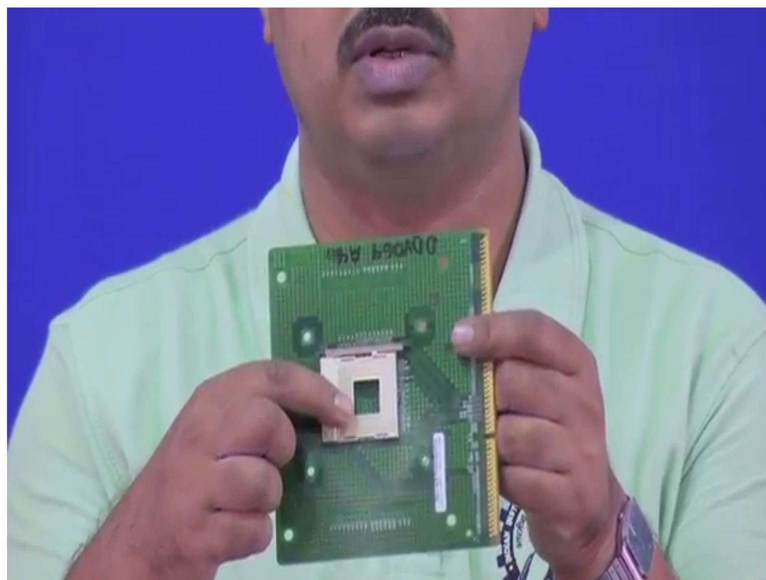
Electronic Packaging and Manufacturing
Prof. Anandaroop Bhattacharya
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 09
Area Array Packages - II

Welcome back to the course on Electronic Packaging and Manufacturing; and what we will do today is will continue our discussion on first level packaging. If you recall in the last lecture, we had discussed about this interconnect technology called pin grid array. So, we had seen what a pin grid array is and I had also shown you an example of a pin grid array as shown here.

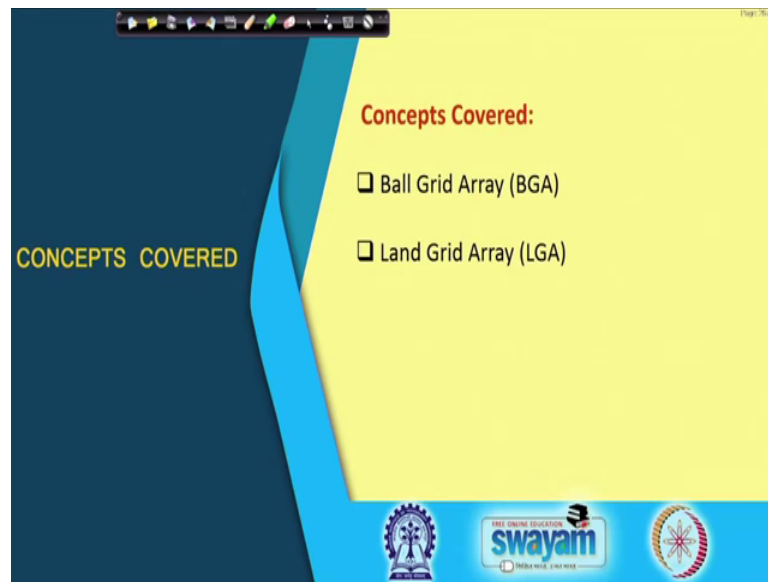
(Refer Slide Time: 00:43)



This is the package or the substrate on which the pins are attached right and then this goes inside a socket like this, as we had seen the last time ok. The pins will perfectly fit in these sockets which has corresponding holes.

So, what we will do today is, we will move on to some other types of packages. So, starting with something called the two that are going to that we are going to do today is called ball grid array and land grid array ok.

