An Introduction to Electronics Systems Packaging

Prof. G.V.Mahesh

Department of Electronic Systems Engineering

Indian Institute of Science, Bangalore

Module No. # 07

Lecture No. # 37

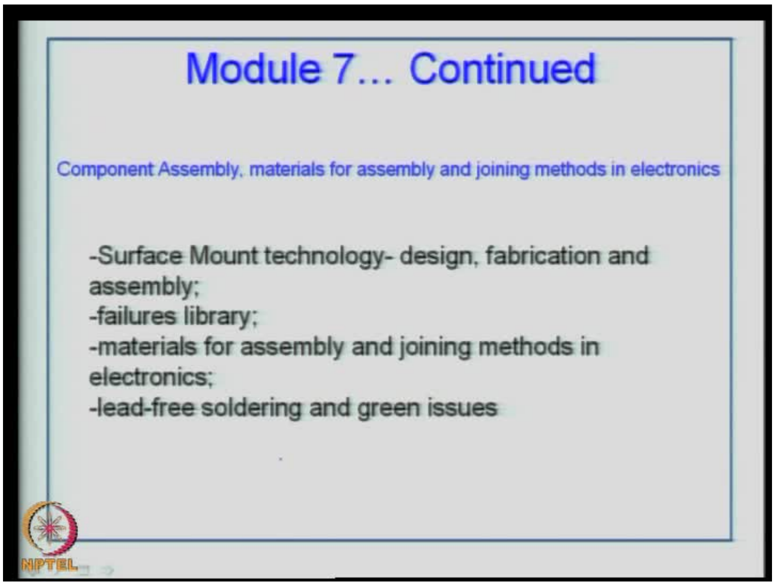
Tin-lead and lead-free solders

Phase diagrams

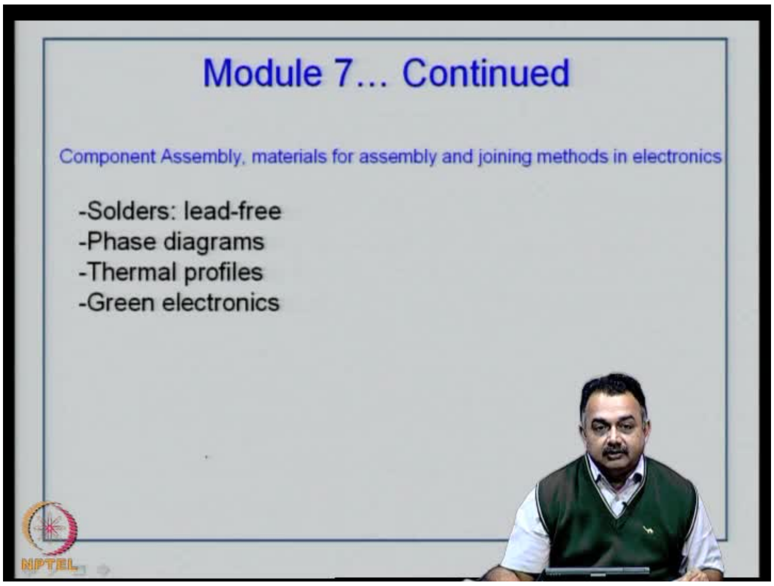
Thermal profiles for reflow soldering

Lead-free alloys

(Refer Slide Time: 00:15)



(Refer Slide Time: 00:34)

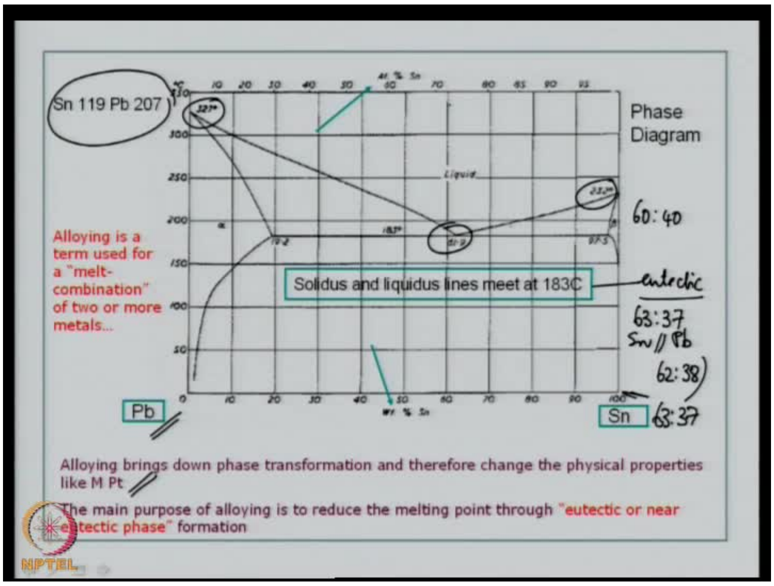


We will continue with the module 7 of this course an Electronic Systems Packaging. In this particular module, the lecture that we have or the topics that we have covered includes all the assembly techniques. In the previous lecture, we have seen the defects or in other words, the previous library have been extensively dealt with and we also look at Lead-free solder materials.

So, today we are going to continue with the materials issue and issues like thermal profiling, that looks very important today in the industry, when you are going to assemble thousands of boards. There are certain entities like the substrate property, the component properties and the solder paste material properties, which together define the thermal profile. So, we are going to spend sometime today on materials, phase diagram of Tin-lead, then the thermal profiles, different thermal profiles that can be set. This is true, if you are doing even prototyping in your lab and then for the industry becomes a very large item that needs careful consideration by designers, manufacturers and the EMS that is the Electronic Manufacturing Services people, which includes the assembly sector.

So today's topics will be Lead-free material, phase diagrams, thermal profiles and we will also spend some time on green electronics, that is materials that are banned in the industry and new materials that are being used by the industry today; so that it contributes to the green environment.

(Refer Slide Time: 02:26)



The first thing that we are going to discuss today is the Tin-lead phase diagram. Although on the one hand, we are talking about phasing away lead and using Lead-free material, but academically I would like to give you some information about the reason, why Tin-lead has been used. In countries like ours, we still use Tin layer and we do not have a complete legislation yet on the removal or banning of lead in our industry, but never the less our industry is also using Lead-free solder material to meet the requirements of end customers or for products that are being exported to other countries.

So, if you look the phase diagram- many of you aware of what a phase diagram is and in this case it is a Tin-lead alloy. So, here on the left side you see 0 percent Lead and here you can see 100 percent Tin. Now if you look at mixing Tin-lead, individual metals to form an alloy and then if this phase diagram represents the mixing of the individual metals and we can see that the solidus and liquids portions of the Tin-lead material, meets at 183 degree centigrade and that we call as the eutectic composition or eutectic melting point of Tin-lead, which corresponds to 63:37; that is 63 percentage of Tin and 37 percentage of Lead.

