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Lead-Free Is Not Home Free

By Casey Cass Scheu, A.P.E. Automated Production Equipment, Key Largo, FL

Ever since the onset of lead-free manufacturing, the electronics industry has been faced with many difficult challenges. Companies have invested in new lead-free production lines only to receive the "benefit" of a reduced product yield. The overall reduction in production yields has caused an immediate increase of work going to the rework departments worldwide.

The manufacturing sector does not represent the only victim of lead-free circuitry; R&D labs, educational intuitions, all branches of electronic repair have seen a drop in yield. Lead-free circuitry is not going to fade away, so it's best to become educated on the subject. The end result will be more products going out the door while saving time and money in the process.

When reworking or repairing circuit boards, an ounce of prevention is worth a pound of cure. The base mantra of this statement is research. An understanding of the PCB's construction, the alloy of solders involved, oven manufacturing temperatures, and profile management are all key to less scrap when attempting to remove or replace ICs. Knowing how the board is constructed along with the ICs involved is only half the battle; knowing what's going on in the lab is equally as important.

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The official deadline for RoHS compliance was July 2007, but as we are all aware the industry is still saturated with "Mixed" PCBs — circuits in which either the PCB's substrate or the IC's are a combination of leaded and lead-free materials. Mixed PCBs are extremely problematic as there are many variables involved and must be taken into consideration before attempting the repair.

Leaded ICs a Problem

Some key focus points at the evaluation stage are whether or not the PCB was constructed for leaded ICs, and if the replacement ICs are lead-free or tin/lead. Attempting to place an IC designed to reflow at 260°C on a board constructed for 183°C solder will push the envelope of the PCB's construction past the point of no return. The laminates and adhesives used for the construction of a leaded PCB are not designed to reach the temperatures required to reflow a high temp lead-free IC. While this type of repair is being done every day, the yields are much lower and there is a much higher rate of latent failure returns. PCB manufacturers have recognized the problems associated with the laminates and adhesives, so new technology was developed. While a solution is in place for PCB construction to meet RohS standards, it does little to solve the problems of rework technicians assigned to work on the hundreds of thousands of PCBs that were produced before the RoHS-conformance deadline. Many of the ICs previously constructed in a Sn/Pb (183°C) configuration are no longer available, forcing techs to deal with extreme challenges.

Life was much easier for the rework tech when all solder reflowed at 183°C. The flip side of placing a lead-free part on a tin/lead board is to attempt to place a leaded IC on a Pb-free board. This should be a piece of cake as the tin/lead solder reflows at 183°C and the card is well constructed to deal with much higher temperatures. Sounds great in theory and I will concede it is easier to place a 63/37 IC on a PCB constructed for lead-free, but you're still not out of the woods. A critical concern here is to not create a cold solder joint, or separation of tin and lead in the IC's solder alloy, while attempting to get the PCB's over plate to reflow. Reflowing leaded ICs to Pb-free cards is normally not an overwhelming challenge when lower melting point lead-free solder alloys are used. A combination of a higher reflow temperature, lead-free solder over plate, a high mass board, and a large leaded IC will be the most difficult repair in this scenario.

There are many variables to contend with while attempting to work with "mixed" alloyed boards. Determining the variables can often be the most challenging part. Lead-free rework on the other hand, can just be plain difficult. Again it is of the utmost importance to be educated on the construction, solder alloys, and base temperature specifications called out by the manufacturers. Many IC makers indicate the maximum die temperature can be no higher than 275°C for a set duration not to exceed 30 seconds. Making things worse, there are millions of ICs whose internal die spec can not be exposed to temps over 240°C at all — not even for 1 millisecond. The combination to heat-sensitive internal silicon die, whose specifications can not exceed the temperatures required to reflow the IC's solder, has placed the industry in a very precarious position when it comes to rework.

Knowledge Is Power

Understanding the construction of the PCB and the IC are critical, but just as important are tools and materials used for the repair. Consistency is the key here.

You may have a board and IC with the same lead-free solder spec called out — let's say 218°C — a very low lead-free solder reflow temp — and the PCB is of moderate construction. On the surface, this looks like it should be a relatively easy repair. After consideration, a ramp/soak profile is selected with a peak temperature of 240°C running for approximately 5 minutes. After a failed test and x-ray, there appears to be opens in the circuit. The IC is reflowed again, this time slightly longer with a thermocouple under the chip for confirmation that the IC is reaching 218° for the set duration. Again, after 6 min., the board is tested and has failed once more because of opens.

Alloy Composition	Melting Range Solidus		Melting Range Liquidus		Mushy Range	
	°C	°F	°C	°F	°C	°F
70Sn/30Pb	183	361	193	380	10	19
63Sn/37Pb	183	361	183	361	0	0
60Sn/40Pb	183	361	190	375	7	14
50Sn/50Pb	183	361	216	420	33	59
40Sn/60Pb	183	361	238	460	55	99
30Sn/70Pb	185	365	255	491	70	126
25Sn/75Pb	183	361	266	511	83	150
10Sn/90Pb	268	514	302	575	34	61
5Sn/95Pb	308	586	312	594	4	8
62Sn/36Pb/2Ag	179	355	179	355	0	0
10Sn88Pb/2Ag	268	514	290	554	22	40
5Sn/92.5Pb/2.5Ag	292	558	292	558	0	0
5Sn/90.5Pb/1.5Ag	287	549	296	564	9	15
5Sn/93.5Pb/1/5Ag	296	564	301	574	5	10
2Sn/95.5Pb/2.5Ag	299	570	304	579	5	9
1Sn/97.5Pb/1.5Ag	309	588	309	588	0	0
96.5Sn/3.5Ag	221	430	221	430	0	0
95Sn/5Sb	235	455	240	464	5	9
42Sn/58Bi	138	281	138	281	0	0
43Sn/43Pb/14Bi309	144	291	163	325	19	34
52Sn/38In	118	244	131	268	13	24
701n/30Pb	160	320	174	435	14	25
601n/40Pb	174	345	185	365	1	20
70Sn/18Pb/12In	162	324	162	324	0	0
90Pb/5n/5Ag	290	554	310	590	20	36
92.5Pb/5In/2.5Ag	300	572	310	590	10	18
97.5Pb/2.5Ag	303	578	303	578	0	0

Melting range of common solder alloys.

The common response so often is "more heat". Off comes the chip, site prep is done, and we repeat the process. Surprise, surprise, the chip is still not working. At this point each step is closely analyzed. The first thing we notice is the IC's solder spec indicates reflow is at 218°C, but for complete wetting +23°C is required for 30 to 45 seconds. This in turn means a higher set point profile, peaking closer to the 265-275°C range. The new profile gets run again, this time with a scope to watch the solder reflow. Without question all the balls are molten, yet when we test the board, to our complete and utter dismay, we get opens. Once again, we go back and review each step. It turns out during the site prep a lead-free solder wire is being used to tin the pads. The melting point of the solid core wire is over 300°C, making our profiles a moot point. Once we have replaced the solder being used to prep the site, yields go from 50 percent up to 95 percent.

The key to increasing successful repairs is understanding that it's all about melting solder. No longer does all solder melt at 183°C, but all solder does melt — at some temperature. Understanding the solder requirements coupled with proper profile management will dramatically increase yields off your workbench.

Contact: A.P.E. Automated Production Equipment, 2 North Blackwater Lane, Key Largo, FL 33037 ☎ 305-451-4722
fax: 305-451-3374
Web: www.ape.com ❒