Rework stations: Meeting the challenges of lead-free solders

Market forces, particularly legislation against the use of lead in electronics, have driven electronics manufacturers towards lead-free solders for PCB assembly and rework. This approach creates challenges because of the relatively high temperatures needed for lead-free soldering. Additionally, lead-free solder alloys typically do not wet or wick as easily as Sn63Pb37 leaded types. As PCBs often include both BGAs and simpler discrete devices, a lead-free rework capability should include a suitable soldering station and a BGA rework station. This article shows how such equipment can be adapted to overcome the lead-free issues and provide a successful reworking facility.

Solders alloys have traditionally included lead along with tin, as lead delivers many valuable mechanical and electrical properties for a reasonable cost. Unfortunately, the metal is also highly toxic, so it is being driven out of applications where suitable alternatives can be used. Since July 1, 2006 this has been enforced by the European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS); these prohibit the inclusion of significant quantities of lead in most consumer electronics produced in the EU.

Lead-free soldering alloys are now being used, but they bring new challenges to assembly and rework processes. Above all, they have a melting point of around 210 - 220°C compared with 183°C for eutectic tin-lead alloys. As a result, many lead-free alloys' peak reflow temperatures are around 240 - 250°C compared with 210 - 220°C for tin-lead products. This increase, especially where multiple reflows are required, means that assembly and rework processes must be optimised to prevent compromising the integrity of the PCB board and components involved.

Lead-free alloys raise other issues as well. The industry has not settled on a standard alloy, although Tin-Silver-Copper (Sn/Ag/Cu or SAC) has become popular. However, even if this does become a de facto choice, it represents more than a single standard because its behaviour varies significantly with small changes in the ratios of its component metals. Wetting angles, tensile strength and other joint characteristics are all affected by alloy changes as small as half a percent. Today, researchers are still investigating the results of mixing different alloys.

This research must encompass more than just SAC alloys; although they have proven to be suitable for production of many devices, they are less suited for applications demanding extremely high reliability. For example automotive and military/aerospace products require a lead-free material that can withstand the higher temperatures of under-the-hood conditions, offer vibration resistance not commonly associated with traditional SAC alloys, and deliver high-temperature (>125°C) thermal cycling reliability levels beyond those available with current commercialized SAC materials.

There are other considerations too. Many lead-free solder alloys lose their ductility very abruptly at approximately -30°C. This transition temperature is affected by the different alloy blends and becomes very important when used in automotive, aerospace or other outdoor applications. Tin whiskers can be also be an issue; these grow on surfaces that use lead-free tin as a final finish. They are electrically conductive and can appear in any time frame from hours to years. Problems arise if they form a conductive bridge between PCB or component contacts.

For applications where they can be used, lead free alloys have been grouped into three melting-point ranges – low, medium and high. Their melting points range from approximately 140°C to approximately 280°C. Most of the low melting point alloys have either strength or cost related issues so it is likely that the eventual replacement for Sn/Pb will fall into the midrange category and have a melting point roughly 30°–50°C higher than that of the established Sn/Pb eutectic. For instance, the alloy 95.5Sn/3.8Ag/0.7Cu has a melting point of 217°C. While variations in the percentages of each metal do have an impact on the quality of the joint, these effects are proving to be minimal.

Alloy Family	Relative cost ratio Sn63Pb37=1
SnInAg(Bi)	3.3-3.5
SnAgCu	2.9-3.3
SnAg	3.1
SnAgBi(Cu)	2.4-3.1
SnBiAg(Cu)	2.1-3.1
SnBi	1.7
SnCu	1.5
SnZn(Bi)	1.4

Source: http://www.jovy-systems.com/images/stories/pdf/lead_free_solder_capsule.pdf

Fig.1: Different solder alloys and their melting points

With these lead-free soldering issues in mind, we can turn our attention to re-work stations and how they can be designed to handle lead-free products. Electronics re-work can be required for a number of reasons:

1. Poor solder joints due to faulty assembly or thermal cycling.
2. Solder bridges – unwanted drops of solder that connects points that should be isolated.
3. Faulty components
4. Engineering parts changes, upgrades or re-designs

In all cases, the re-work effort involves soldering and desoldering of single SMT devices for repair and replacement, and is not amenable to mass processing techniques. Skilled technicians and specialised tools are needed to melt the solder, repair PCB surfaces, and pick up and position often tiny components. Area array packages such as ball grid arrays (BGAs) must also be handled.

Hand soldering tools

Hand soldering tools are essential for removing and replacing the simpler components, and 95.5Sn/3.8Ag/0.7Cu alloy, with its 217°C melting point as previously mentioned, is amenable to these. It requires only a slightly higher operating temperature than lead-based alloys, and allows soldering iron tip temperatures to be maintained below recommended 400°C levels – in practice, most applications can be addressed with much lower temperatures. Under these conditions, provided that tips are maintained as specified by their manufacturers and the same fluxes are used, tip life and performance should not be compromised.

Jovy’s I Solder 40 soldering station, available in the UK from Cupio, offers tight temperature control, to protect the iron tip as well as the components and PCB being worked. It uses iControl soldering technology to supply the thermal energy required to the soldering tip, achieving the required temperature in a few seconds with no overshoot. iControl requires no calibration and ensures a well-controlled soldering process. The system comprises a thermocouple sensor embedded in the soldering tip, connected to a control processor that calculates precisely the heating power required to melt the solder on the PCB contact. If enough time passes without dissipation in the tip being detected, the system goes into power saving mode. This guarantees safety, saves power, protects the tip and increases its shelf life.

