Electronic Packaging and Manufacturing
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Lecture – 13
1st Level Interconnections - II

Welcome back. So, today we will continue our discussions on 1st level packaging ok. As you can see 1st level packaging is continuing for quite a long time, because you know maybe some of the most critical concepts, processes, technologies, they are all part of 1st level packaging that is the most important where the silicon actually becomes part of a package ok. So, today we will continue with that. If you recall in the last class we have talked about wire bonding and the techniques of wire bonding.

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So, the next one that we are going to talk about the concepts we covered today is called Tape Automated Bonding, and sometimes in short it is also called TAB - T A B ok. So, we will talk briefly about TAB or Tape Automated Bonding. And after that we will go over to flip chip bonding. And again see flip chip bonding also we know we know what is flip chip bonding, what it means etcetera which we discussed that I think two lectures back. But what we are going to talk about today is the process ok.

Similarly, for example, we knew water wire bonds how they look like. But in the last lecture we learnt about how the wire bonding process happens what are the tools that are

involved and so on and so forth. So, today we will look into that process of having or manufacturing a ball flip chip ball grid array package, so that would be the second part the first one is tape automated bonding.

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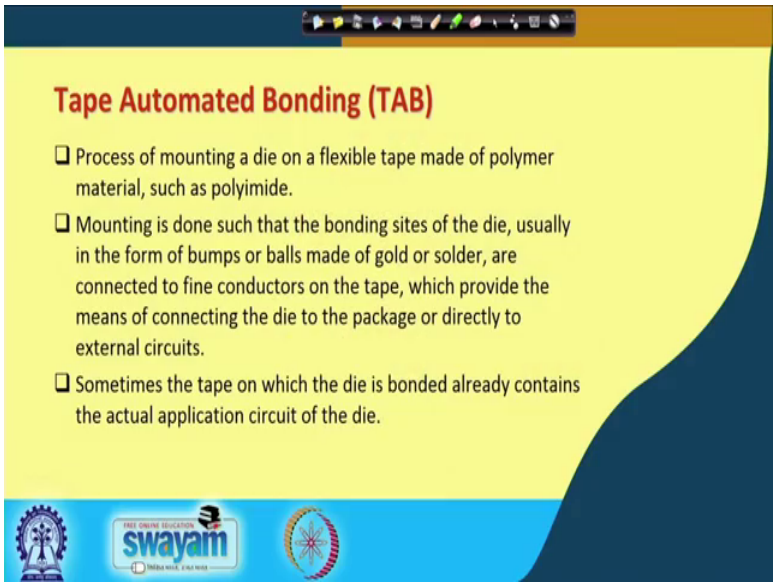

So, let us move into tape automated bonding. What is it? The tape automated bonding is a process of mounting a die on a flexible tape, made of a polymer material such as polyamide. So, here the chip carrier that we are calling or the other substrate that we have been calling so far is actually a flexible tape. And inside this tape we have these traces of interconnects going through. We will see in the pictures that will be a little more clear when we see the pictures.

The mounting is done such that the bonding sites of the die usually in the form of bumps or balls made of gold or solder. So, the die which is this piece of silicon or the microchip it has its own connections typically in the form of solder bumps or solder balls they are connected to fine conductors on the tape ok, and which provide the means of connecting the die to the package or directly to the external circuits alright, so that is what it is.

And the last bullet was the sometimes the last bullet says that the sometimes the tape on which the die is bonded actually contains the actual application circuit of the die ok. So, we will talk about all these, but in a sense you have a flexible tape on which you have these traces, so that is like the chip carrier, and then the chip which is a silicon is going to

come and get bonded onto ok. And typically this is a flip chip ball grid array package, ball grid array die ok.