This is the very common material that is being used in the industry for decades and the reliability of this solder alloy has been well established. So, alloying is a term used for a melt combination of two or more metals and in this case it is Tin-lead.

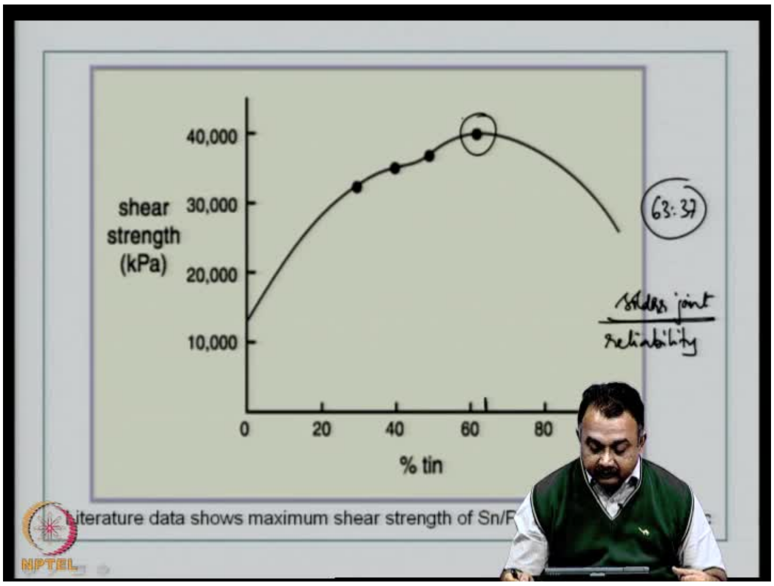
Now, what does alloying do? Alloy brings the phase transformation and therefore changes the physical properties like melting point, which is exactly what we have achieved by mixing Lead with Tin. So, the purpose of adding Lead to Tin is to reduce the melting point, because individually the melting point of Tin and Lead are very high. So, the main purpose of alloying is to reduce the melting point through eutectic or near eutectic phase formation.

So, if you look at this diagram here, this is the melting point of Tin and here you can see 327, the melting point of Lead and then when these two are mixed, there are various compositions that are obtained during the mixing. Obviously, in the electronic industry 63:37 are not the only composition that has been used. There have been composition like 60:40 Tin-lead and high lead content or high Tin content compositions have been used by the industry for various purposes or applications.

So, this is the liquids phase and then you can see bottom is the solid as phase and then you can see various compositions being formed and then the eutectic temperature is 183; so this eutectic is 183. The composition here will be 63, 37 and now there are impurities in the individual metals of Tin and Lead. So earlier, it was assumed that 62, 38 would be the eutectic temperature, but because of the impurities added it was later reassigned that including impurities which are very difficult to remove, because they are in traces. 63:37 is the ideal composition at the eutectic phase formation of the Tin-lead phase diagram.

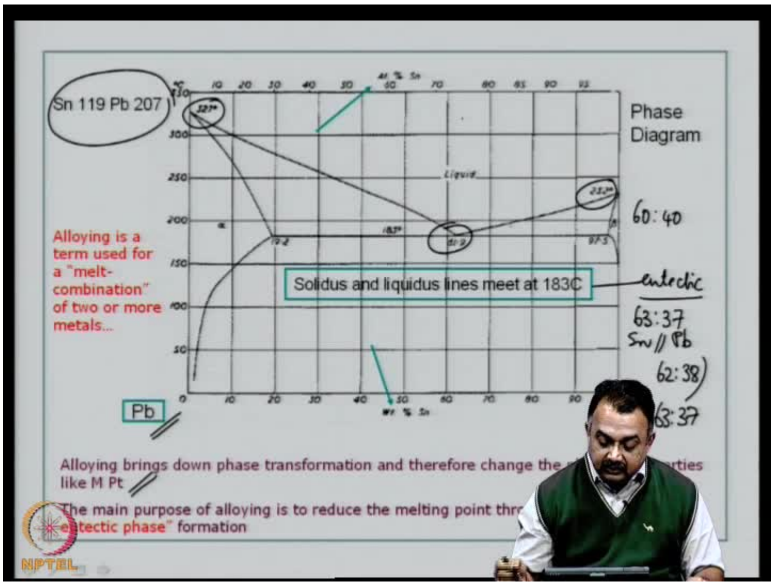
Now, the reason why I have put this number here is the atomic ways of Tin and Lead. If you look at the atomic percentages of Tin and Lead, then it will be slightly different from the weight percentages. The 63:37 that we are talking about is actually, the mass- weight percentage compositions of Tin and Lead. So, one needs to understand the Tin-lead phase diagram, because if you are choosing alloys of Tin-lead in electronics other than 63:37 you need to know the melting points, which will definitely be higher than 183 for all other systems.

(Refer Slide Time: 08:26)



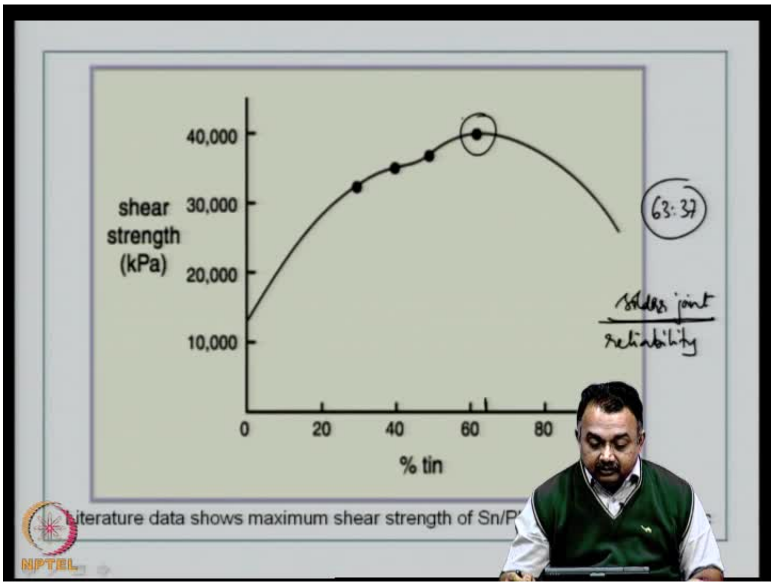
So, here if you look at the importance of understanding the Tin-lead phase diagram and why we choose 63:37, one of the studies that have been done over the years is that literature shows maximum shear strength of Tin and alloy at 63:37 eutectic, because when you are talking about solder joint using Tin-lead alloy, we are worried about the solder joint reliability. So we need a joint that is highly reliable than other and can withstand various thermal cycles when a Printed Circuit Board is powered up and when it is subjected to extreme conditions of operation. So, here you can see that at the 63:37, the shear strength is at the maximum that gives obviously most favorable condition for solder joint formation.