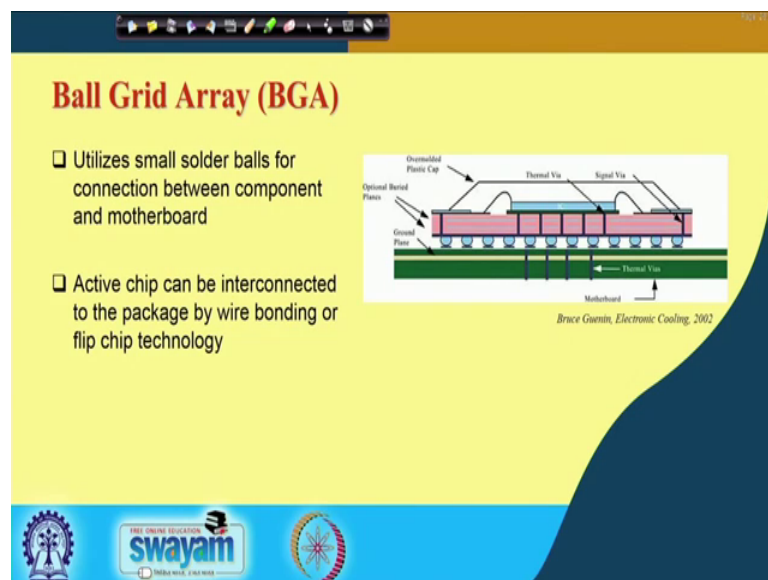
(Refer Slide Time: 01:25)



So, this is the concept that will be covered today Ball Grid Array or BGA and Land Grid Array or LGA ok.

So, let us talk about each of these the first starting with a ball grid array.

(Refer Slide Time: 01:41)



So, what is a ball grid array? So, we will spend a bit of time on this slide, trying to understand what we are talking about ok. So, the first thing if you look at the wordings the ball catering utilizes small solder balls for connection between the component and motherboard ok. So, unlike pins that we saw in pin grid array, here the interconnection or

the connection with the motherboard is through solder balls ok. And there are of course, different manufacturing methods and fabrication processes by which these balls are you know are put in place, but at this point let us assume that the balls are there, it is somehow it is possible to just have these solder balls positioned right at the places where these connections have to be taken out ok.

So therefore, instead of pins that we saw in pin grid array, we have solder balls that are connecting you know that are basically forming the connection between the corresponding points on the motherboard and on the chip carrier ok. Now inside this as you can see, the active chip that is connected to the package or the chip carrier by wire bonding ok. That is what you are seeing over here right. I have also written over here that it can be connection can be to the package through wire bonding or flip chip technology.

So, at this point just hold on to what flip chip technology is, because that is something we are going to discuss maybe two lectures from now. Flip chip is a different technology we are going to talk about that. So, at this point just do not pay too much attention to that term except that let it be there, because technically that is correct ok. So, what are we seeing here? We are seeing that we have this silicon, from the silicon we have these points from which these connections need to be taken out. And that is done through wire bonding and connected to the leads or the connection points on the chip carrier ok, which is also sometimes called the substrate, which we have used this chip carrier and substrate terms interchangeably. There is a little difference between the two, but for this point let us say this is basically the substrate on which this microprocessor or the chip sits ok.

Now, through the substrate from the substrate, typically in pin grid array or let us say in a dual inline package or in a quad flat pack package, we saw connections coming out from the periphery right. But now when we talk about area array packages we said we are going to take care take make use of the area under the substrate and an example that we saw in the last class is pin grid array. But here what is done is instead of pins coming out from the bottom of the substrate, we have these solder balls ok.

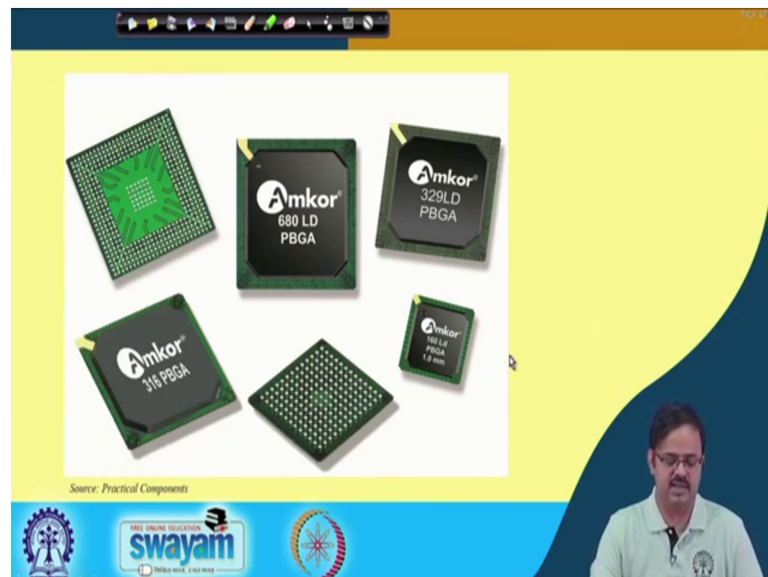
You see these, if you look at the cross section you see the solder balls, these blue circles as you can see and then this comes on the motherboard. And the motherboard will have corresponding solder pads. So, the balls are going to get connected on the corresponding solder pads as is shown here by you know you see this dark blue lines over here, these

are kind of the solder pads on the motherboard ok. So, this is how the connection is made.