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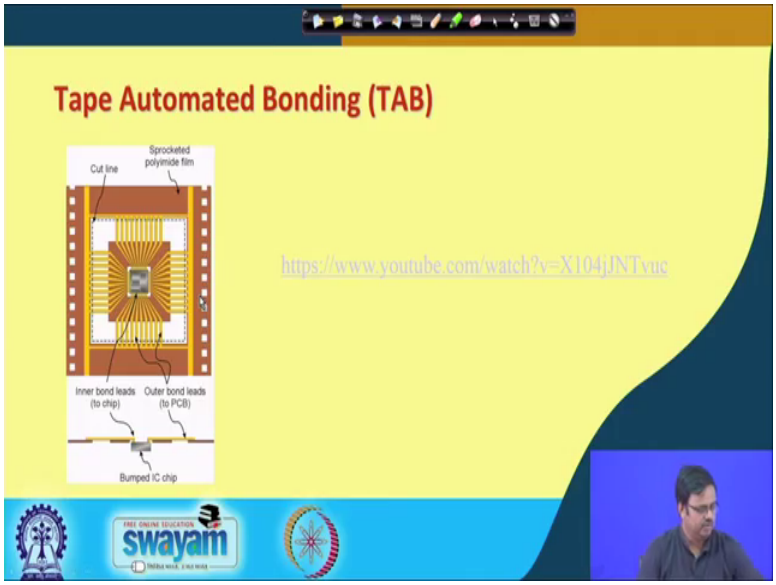

So, how does this happen? If you look into this one, let us spend a little time on what we are seeing on the left hand side ok. This is a picture ok. So, what do we see, we see that this is like a film, if you recall the old cameras before digital cameras became so omnipresent. We used to use film cameras. And if you recall the film in the film camera, you would recall something like this right. So, this is almost actually the tape reader, the tape automated bonding the tape actually looks very similar to the old film camera, the film of a film camera.

So, what do we see here we see that this is the tape, and you have the circuit traces going inside. And then this central position is where the piece of silicon is going to come and get bonded ok. So, once the bonding happens, so you have the leads that goes to the chip, and then outer ones that goes to the PCB and so on and so forth. And if you look at a side view after the bonding is done, this is how it will look like. This is a top view from the top, this is on the side view ok.

Now, this is very common many a times it is used in very you know in cell phone cameras, in SIM cards, these are the typical applications where you need to make a lot of them and in a probably type of an assembly process. So, you imagine this is just one part

of the film one part of the tape that is. And you have this structure (Refer Time: 05:32) die of course, this structure replicated one after the other periodically ok.

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So, let us look into a video where [noise this will become probably a little more clear. Right in this picture what you can see is the tape ok. So, let us now play that. Tape automated bonding is a high volume technology for making the interconnect to silicon devices. The interconnects are simultaneously attached to the silicon chips using hot pressure welding or soldiering processes. It is often used in components like smart cards and bank cards, tagging devices and SIM cards for mobile phones. The technology is also used in the manufacture of pocket calculators and digital radios.

So, we saw that. We saw that video which kind of showed the tape, and you saw the how there were a lot of them just periodically placed one after the other on the tape. So, you can make a lot of the you can now attach these chips one after the other if you want to make a lot of these devices all similar then this is a wonderful way. But of course, you do not this a this is limited interconnect and so you do not really make very high end chips, but the examples that were told in the in the video those are very common its very common to use tape automated bonding for such applications ok, so that was tape automated bonding.

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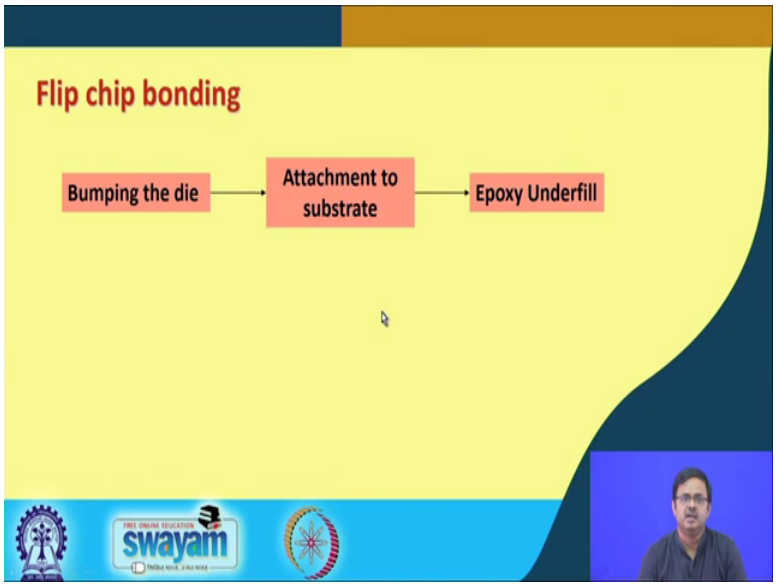