(Refer Slide Time: 09:34)



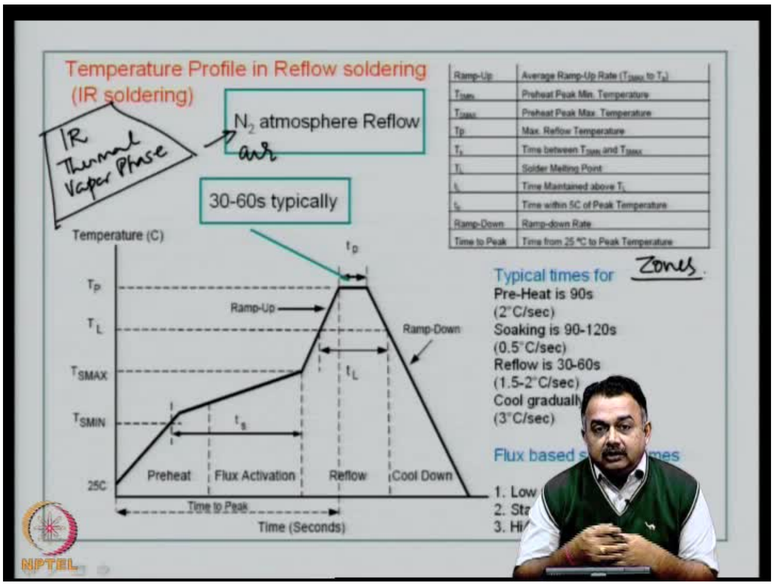
So, coming back to this Tin-lead phase diagram there are two things that you must know: You can look at weight percentage, for interpreting the exact materials of the percentages of Tin and Lead or you can simply look at atomic weight percentages of Tin and Lead. So, we will get different compositions.

(Refer Slide Time: 11:15)



So, depending upon the package, different packages use different Tin-lead alloys. It is not very universal throughout. A BGA package can have 63:37 solder balls and it can also have 60:40 solder balls. A QFP package, which has got a Fe-Ni 42 base frame, can have a Tin-lead coating or plating with composition of 63:37 or 60:40. In some cases flip chip, we have seen they use high Lead content 90:10; 10 percentage of tin. So you need to look at the package data sheet to understand what kind of balls- solder balls or what kind of plating has been used in the pins of SMD components or through hole components. This is very important, because you are going to understand the effect of melting point, the solder paste melting point and the substrate TG; all three are very important in deciding the thermal profile of your reflow process or your wave soldering process. Typically thermal profiles are very important for doing a reflow process in a wave obviously, you are using molten solder for through hole components and a few SMD devices.

(Refer Slide Time: 11:49)

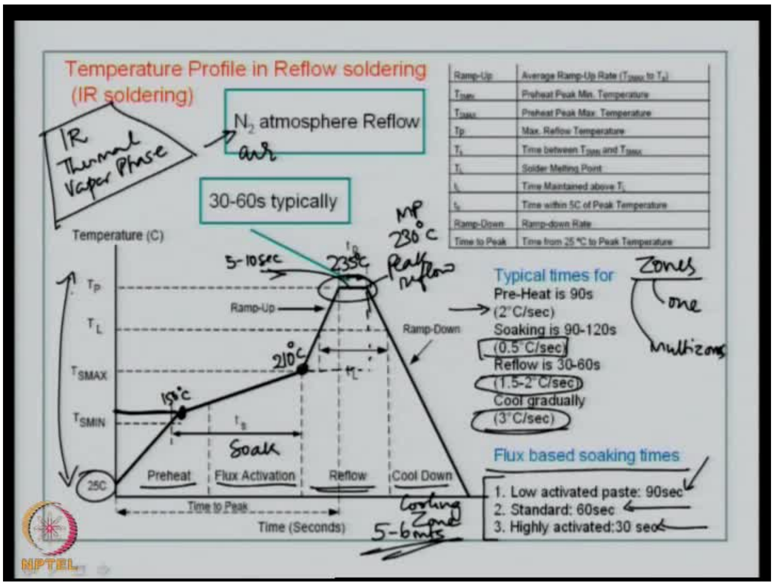


So, this lecture we will focus on reflow process and the reflow thermal profile. What I am showing here is temperature profile or the thermal profile in a reflow soldering process. Let us say IR soldering reflow; soldering as you know, are of three types: the first one could be by IR; the second one could be just by thermal convection air; and third one could be vapor phase. We have seen all these three types of reflow soldering processes.

Now, the atmosphere for reflow could either be just air or it could be done in Nitrogen atmosphere. The influence of air or Nitrogen in the reflow process goes with the experience and goes with the careful study of the components that are used and the solder paste material, there is being used. Now, we are going to look in detail at this thermal profile and typically, understand what are the zones in reflow soldering process.

So, we are worried about the various zones that the board undergoes. Now, for you to recollect- recap at this stage: there is a Printed Circuit Board, which has been fabricated. It could be a high density interconnects board or it could be a double sided board or a conventional multilayer board. Now you are going to do reflow soldering, let us say in air. Now, the process steps for soldering would be applying the solder paste, pick and place the component do a tacky cure at room temperature or at low temperatures for a very short time of 5 to 10 minutes, and then you send it to a reflow soldering.

(Refer Slide Time: 14:28)



Now at the reflow soldering, solder paste will melt. It will fuse with the component leads and then realign itself so that there is no miss registration. The surface tension of the solder is good enough to pull back the component to its original coordinates. So, that is the process step for soldering and now in typical industrial setup when we do machine soldering, there could be various zones for reflow soldering. Now if you look at this graph here, you will understand the various zones that have been used in a large volume setup. Typically, in a lap scale you will have just one zone and you can easily finish the process, of course you can set the thermal profile for that single zone, but in industry you can have multi zones for reflow soldering.

Now, you can see the terms here preheat, that is a preheat zone flux activation or you can call it as a soak zone; then you have the more important reflow zone; then finally, cooling zone.

Now typically in industry, huge machines are available with zones perfectly defined. That means the board will first go through the preheat zone, then the temperatures will vary for the flux activation zone and then it will go into the more important reflow. It will attain the peak reflow at this stage and then the board will be slowly cooled down to room temperature- cooling should be a very slow process. You should not immediately remove the board after the peak reflow is done, because that will be a bit of a thermal shock. Therefore, cooling process also has to be well defined.

Now the terms referred here and I will try to explain. We start with the room temperature, let us say 25, then it slowly moves to a predefine temperature. Let us say that is known as the preheat peak minimum temperature and maximum temperature can be defined. So typically, somewhere here could be your first air mark for defining the preheat zone from room temperature and this could be typically from 25 degree centigrade to let us say 150 degree centigrade, depending upon your TG of the board. You want to activate the board; you want to activate the interconnects the Copper and then you are also removing moisture from the components. Remember we talked about moisture and trapment in capacitors in BGA packages, in epoxy packages and so on. So, when you are having such a situation, where you might be having large number of epoxy based packages or tantalum capacitors or ceramic capacitors, you want to remove the heat slowly and gradually. So, you do not want to hurry up in this preheat zone.