The other thing that you can see over here which we are going to talk about later, but at this point you see some of these you know these lines that cut through the motherboard is called and denoted and named as thermal vias. So, these are thermal vias actually help in conduction of heat through the motherboard. I just want to make that passing comment here, because thermal vias are going are important and we will discuss it more again when we come to thermal design.

But thermal vias are very important because as you can see especially in this configuration which is a plastic you know package. So, plus you can see a plastic moulding on the top. So, the heat can only get transferred in the downward direction ok. So, it gets transferred through the substrate, and then into the through the solder balls to the motherboard and then through the motherboard to the bottom surface, from where you can either have an active thermal solution like a fan blowing air or it will just get dissipated by natural convection ok. So, I wanted to spend this time on ball grid array, just to explain that what is it that we are talking about ok.

(Refer Slide Time: 06:53)



Now, if we go to the next slide these are some pictures of ball grid arrays ok. Typically Amkor its a company, I believe it used to be based out of out of Arizona in US they may have shifted headquarters I do not know right now, but Amkor makes these micro these

chips and packages and as you can see that here these are many PBGA packages. So, BGA we just talked about ball grid array PBGA plastic ball grid array. So, this is a plastic ball grid array packages. So, from the top you will see it I mean it will appear like this.

So, this black or dark gray is the plastic moulding compound and on the bottom surface what we are going to see are these solder balls ok. You can there are certain specialized packages where the entire surface area can be used for solder balls as is shown in this bottom corner or you can see some packages, where there is a an area in the center that is left out ok. So, this kind of shows some pictures of BGA or ball grid array packages ok.

Now, unfortunately I do not have a ball grid array package to show you in this form and can you tell me why? The reason is obvious because ball grid array its a disadvantage that this once you make this connection to the motherboard over here, the solder ball is connected to the solder pad on the motherboard, it cannot be removed it is not detachable its not like a socket pin socket arrangement as in a pin grid array.

So, once it is connected it is a permanent attach. So, whatever these pictures that you see here especially on the bottom side or even here, these are before it is bonded to the motherboard. However, what I have with me is a again a substrate, where you can it is difficult to see, but I will try to show you here ok.

(Refer Slide Time: 09:19)

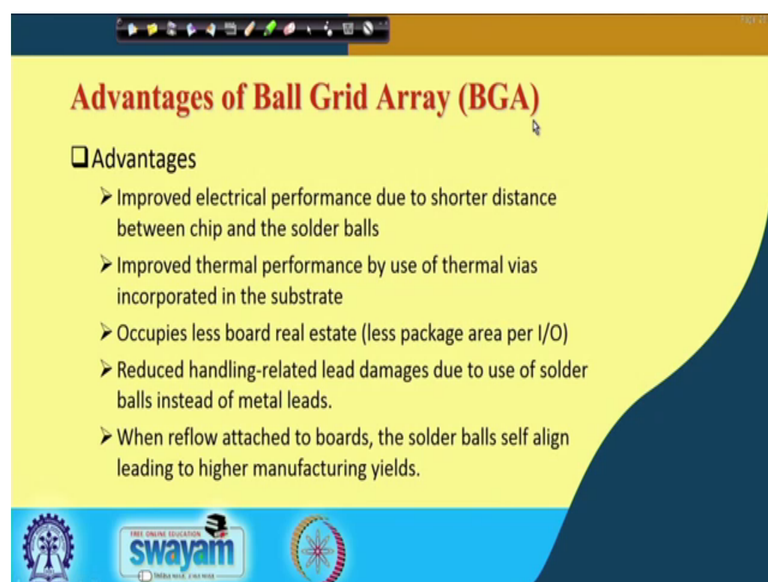
If the camera can zoom one on me so, again this is a motherboard, this is a piece of silicon and then this is the substrate ok. This little different green type is that that is the substrate. Now this substrate is bonded to this motherboard using a ball grid array and if I just go and as I said I cannot remove it, I cannot move it out and the reason is because it is permanent attached it is soldered.