Next, what we will do is we will move onto flip chip bonding. And if you look at flip chip bonding, recall what was flip chip the active side of the die where you had this connection pads, that is flipped over ok, and then attached to the substrate alright. So, the first thing was in the and we saw that in flip chip typically most commonly, it is a ball grid array package, you have solder bumps or solder balls.

So, the flip chip bonding if you look at the entire process it has three distinctive steps. The first one is what is called the bumping of the die. Now, what is bumping of the die? Look you have a piece of silicon with some connection points on top. So, the first step is to have the solder bumps or solder balls connected on those connection points and that is not easy that is probably a very complicated process. The most complicated in this entire, in this three step process.

What is the second one? Second one is attachment to the substrate ok. So, what is the first one you have the piece of first one is typically again oh sorry the first one is strictly on the silicon side, on the chip side. I have the connection points I have to place my solder bumps or the gold bumps whatever it is at the corresponding connection points that is step number 1. Step number 2, you recall we will flip it over and then the substrate will come and the two of them have to get attached that attachment to the substrate is the second step. And the third step which is very important, and if you recall we were not talking about this, we saw mention of this one at several points, it is the epoxy under fill.

So, the flip chip bonding of the chip onto the substrate or chip carrier is a three step process, bumping the die or bumping of the die, attachment of the bumped die to the substrate, and finally the epoxy under fill process. So, what we will do next is we are going to cover each of them step by step, one by one ok; starting with bumping of the die. What is bumping of the die alright?

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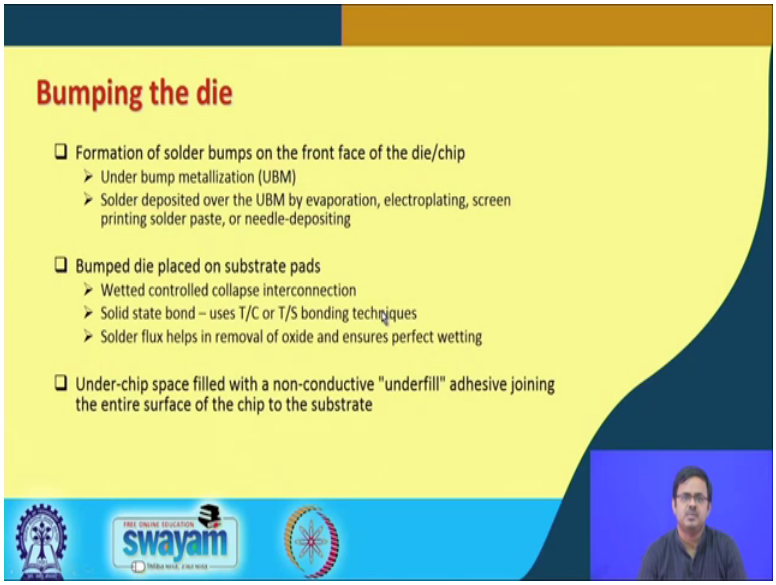

As we just said that it is the process by which the solder bumps are formed on the front face of the die or the chip ok. The front side which is where the connections are made, and which is what gets flipped over in flip chip, so that the back side now becomes exposed and the front side faces the substrate ok. So, if you look at this, there are under this process the first one in the bumping of the die, there is under bump metallization and then deposition of solder ok. So, we will cover each of these one by one.