So this typically should be done at 2 degree centigrade per second and you can have a preheat zone, dual in time of about 90 to 110 seconds. So, that is the kind of guideline that I can give you for preheat zone. Now, once the preheat maximum temperature has been reached, you move into the activation zone. The important point here that you have to consider is, activation zone will be crucial for the solder paste getting activated. Now let me take your attention to this bottom of the slide, where I have talked about flux based soaking times.

The solder paste contains flux. As you all know, it also includes some kind of an adhesive, because it helps in pick and place. It contains an epoxy media in it and contains flux; flux is necessary for soldering and we have seen it improves wetting, Prevents corrosion and so on.

We have also seen different kinds of fluxes in our previous lectures. So, the dwell time for soaking zone should be based on what kind of flux you are using in the solder paste. If you are using a low activated flux, then it is known as a low activated solder paste and the dwell time should be larger compare to a standard flux, where the dwell time is about a minute or so. If it is the highly activated flux, that means the flux in the solder paste is already activated, then you can reduce your soaking time.

So typically, from this let us say, in this case 150 to range where you are going to start the reflow process. Now, here this is the peak reflow and this is the guideline that you need to have, when the information like the melting point of the solder paste needs to be very clearly understood. Suppose you are using a solder paste, which melts at 230 degree centigrade; so your peak reflow should be over around 230. So, ideally you would like to keep about 2 degrees to 5 degrees, more than the defined melting point of the solder paste.

So, typically your peak reflow in this case could be 235 degree centigrade, if the melting point of the solder paste is around 230. So, the reflow zone actually starts from here and then goes up to this point. So, the rate of heating will be different for preheating zone, soaking zone and the reflow zone. Reflow zone activity should be fairly less time consuming, because you do not want to expose the board, the components and exceed the temperatures that are defined for thermal shock of components and so on.

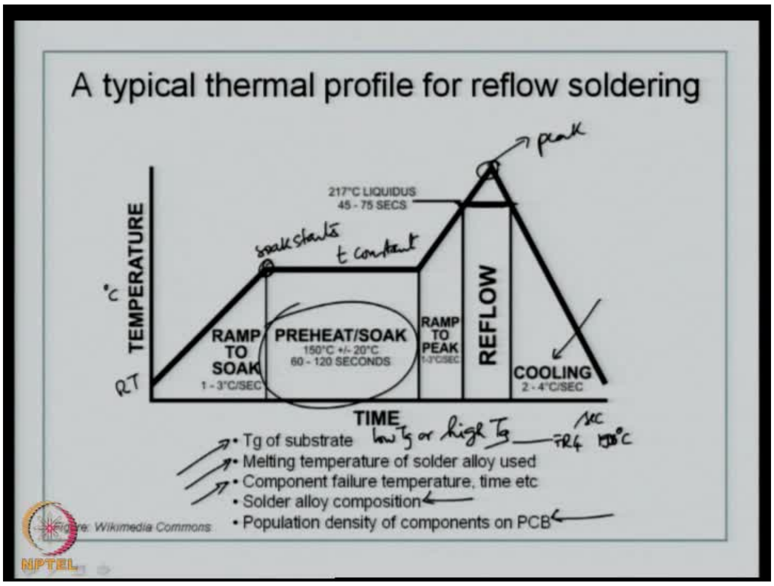
Soaking zone can be large. So, typically from 150 degree centigrade to let us say 210 or 220 can be a typical reflow profile for a solder paste, which is melting at 230 and then from 210 to 235 can be your reflow zone. Soaking temperature like for example, it should be very slow 0.5 degree centigrade or 0.75 degree centigrade or maximum 1 degree centigrade per second, should be the heating grade that you should set in your equipment for the activation zone or the soaking zone so that your solder paste works up quite slowly. The advantage is that, there would not be any solder beat salvation; there would not be any spattering of the solder paste material; and you will have a very good activated solder paste ready to reflow.

At this stage- all the solvency are gone, the flux is activated and the Tin-lead is ready to fuse with your component leads. So, from 210 to 235 will be your reflow zone; this should be fairly fast, 1.5 degree centigrade to 2 degree centigrade per second. Then you can have every small resident stain here at the peak reflow for about 5 to 10 seconds. In some cases it could be larger and then you can start the cooling zone. So, cooling has to be gradual, you cannot immediately remove the board from the cooling zone and then try to finish your process faster. Remember from 230 degree centigrade to room temperature has to be done at something like 3 degree centigrade per second or 4 degree centigrade per second.

So, the entire process you can expect from the four stages we have defined: preheating zone, the flux activation zone, the reflow zone and the cooling zone. Typically, it should end about in 5 to 6 minutes.

So again, we are talking about industry; we are talking about yield and throughput of this machine. Therefore even 5 to 6 minutes could assume to be a larger time, but again the industry people know better in terms of what kind of combinations of components, material they are using. So in any case, in reflow zone you can accommodate quite of few boards in a particular batch and depending upon the conveyer belt size and so on. Therefore, it can never be less than 5 minutes process cycle typically, takes about 5 to 6 minutes. So this is what information I would like to give about what a thermal profile, because we have been talking about thermal profile for some time now. You need to know very important issues regarding time- for reflow time, for activation, preheating and cooling and then the various temperatures that you need. You have a flexibility in defining these points; this is left you as a designer also you need to understand this. If you understand this, you can interact with your assembly guys much better and you can get the product that is a finish board in much better reliable condition.

(Refer Slide Time: 25:05)



Now, this is another thermal profile for reflow soldering. The earlier one you can see the shape of thermal profile is quite different and now here you can see there is no residence time and there is a peak here. There is no residence time for the board that the board spends at the peak reflow zone. So, that depends again on your judgments of all the various parameters.

Now let us look at part of the zone here, on this axes you have the temperature and you have the time; time in seconds and temperature in degree centigrade. Then this is the room temperature, you are going to start with and then this is the ramp up zone; straight away you are ramping up to the soak zone; the soak zones start here.

Here you can see, compare to the previous slide the soak zone is maintained at a particular temperature; here temperature is constant for a particular time, then the ramp up to the peak reflow starts and like the earlier one, where you had residence time here, the peak reflow is attained and immediately it starts cooling. This is very useful when you have narrow process windows based on the melting point of the solder or the TG of the substrate or the type of flux that is used in. In some cases, if it is a very reliable solder paste material and if your very sure of the reflow process being done at up a smaller window, let us say plus minus 2 degree centigrade, then this kind of profile can be used, but if you are using a materials which you have not used before or if it is having low activated paste, then you want to keep more residence time at the peak reflow.