But however, let me try to show you from the side if you can probably see, if you really zoom in you would be able to see the first row of solder balls between the underside of this above package and the motherboard ok. The other thing I want to tell you is over here what you can see is, there is a numbering on this side and there is also a numbering on this side and that denotes the position or the location of the of the solder ball.

So, for example, on one side you have you know abcd, on the other side you have 1, 2, 3, 4 this is a little damage package and that is why I have it with me because these are expensive. This was abused and damaged as you can see, but this kind of shows you that what is a ball grid array and the ball grid array as I said is difficult right now for me to show you a package like I could show for pin grid, because that is a removable part whereas, ball grid array is permanent attached ok.

So, what are the advantages of ball grid arrays? So, I have listed some of these and let us look at them one by one.

(Refer Slide Time: 11:13)



Improve electrical performance due to shorter distance between the chip and solder balls, you could see right away from the package that I just showed, the fact that this is a much thinner structure ok. The pins in a pin grid array is much taller, but however, in a ball grid array that is not the case. In a ball grid array, the balls are of much shorter height and as a result what happens is the electrical connections are much shorter ok. This improves electrical performance because there is no resistance there is shorter electrical paths compared to pins.

The next thing is because I could put thermal vias, this has a better thermal performance ok. So, because the solder ball directly forms a connection and end up and forms a path for heat disappear or heat transfer by conduction all right. So, improve thermal performance the use of thermal vias that can be incorporated in the substrate ok.

The other thing is; the pitch between the solder balls the requirement is much smaller compared to a pin grid array. So, therefore, it can have higher number of interconnects for a given area compared to a pin grid array ok. The other thing is once it is attached, the handling related damages is less in a pin for example, if I take it every time I take it out put it in etcetera there is always a possibility of having some of these slender pins and delicate pins getting damaged.

But in this one once you bond it, because it is not removable whereas, it poses its own disadvantages, but the good thing is that it is a much more robust connection in the sense now these connections the solder balls are not subjected to a typically not subjected to regular abusive handling, which can lead to damage ok. The other thing which we are going to see later is when reflow attached to boards the solder balls self-aligned leading to higher manufacturing yields.

Now, what does this mean? What it means is as I said before. So, this is your package with the solder balls right, and then you have a motherboard with what we call the solder pads correct. And then this by some way the solder ball has to be attached to the solder pad to form the connection right. The weight is done is through something called a solder reflow oven; where the motherboard is put in the oven and the package with the solder balls like what you see in this picture the package will the solder ball is going to come and be placed accurately by robotic arm it is called pick and place machines.

It is possible it is possible to have it very precisely positioned and automated ok. So, once the package comes and falls on the motherboard, then this entire structure or this assembly goes through this reflow oven. At the reflow oven it is heated to a particular temperature for the particular period of time and it is very important to have this time temperature controlled in the oven. And when we do that what happens is, the salted ball just melts and forms a connection and by the time it comes out of the oven and the temperature goes down, it resolidifies and the connection is made ok. So, this is how it is done.

So now, what is happening? That in one shot let us say this has 500 such interconnections on the package what will happen? In one shot all these 500 connections will take place. As a solder ball with the package flows through the oven, it melts and all the connections happen simultaneously. And then you can have you know a whole assembly line a conveyor belt having many of these package on the motherboard, and each of them will get the connections made as it flows through the oven.

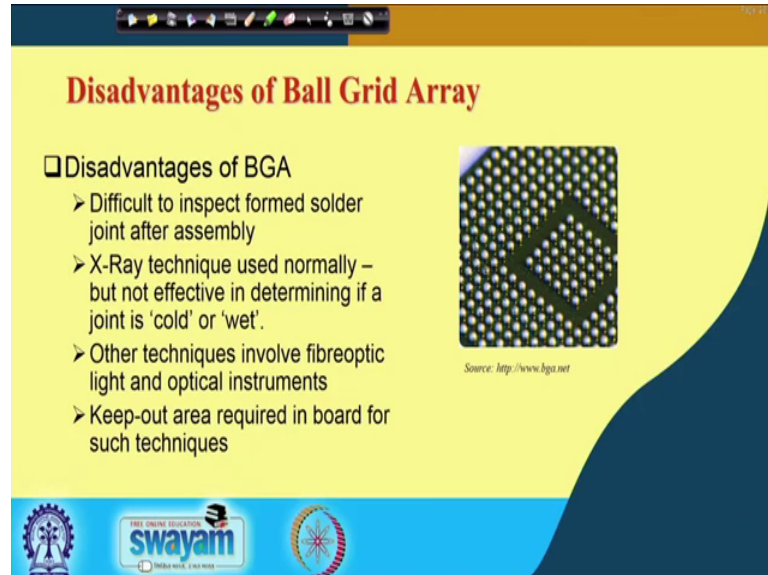
So, this leads to very high manufacturing yields ok. The other thing the self-alignment of the solder ball that is from mechanics point of view and basically force balance, the solder balls how does it form this perfectly shape it balls? They are not exactly spheres because at the two ends there are connections.