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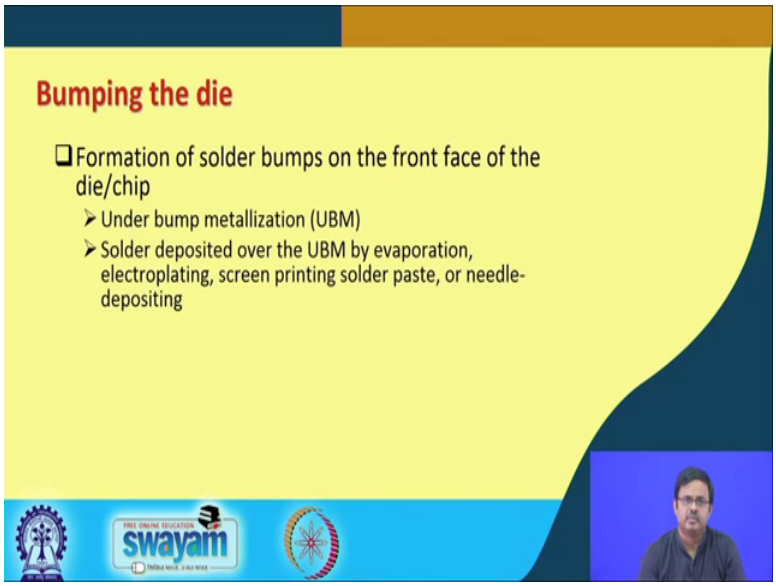

So, bumping of the die that is the formation of the solder bumps the first step is something called UBM standing for under bump metallization, clear. So, what is UBM, again under bump metallization why is it required we will come to that. So, after under bump metallization, you have the solder deposited by various processes some of which are written there ok. And we are going to look at these alright. So, once again the first step bump bumping in of the die has these two sub steps. The first one is UBM or under bump metallization, and the second step is in the formation of these solder bumps on the at the connection points which has now, and what is called the UBM coating.

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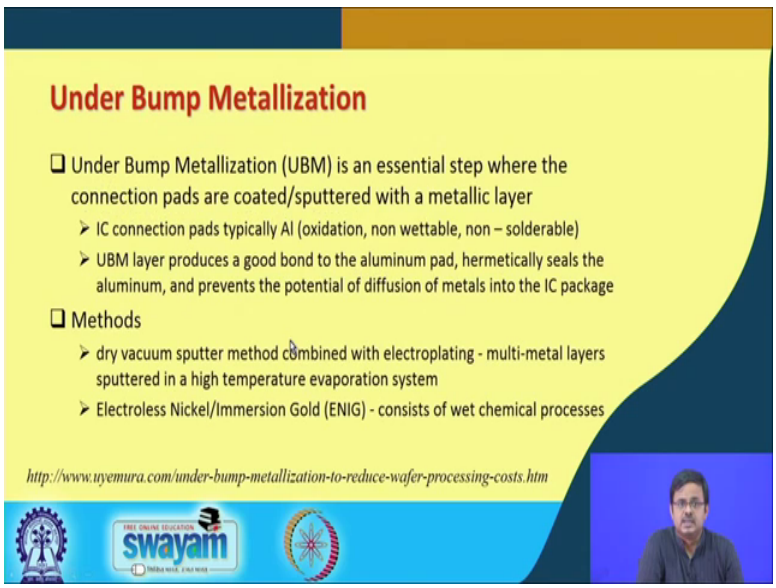

So, what is UBM in the first place? So, UBM is an essential step where the connection pads are coated or sputtered with a metallic layer. And the metallic layer is typically nickel, gold, or combination of both ok. So, it is an essential step where the connection points on the silicon is coated or spotted with a metallic layer. Now, why is it required look the connection points or the pads on the silicon are typically made of aluminum or some aluminum alloy.

Now, aluminum is not has several drawbacks that we need to keep in mind. Aluminum gets oxidized immediately almost immediately. If you expose pure aluminum to air an oxide layer forms on top in no time ok, and this oxide layer is typically electrically non conducting. So, it is not a desirable deposition or coating on the surface of the aluminum especially for the application that we are talking about.