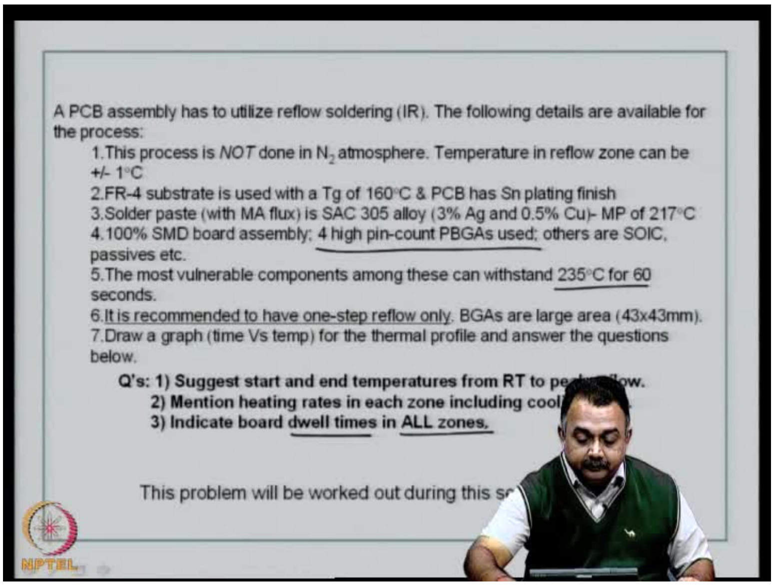
So, these are the two basic thermal profiles that you can see in literature today and you can fine tune it or change it according to your requirement. So, once again here we have cooling; typically for example, 2 to 4 degree centigrade per second, it is up to you to have a more dwelling time at the peak reflow or you can go up to the peak reflow and then get back to the cooling zone immediately and then here the most important thing visible, striking difference between the previous graph. This one is that, the board spends a considerable amount of time in the soaking zone.

Now the important things, anyway which you must consider for any thermal profiling is that look at the TG- is it a low TG substrate or high TG substrate, then you can fix a process window ideally, according to that.

Today most people are using FR4 with a TG around 190 degree centigrade; so you have more flexibility in defining the preheating zone. Then the other thing I want to repeat, melting temperature of solder alloy that is to be used. In certain cases, you have a problem if you look at the entire bill of materials, your component list; there will be one component, which says this component should not exceed 230 degree centigrade for more than 45 seconds. The component is vulnerable to such a residence time during soldering. So, in such cases you have to be very careful in deciding the peak reflow or choosing the right type of solder paste for mounting that component or if it is only a single component in the entire batch, then you can do hand soldering of that component if it is feasible; otherwise these considerations become very important. The other thing is solder alloy composition and then the population density of components on your PCB.

Remember if you have a high density board, you can do reflow soldering. Parts of it can be done by manual soldering like your through hole connectors and a few through hole components. You can do double reflow, that is if you have double sided assembly, then the board can be subjected to twice reflow. So this is the maximum, generally as a guideline, as the rule of thumb; you can take it that a double sided board assembly can undergo thermal shock through soldering process twice. Typically in dual reflow process, a few components have to be mounted by manual soldering. If you have to use wave soldering let say, then it could be one wave one reflow or it should be dual wave for double side. If you have such a kind of the choice of components and if you have 2 reflow processes and then a wave, then it becomes too much of a thermal shock for a substrate as well as a few components. So use a judgment in understanding the layout of your board as we saw the assembly process.

(Refer Slide Time: 31:05)



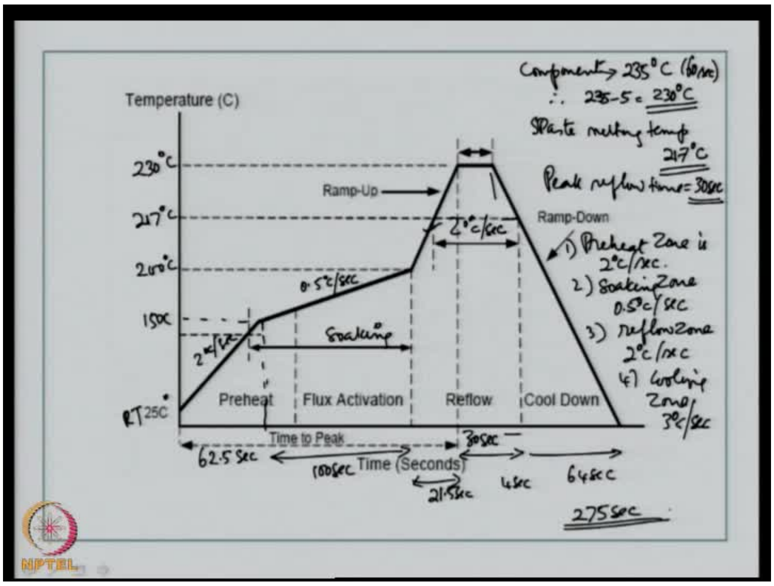
Now, what I am going to show here is a problem for us to work out today and see how we can understand, because I feel for designers this is a very important issue. Very often the board is manufactured and then you give your components to assembly personnel in a EMS. Then if you do not interact with them on the circulates involved, which will make a large count for reliability, then you have problem. Therefore, I like to spend a few more minutes on understanding thermal profile, because as a designer if you can give this information to the EMS, then your board comes out well assembled. So, I will take a simple example. I will read it out- a PCB assembly has to utilize reflow soldering, let us say IR or it could be thermal, that is not a major issue. The falling details are available for the process. The process is not done in Nitrogen atmosphere that means it is done in air. Temperature in reflow zone can be plus minus 1 degree centigrade and that is the kind of setting, because it is done in Nitrogen atmosphere. FR4 substrate is used for this assembly and with a TG of 160 degree centigrade and the PCB has a tin plating finish, not Tin-lead- tin plating finish. Solder paste with mainly activated flux is used in the solder paste alloy that is a SAC 305 alloy. So, SAC 305 alloy is basically Tin Silver Copper alloy, where the percentage of Tin is 3 and Copper is 0.5 percent, which has a melting point of 217 degree centigrade. It is a 100 percent of surface mount device assembly and there are 4 high pin count BGAs, plastic BGA that are used and others are small outline IC passives etcetera.

The reason why I am giving this information is that if you have a high pin count PBGAs, let us say there are 800 solder balls to be soldered then you have to give more residence time for all the flux that is being used under the plastic BGA to get activated. You also consider giving more residence time at the reflow zone, so that we will not end of with the plastic BGA, where 30 percentage of the solder balls are not at all attached or reflow.

So, make a point about this, why I am giving this in your board. In your system, you could encounter such day-to-day problems and the most vulnerable component among the entire components that are being used in this design can with stand 235degree centigrade for 60 seconds only. So, that clearly defines your peak reflow zone residence time and it is recommended to have a one-step reflow only.

