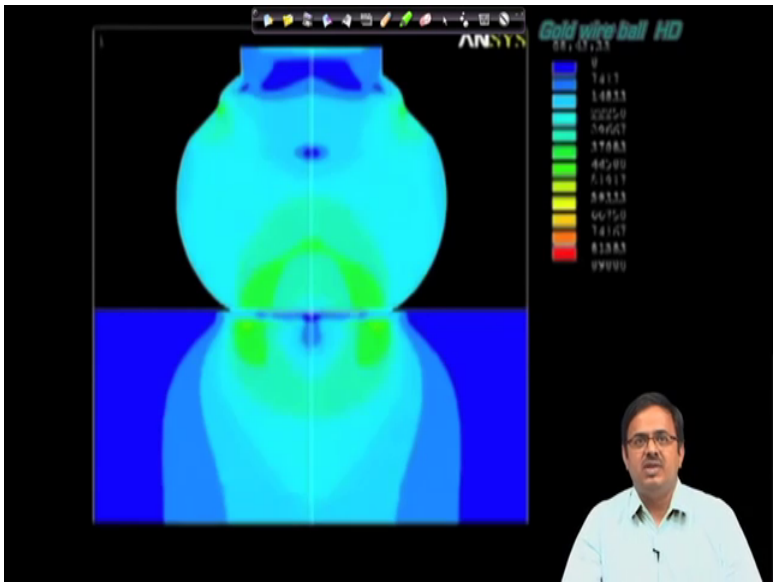

So, this one is an as a simulation not very important that kind of shows, you know some of these animations over here all right.

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So, let us stop this one and go back to the next video, which is a short one, but here you can see it at slow motion, you see how the bonding is happening look at this picture. So, if we spend a little bit of time over here, this is the edge of the chip where the interconnection points are there that is the chip surface from where the wire bond is taken up and then bonded to the corresponding pads on the interconnections on the leads ok.

So, that is what it is and you see that this there is an another second row of such interconnection points or leads all right ok. So, I just wanted to show you those videos to give you an idea of how wire bonding happens, we saw those I mean we saw in this picture we saw how it happens right. Do you have a capillary? We saw up this is a schematic these are actual pictures of the tools.

But when we saw that video you see that at what speed it happens? The second one was a slowed down motion right 4000 frames per second I think that, that is what it was captured at and then you were seeing frame by frame. And over here also you can see these wire bonds that are formed and a zoomed in view over here so, wire bonding till flip chip came up and even today also many of these low level packages are still wire bonding, it is not (Refer Time: 22:56) chip all right. So, that is what it is.

So, today what we did was we if I have to summarize what we just discussed is about wire bonding methods, we started with the definition of wire bonds what is a wire bond. And we talked about that of course, it is it is bonding between two surfaces sorry between a wire and the surface.

Now, how is that done how is that done well depending on the process and in terms of what kind of energy you need you can have thermo compression bonding, you can have ultrasonic bonding or you can have thermosonic bonding. And this table kind of captures at what conditions under what conditions you need or I mean temperatures pressures excreta required for each of these processes, this is about the connection between the wire and the pad.

But then what is the process how do you draw this wire from one point to the other and that is where we talked about ball bonding and wedge bonding ok. In the ball bonding it is a capillary tool in the wedge bonding it is a tool of a certain shape which is called a wedge. And through the wedge through the holes in the wedge is where the wire is fed whereas, in the capillary to the wire is fed through that capillary tool as shown here yeah.

And then what we did was we went through a couple of videos, where we actually saw how this wire bonding process happened. And the takeaways from that video are as follows number 1 wire bonding can be is a number 1 it is an automatic process ok, you have these automated controlled machines wire bonding machines, where these can happen if you can beat can be programmed and the tool can be made to move from point to point and do these ok.

Number 2 it can be very fast process we saw that and what speed it was happening right, number 3 in spite of; however, fast it is it is a sequential process. In the sense that the bonds cannot happen simultaneously a single tool it has to form the first one then do the second one and like that. So, that is you can say compared to flip chip it is a drawback, even though however, fast it is it is still a sequential process ok.

So, with that we will end today's lecture where just to summarize again this lecture was focused on wire bonding methods all right. So, this lecture was focused on wire bonding methods and we looked at the different sorry, we looked at the different wire bonding methods and the tools and we also saw a couple of videos, when we come back in the

next lecture we will start with the next type of bonding which is known as the tape automated bonding or tab t a b.

And thereafter we are going to move to flip chip bonding ok, which is probably going to take another couple of lectures at least one more lecture ok. So, that is what we are going to talk about in the next few lectures ok, and that is going to be the last topic in first level packaging and after that we will move to the second level so, till then.

Thank you very much until the next lecture.