Second one is aluminum is non-wettable, it is non-solderable, you cannot solder aluminum ok. Sometimes the connection pads are also made of copper, but there also you need under bump metallization because even though it does not have all the drawbacks of these, but that is also not a very amenable coating. But aluminum being most common I have mentioned some of the drawbacks of problems of having aluminum.

So, what does UBM do the UBM late layer produces a good bond to the aluminum pad ok. So, as I said before under UBM, it is a metal layer that covers these aluminum pads. So, this metal the UBM layer, it bonds well with the aluminum pad; it seals the aluminum hermetically ok. It is a hermetic sealing, so that it is prevented it is protected from the from the atmosphere, especially from the oxidation point of view if you think about it, and prevents the potential of diffusion of met metals into the IC package ok.

The other problem is when you finally, attach this die to the package then there may be diffusion of metal atoms from one layer to another. But this UBM the under bump metallization layer also has a function of preventing this diffusion of metals into the package ok, so that is UBM. And why it is required?

Now, what do we do to have this metallization or metallic layer deposited on the aluminum or copper connection pads. So, the first one which is most common is a dry vacuum sputter method ok. So, it is done by sputtering that is most common. So, you take this dig this silicon and then you have this metal sputtering process in an oven and

combined with electroplating ok. So, in a high temperature evaporation system, you have multiple metal layers that are sputtered, and therefore, deposited on these pads typically made of aluminum or copper ok. There is the most common method of under bump metallization or UBM ok.

The other one which is which has become more common these days even though it is not the most popular yet dry vacuum sputter is still the most commonly used, but this is also becoming popular it is called electro less nickel immersion gold E N I G or ENIG. So, this is where this is a different process it is an electro less process; it is not electroplating. And certainly it for less plating probably and it consists of wet chemical processes; it is a different process. We are not getting into details of these. But if you want to have more information about these various methods etcetera the drawbacks, the difference between UBM of aluminum and copper, then the link that I have given at the bottom of the slide that is quite good it is quite informative if you go there you will be able to find a lot more information on under bump metallization ok.

So, once again under bump metallization is the first step under bumping of the die. So, bumping of the die again involves it is a two step process, first is under bump metallization, so that is like preparing the surface of this of the chip for formation of these solder balls ok. And thereafter what we do is we do the actual bumping process. Now, how is the under bump metallization done, and why is it required as is shown on the slide, it is to protect the aluminum which has the drawback of getting oxidized. And the other thing is when you form the solder balls on top it facilitates that formation because aluminum per say is non wettable by solder, then therefore non-solderable ok. So, the under bump metallization helps in both.

The methods again dry sputter method is the most common and it is still the most pop commonly widely used. But then the ENIG method, the electro less nickel immersion gold that is also becoming popular that is has it is consists of wet chemical process it is not a dry process; it is a wet chemical process. So, if you have to do it, you have to do it in a wet lab, but it is told that the throughput of the process is more compared to the dry vacuum sputter method in that evaporation chamber ok. So, that is UBM, and there is the first step towards bumping of the die alright.

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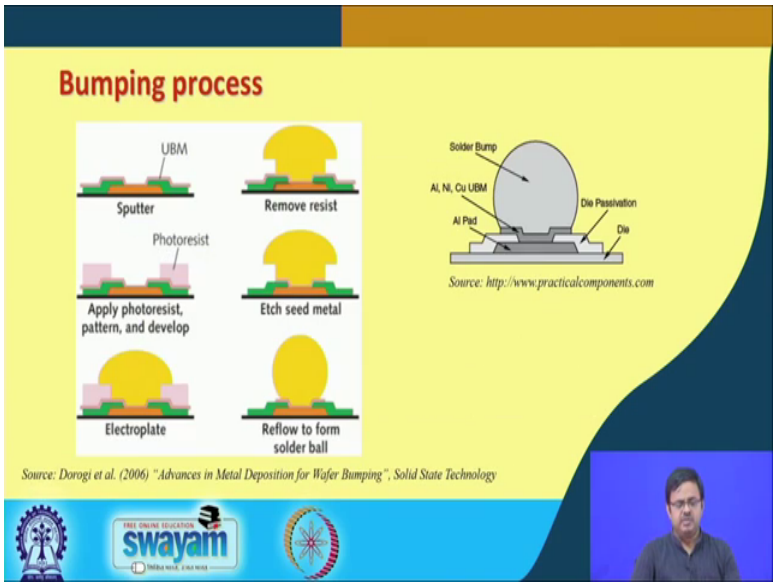