BGAs are large that means if it is double sided boards, then one side undergoes the reflow and the other side undergoes another reflow process only. There is no other process involved here. BGAs are large, so that is also given here 43 by 43 millimeter. So draw graph, time versus temperature for the thermal profile and answer the questions below: suggest start and end temperatures from room temperature to peak reflow; mention heating rates in each zone including the cooling zone; indicate board dwell times in all the zones.

(Refer Slide Time: 35:24)



So now, we are going to work out this problem. Now, if you are going to assume this kind of a graph, then what are the parameters that you can set? The first thing that if you look at the problem is that the vulnerable temperature for components is 235 degree centigrade and component vulnerability- we have seen that there is a component, which if it exceed to 25 during centigrade for 60 seconds, then it is vulnerable for failure. Therefore, you can keep the peak reflow temperature at 235, that is see minus 5 degree centigrade which could be 230 degree centigrade. That is the first information that you can get and then the solder paste melting temperature is known, it is given to you that is 217 degree centigrade, that information you have.

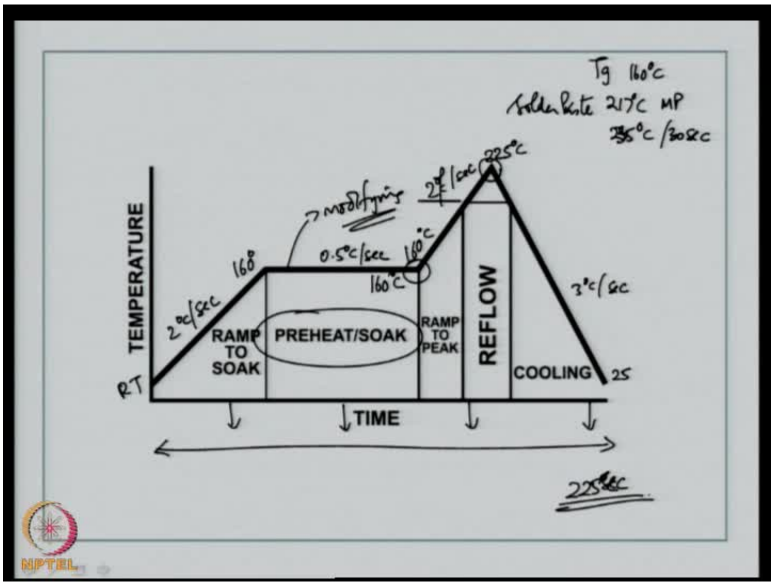
Now the peak reflow temperature time, because we are talked about the component; so the peak reflow time can be kept as 30 seconds and it is a tight guideline process window, but 30 seconds is accepted. Now, the other things that you can consider is the ramp up rate in the preheat zone is what you have to consider now; preheat zone is typically, we can choose 2 degree centigrade per second- first thing.

Second thing is, soaking zone or the activation zone here you can keep 0.5 degree centigrade per second, then the third one is to achieve peak reflow that is to go into the reflow zone, you can keep it at 2 degree centigrade per second, because if you look at the problem it uses mainly activated flux. So the soaking zone- it is fairly slow, but you can keep it for a longer time.

So this can be 2 degree centigrade, although ranges are different as we have seen. Now the cooling zone, cooling zone can be 2 to 4 degree centigrade, but will keep it as 3 degree centigrade per second. So these are the basic analysis that we have done now. So this is time and temperature and here we can keep it as 30 seconds peak reflow and this is 230 degree centigrade. Now, the other one here if this is 2 degree centigrade per second, then we can have this temperature around 217 degree centigrade. Then we can have this is 200 degree centigrade and then here it could be around 150 degree centigrade. So, preheat zone- this is 25 degree centigrade room temperature typically could be, if it is a 2 degree centigrade per second. So, 25 to 150 degree centigrade- this could end up in 62.5 second.

Then we have the soaking zone or the activation zone. We said it is 0.5 degree centigrade per second and so this could be 100 seconds. These are ideal because we have seen the conditions for this board. Then this one, the ramp up which is at 2 degree centigrade per second. This will be around 21.5 seconds and then this is 30 seconds, we have seen residence time. Then you can create a window here, this one could be about 4 seconds and then the cooling takes place at 3 degree centigrade per second. So, this will be over in about 64 seconds. So, if you add up the total time requirement from start to finish, could be about 275 seconds. It is less than 5 minutes, the entire board is going through the various zones including the cooling zone and then we can expect that the flux is activated properly and the solder paste is melted completely, because of the volumes involved especially, a plastic BGA which is used and in this particular problem you are talking about 4 such plastic BGAs of large size that is 43 by 43 and this is a good guideline. So, you can work on this problem and if you have any other suggestions on to how you can improve this total time and the temperature definitions for the various zones you can work out and then get back to me by email.

(Refer Slide Time: 41:21)



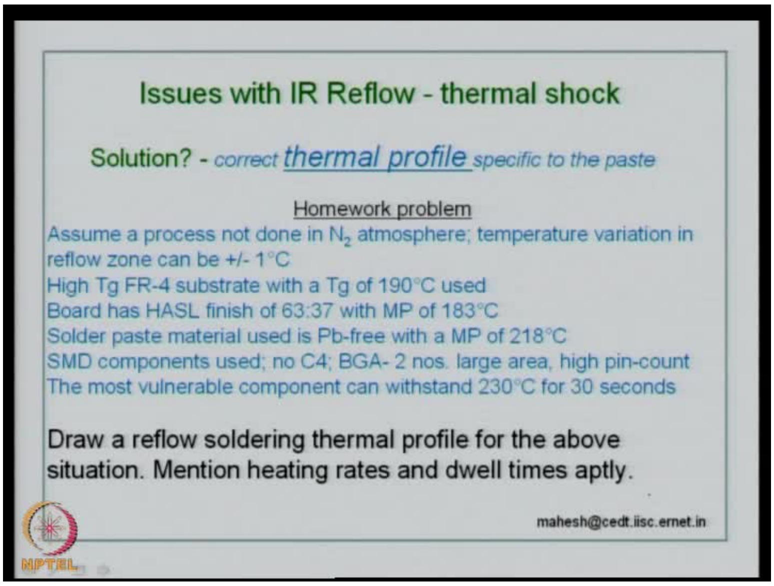
So, this is one situation that we have worked out and now the other problem that also I would like to explain if you are looking at the same problem using the other thermal profile. So here again same considerations, the TG is 160, then the melting point is 270 degree centigrade for a solder paste.