But they kind of self-aligned and hold them hold in place hold themselves in place ok. And that happens because of the balance of forces and surface tension; thus play a major role minimization of the surface energy ok. So, there is lot of lot of research work that has happened on this one, on solder reflow the self-alignment so, on and so, forth ok. But these are the advantages of ball grid array let us just go through them one by one now that we have explained each point.

Improve electrical performance because the electrical path for transport of signals electrical signals is shorter. You can you can put thermal vias. And therefore, that forms a path for heat to get conducted ok. So, improve thermal performance. Now the BGA the solder balls can be very close to each other ok. The pitch requirement is smaller compared to a pin grid array. And therefore, for a given real estate for a given surface area you can accommodate more number of interconnects ok. That a disadvantage of ball grid arrays it is a permanent attach, but it also you know protects it from any abusive

handling. And finally, we just talked about the reflow process, which leads to high manufacture which can lead to high manufacturing yields ok.

(Refer Slide Time: 18:09)



So, all good so, far, but everything comes at a cost. So, everything cannot have only advantages ok. So, ball grid array also has its own disadvantages ok. And the first one is you know it is difficult to inspect any deform solder joint or any damaged solder joint inside we summer sometimes can use an X-Ray techniques XRD and all that, but its not very effective and we are talking about you know a lot of these solder balls as is shown in this picture ok. It is very difficult to have especially for the internal layers, proper visualization non-destructive visualization technique to see if the joint is actually formed or it has not formed ok.

When we say if a joint is cold or wet; cold means the connection is not formed maybe while it while going through the reflow process something happened maybe there was some curvature in the on the board or the package etcetera, for which this solder wall could not connect it melted, but then it again solidified and the connection did not happen there was a gap ok. There was gap between the two it should have touched, but it did not now how do you inspect that? Very difficult; let us look at this if there is a defective solder joint inside I just cannot make out because this is all I can see.

If even if I try my best I can only see probably the first layers nothing else right. The X-ray techniques thus let you go in, but again is very difficult ok. So, solder joints thus

have a problem. The other problem I would say is that if the any of these solder joints go bad or even this package goes bad, I have to throw away the entire chip entire motherboard. Well this is a test board which just this package on, but in an actual reality there are the motherboard contains many other equipments, many other components or packages; if one of the BGA packages go wrong most likely you will have to throw it away ok.

So, that is the problem of ball grid array packages that is the drawback. I think I remember I told you an example that I had a very thin laptop and these were all BGA attached. The problem what happened was one day my display was not working, and when I took it to the when I took it to the repair shop they just said that you know these are all ball grid array connections and so, you have to completely change the motherboard. And the cost of changing the motherboard along with all the other components was almost close to buying a new laptop ok. So, that was the problem. It is very difficult to rework these defects ok.

So, that is what the ball grid array the disadvantages are. The visualization is a problem and if there is a defect you have to throw it out. The apart from X ray there are some other techniques, really fiber optic light optical instruments etcetera, but again they have all have their limitations. Not so, in other words it does not give you the flexibility of a pin grid array or a connector type ok. So, that is the problem.

So, today what we have learnt is about, a new type of package known as the ball grid array packages ok. What it does is; if the connections are instead of pins are through solder balls and we saw a different pictures different configurations, what is done and how it is made the advantages and disadvantages ok. So, in the next class; so we will wrap up this class right now or this lecture for now. And what we will do is, when we come to the next class we are going to talk about another technique or another interconnect technology known as the Land Grid Array LGA ok

Thank you very much and see you in the next class.