So, next what we will do is we will look at the bumping process. So, bumping process involves what it is the formation of the solder ball on the connection which now has the under bump metalized layer ok. So, the first thing that is done is as you can see the step one is the sputter process by which the UBM has been done. So, this one step one is where you had this connection pad and then you have an under bump metallization which is done. So, this light pink is what you can see over here ok. So, under bump metallization is complete.

Thereafter what is done is now you have to deposit solder on where right at this location, not elsewhere, not here. So, what do you have to do I have to prepare a mask. Remember photolithography that we talked about several lectures back, we will use the same thing. We will use a photo mask and apply that photo resist ok, so that is the photo resist with the with the pattern that we need. So, that just the areas where we want to deposit the solder is exposed, where we want to bump that is the area that is exposed alright.

So, thereafter what is done is through this electroplating process, I am showing gold over here, it can be soldered as well. Through the electroplating process the gold is deposited in the form of this bump ok. So, now, I have this arrangement. What next? I have to now remove the unnecessary or unwanted layers or components from this assembly which I am seeing over here in this bottom left diagram. So, the first thing I do not need the

photo resist. So, I need to remove that. So, remove it. We know how to remove. Therefore, it is removed.

Next is when I did a UBM, I did it on the entire surface. Now, these are places where I do not need I need the under bump metallization where the solder is going to come, but at the rest of the places I do not need it. So, why waste that metal take it out and so you etch metal away. And then this is how you are left with it looks like a mushroom is not it. Now, what that is not the final structure that we want alright. So, what is therefore, done is this structure with the gold or the solder is then made to reflow and it forms a solder ball which is typically spherical in structure ok.

The reason this is done is you reflow it in an oven, so that it just melts for a certain period of time, and then because of minimization of surface energy, it takes the shape of a sphere and thus forming this solder ball or the solder bump ok. So, this is the process of bumping. And if you look at the right hand corner right hand side picture, you see another schematic. And this is where again you if you look at it this is the die this is the aluminum pad the next one. So, aluminum could. So, we could not have deposited the solder bump on this aluminum this dark gray aluminum. So, I had to do and under bump metallization ok.

And now once I did the under bond metallization, I go through this process described on the left, and finally end up with the solder ball or the solder bump deposited over this site the connection pad that had the UBM layer. Agree? So, this is the bumping process ok. So, let us recap. Before we end today's lecture, let us recap. Bumping of the die what we saw was the first step under flip chip bonding and this is what we are talking about right now bumping of the die. Bumping of the die in turn has two major steps. The first one is under bump metallization, and the second one is deposition of the solid ball or the solder bump on the on that under UBM coated connection pad on the silicon die.

So, what we did was we looked through both of these processes and we looked at why is under bumps under bump metallization required, what are the different processes. And then once the UBM layer is coated on the connection pad, then what are the next steps to do the pumping the solder bumping. And as you can see it does involve some micro fabrication techniques as is shown here.

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And finally, at the end of this you get a structure in this form. This is a real picture a scanning electron microscope or SEM image. And here you see the die with the solder with an array of these solder balls deposited or bumped on the active side or the front side. And now this is ready to be flipped over and attached to the substrate ok, so that is the kind of what we were discussing today and that kind of wraps up the first part of our flip chip bonding process. So, today again to recap in this lecture, we started with tape automated bonding, and thereafter we got introduced to the first step of flip chip bonding which is bumping of the die. When we come back in the next lecture, we will complete the process of flip chip bonding.

Thank you very much.