Then the vulnerable components, thermal soak is at 235 degree centigrade for 30 seconds. Now you can start from the room temperature, the same conditions apply. You are going to give more preheating or soaking zone time. So, you can keep typically about 125 to 160, let us say 160 could be your temperature. So, room temperature is 160 and you can go at heating rate of about 2 degree centigrade per second. This could be 2 degree centigrade per second. Then the soaking time, you can keep it for longer time, 0.5 degree centigrade per second at 160- you can keep for a longer time. Then from 160 if you set the peak reflow to 225, there is no resident time as such. So, from 160 to 225 is your ramp up time at the rate of let us say 2 degree centigrade per second; then your cooling zone typically, again 3 degree centigrade per second. So, 225 to 25- if you calculate the times accordingly, you will get the total time for each of these. You can calculate the time and then totally you can get the time taken for reflow, if you are using.

The only difference that you see here is the TG of the board, is 160. So you are utilizing that temperature to ramp up in the preheating zone, from room temperature then at 160, because you are also talking about the flux and so this could slightly be changed. You can split this soaking zone into two zones: from 160 to 180 and190, you can have a quick ramp up; and then from 190 to 225, you can have the reflow ramp up and that could be modified.

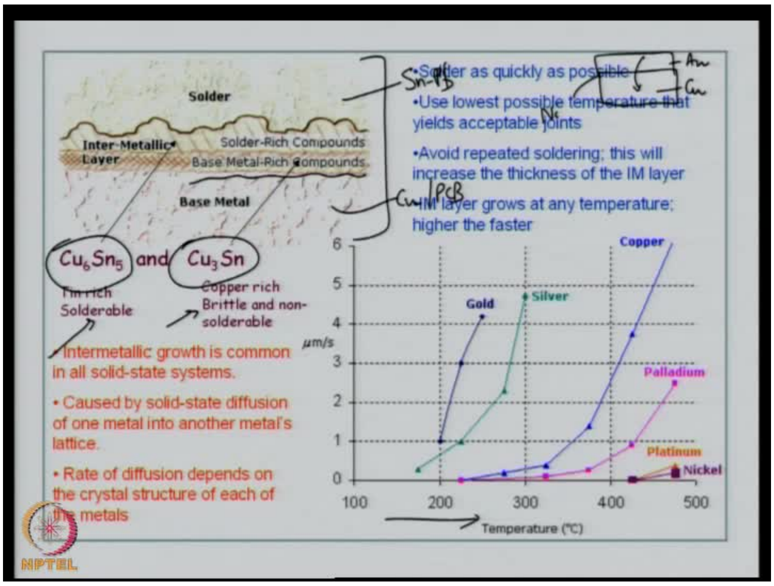
So, you can also consider modified this zone based on the information that we have. So this is also workable, because you are trying to activate the entire system at 160 degree centigrade. Then you are moving from 160 to 225 without residence time and then getting back to room temperature gradually. So, typically if this also you should end up in about 225 seconds, which is less than 5 minutes and acceptable for the industry process. So, the underlining point that we take away from these two slides is, that I have talked about is that.

(Refer Slide Time: 45:38)



There is no consistent thermal profile or universal thermal profile and it depends on the system that you are using. So look at all the issues carefully, look at the problem that you have in terms of components, substrate and paste and then draw your own thermal profile. Do a trail run 3 to 4 times on a board, look at the solder joint and examine the solder joint visually and then go ahead, if it is a mask products. So what I intend to do now is? Give you homework problem; so look at this homework problem, the entities are slightly different here. The temperatures are different here and then you can also try at home, how to arrive at a thermal profile for such a system and then you can email me or a posture comments on the web.

(Refer Slide Time: 45:56)



Now, getting back to some more basics of the solder system if it talks about Tin-lead, there is always an intermetallic layer that is formed.

If you talk about a system like this, this is Copper; you talk about base metal in PCB, this is Copper and this is let us say, Tin-lead solder material. Now this is what happens when you do soldering? Soldering gets attached to the Copper and once that alloying happens the intermetallic are immediately formed and as the temperature increases, the inter-metallic layer thickness also increases. Even at room temperatures over a period of time the intermetallic thickness grows, so initially there will be a particular phase or a composition or compound and if the board is been used for a longer time let us say and if you analyze the layer thicknesses, there will be difference in the thicknesses that is because the intermetallic growth phenomenon is continuous. If it is done at higher temperature or if it subject to higher temperatures, the growth rate is very high- that is why I have put this graph here to show typically, temperature verses microns per second growth rate and you can see for Copper, this is the temperature. So as we move up the temperature, we can see the growth rate for Copper fairly high Gold, Silver, Palladium, Platinum and so on.

We also see in an earlier class, that when you have Copper and if you want to plate Gold on Copper, you need to have an undercoat of Nickel to prevent diffusional Gold into Copper. So the intermetallic properties are dependent on the alloying system, the plating, the base metal and the plating that it takes and the multiple coatings that normally we do with the Printed Circuit Board cross sections.

So typically in Printed Circuit Board, you will have base Copper, then you can have a Nickel-gold coating on which you can do a soldering process done for components. So, then you will have much more complex intermetallics that could be formed; the only thing is, the gold can prevent diffusion of Tin-lead into Copper, but if you look at this picture here as a cross section, what it say is basically at the area close to the base metal you will have base metal rich compounds. What are the base metal rich compound interfaces? Typically, Cu 3 Sn. Then on the solder side you will have solder rich compound typically Cu 6 Sn 5.

Cu 6 Sn 5 is solderable and Cu 3 Sn is brittle and non-solderable, that is why you have to make sure that soldering process is done on a clean Copper surface. If you try to repeatedly do desoldering and soldering on the same surface, you will not get a wedge joint because of the different intermetallic layer that is formed and which is not enabled for soldering process. So, intermetallic growth is common in all solid state systems and it is cost by solid state diffusion of one metal into another metals lattice structure rate of diffusion depends on the crystal structure of each of the metals. Therefore you have to solder as quickly as possible and use lowest possible temperature that yields acceptable joints. Avoid repeated soldering this will increase thickness of the intermetallic layer as I told you any board, any system which is as Tin-lead if you repeatedly solder, desolder and repair components, the reliability is going to go down. Intermetallic layer growth takes place at any temperature, even at room temperature and at lower temperatures and the high temperatures- never the less as I mentioned it is faster.

(Refer Slide Time: 50:53)

Some common electronic solder alloys and their designations

Tin %	Lead %	Silver %	MP °C	Application areas
62	36*	2	179	SMD assembly
63	37*	--	183	SMD/ Hybrids
60	40*	--	183-191	SMD/ Hybrids
96.3	--	3.7	221	High-melting lead free
10	90	--	275-302	BGAs
3	97	--	314-320	C4 flip chip
5	93.5	1.5	296-301	High temperature component manufacture

*Indicates that it contains 0.2 to 0.5% Antimony (Sb) for improvement in low temperature performance

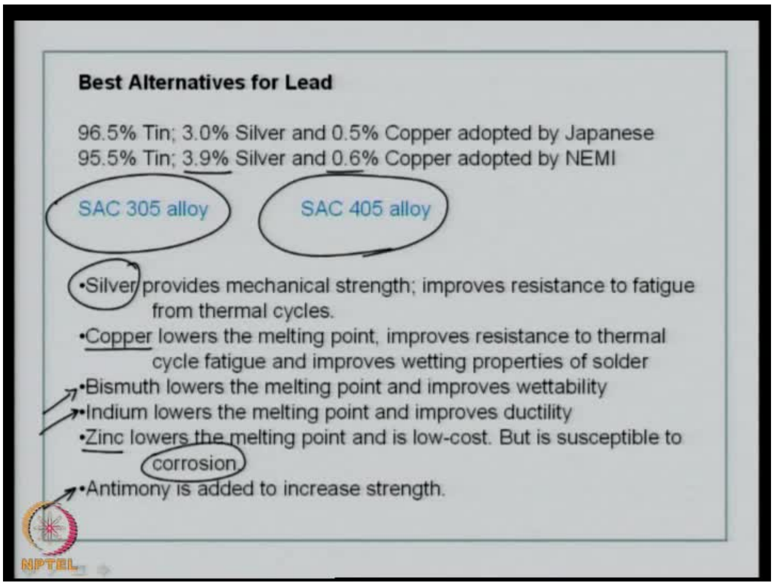
Some of the common electronic solder alloys and the designations will now be discussed. So we have seen Tin 62, Lead 36 and 2 percent of Silver added normally to reduce the melting point from 183 to 179. This has been in practice for surface amount device assembly for a long time. Now, you get a very good joint more wettability, more mechanical strength to the component leads and it has a much better appearance and finish.

So, the common one is 63:37, which includes impurities of course, then the melting point 183 used for through hole component, SMD, Hybrids devices and so on. I talked about 60:40 is also possible and melting point range is 183 to 190 used in SMD and Hybrids.

Then you have some uncommon solder alloys like Tin is 96.3, Silver 3.7 and melting point is 221, this is high melting Lead-free material. So, if you are using system away from the normal eutectic, then you have to look at your thermal profile in a different way. I also talked about possibility of high lead content, low tin content, temperatures are very high, some BGAs and flip chip bumps have been manufactured before the ROHS legislations. Even toady I assumed that certain packages, very few in numbers are still being allowed to use this because of the reliability issues and so on.

So again 97:3 percent Tin, C4 flip chip manufacturers have been using that so temperatures are very high. Now of course, C4 flip chip are available with Lead-free materials and this is another such example from the literature that we have. So, academically this table gives you the various compositions of Tin-lead Silver that have been practiced in assembly.

(Refer Slide Time: 53:35)



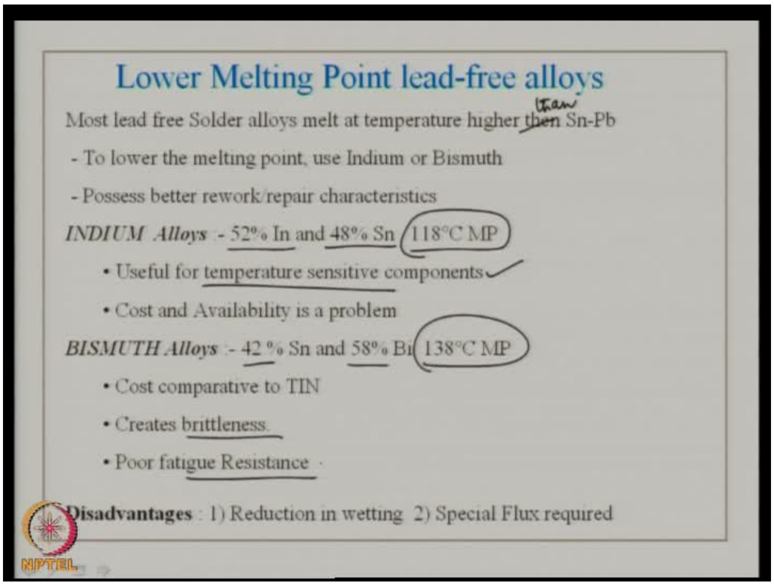
Now look at best alternatives for lead, because now we are moving away from lead. We have to look at alternatives for lead. So, the best thing of the best match would be SAC 305 alloy and in some cases people are using SAC 405 alloy. Now, what is SAC 305? SAC 305 indicates that there is 3 percent Silver in that and 0.5 percent Copper and the remaining percentage that is 96.5 percent is Tin. So it is a more tin based lead is removed and replaced by Silver and Copper adopted by the Japanese and then, but being synthesis by major solder companies and its available in India elsewhere and is being extensively used for SMD assembly.

The other one is SAC 405 alloy, so here you have about 4 percent of silver, 0.5 percent Copper or they say some literature gives it as 3.9 percent silver and 0.6 percent Copper and the remaining 95.5 percent tin adopted by NEMI that is National Electrical Manufacturers Initiative of viewers. So silver provides mechanical strength and so why do we use silver is, it improves the resistance to fatigue from thermal cycles; the use of Copper in this alloy is, it lowers the melting point, improves resistance to thermal cycle fatigue and improves the wetting properties of solder.

In some cases tin has been alloyed with Bismuth. So Tin-bismuth alloys are known it might be prohibitive in terms of cost and in terms of application. Bismuth might not be a good choice, but in certain cases it is acceptable- it lowers the melting point, improves the wettability. Tin indium alloys are known expensive though lowers the melting point, it improves the ductility.

Zinc, if it is used in any of the tin alloys for lead-free, lower the melting point and is low cost, but it is susceptible to corrosion. So, you do not want to really use that, antimony is added to increase the strength very small percentage so these are the best alternatives for lead-free solder.

(Refer Slide Time: 56:23)



So lower melting point lead-free solder alloys, most of them melt at higher temperatures than Tin-lead. To lower the melting point Indium or Bismuth possess better rework and repair characteristics. For example, if you talk about Indium as the component in the Tin-lead-free alloy, Tin is 48 percent and you can see the melting point is very low, quite lower than the eutectic Tin-lead useful for temperature sensitive components. So, this is the ideal requirement or application when you are using this, because today in certain electronic products the components that are being used of sensitive to higher temperatures cost and availability is a problem.

Bismuth alloys, you can see the melting point is 138 quite low, the percentage of Tin is 42 and Bismuth is 58. Cost is comparative to Tin, but it creates brittleness and poor fatigue resistance. The disadvantages are reduction in wetting property and special flux is required. So, there are advantages in using lead-free alloys like lower in the melting point, but the same time if you looked bottom line you have problems in terms of the reliability, in terms of wetting fatigue resistance and so on and obviously, there have been some applications where these are used, but they are more special in nature.

So, we will continue with the lead-free alloys and then moving to green electronics. We will discuss some of the issues that are affecting the electronics industry globally in terms of material choices for green products.