Fig.2: Jovy Systems’ iSolder-40 soldering station

BGA Re-work

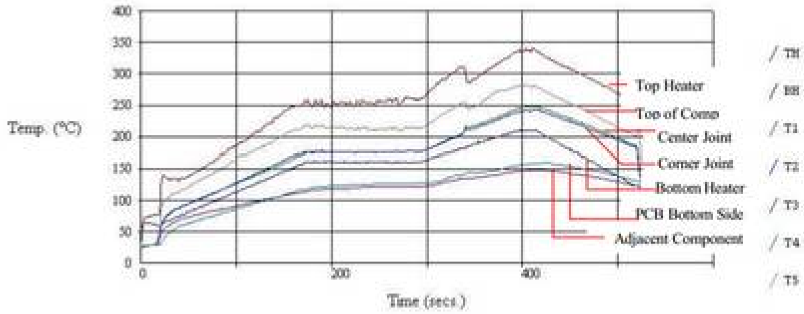
Re-working lead-free field array devices such as BGAs is similar to that of eutectic tin-lead devices, but with the added requirement of handling the higher melting temperatures. Both cases include the following steps:

- Thermal profiling;
- Removal of defective component;
- Site re-dressing;
- Solder replenishment or flux application;
- New component placement;
- Reflow soldering

In BGA rework, the PCB is subjected to multiple reflow cycles during component removal, site redressing, and soldering of the new component. With the use of lead-free solders, the board is subjected to multiple thermal excursions at temperatures in the range of 240°C-250°C.

These high processing temperatures potentially degrade the PCB materials and may lead to excessive warpage, delamination, solder mask discolouration, and damage. In addition, multiple reflow cycles during rework may cause degradation of the PCB surface finish and oxidation of the copper pads. This is typically observed in PCB pads with Organic Solderability Protection (OSP).

Such conditions highlight the importance of thermal profiling. An improper profile may result in pads being lifted if the solder is not molten before removal is attempted. On the other hand, excessive component heating can cause the problems described above. Ideally, removal and replacement profiles in the re-work station should duplicate the original reflow soldering assembly profile as closely as possible. However this can be difficult due to the different heating strategies and limitations of the re-work station, where ramp rates can be limited to 1.7°C/sec. Fig.3 is an example of a rework reflow profile that can be used in practice.



Picture source: http://www.jovy-systems.com/images/stories/pdf/lead_free_rework.pdf

Fig.3: Rework station reflow profile

Once a suitable thermal profile has been set up, the removal and replacement process can take place. Components can be removed from the board, provided that the board and heating elements can be accurately positioned, and that components can be safely lifted once the solder has melted. After component removal, the board may need redressing, where residual solder is removed to leave a flat surface. Otherwise open joints, odd-shaped joints and component displacement can arise during soldering of the new component. Successful redressing depends heavily on the skills of the rework station operator. This can be mitigated and improved by a process called copper coupon redressing. However the process involves subjecting the assembly to an extra reflow cycle, which could negatively affect the integrity of the PCB site and the reliability of the assembly.

Placement of the new component is also a challenging task. Either solder paste or flux paste can be used, but the question of which is better is controversial. Solder paste is mostly used for repair or rework, whereas for production it depends on the type and accuracy of the stencil used. Some studies claim that the extra metal provided by a solder paste will produce stronger, more reliable joints, assuming the joint geometry is correct. Also, solder paste may help to overcome variations in solder ball height caused by variations in surface finish height, warp in the board or warp in the device itself. A solder paste may also perform better than a flux-only paste in providing sufficient tackiness on the PCB pads to hold the component in place during soldering. However, in applications where sufficient solder is already present on the chip or PCB, flux paste may be a more appropriate alternative.

BGA rework station – a practical example

By reviewing a real-world BGA rework station such as Jovy Systems' Jetronix-Eco station, available in the UK from Cupio, we can see practical ways in which the issues raised by lead-free removal and replacement activities can be addressed. Other BGA re-work stations, including the Re-7500, Re-7550 and Re-8500 are available for different PCB sizes and functionalities.

The Jetronix Eco is semi-automatic, and uses 'dark medium' infra-red (IR) energy for lead free PCB component soldering and desoldering. IR heating's key advantage is that it distributes heat energy uniformly and equally over the entire application to prevent warping of the board, the device or the application. Also, IR waves easily achieve deep penetration and heating rather than just surface heating. Efficient transfer of reflow energy into the target component can be guaranteed, while adjacent components can be protected from over-heating harm. IR radiation is also a safe and environmentally-friendly heat source.

The Jetronix's heating is provided by a 400W upper heater and five lower heaters with 2800W total power. The upper heater can be moved freely both vertically and horizontally to allow easier and more accurate heating control. The heaters form part of a PID closed loop control system that also includes one or optionally two thermocouples and a controller. A process profile of one to four stages can be configured, with user-settable target temperatures and dwell times for each stage - apart from the preheat stage where parameters are pre-defined. Each stage after pre-heating can also have multiple heating zones.

Accurate temperature control is facilitated by embedding the thermocouple within a Flexi tube to allow easy and precise placement over the target PCB. A second thermocouple is available as an option. Small components can be clearly identified and the whole process monitored easily with the station's 40x zoom camera and LED light source which improves visibility. Enough power is available to handle all types of high temperature demand, while damage to chips during rework is prevented by alarm signals and safe temperature limit controls.

As indicated above, successful lead-free BGA removal and replacement calls for precise, effective handling as well as accurate temperature profile control. The Jetronix features a durable suction pen with a lifting power of 120gm allowing components to be handled and lifted from the PCB. The BGA rework station also has a built-in X-Y table to handle the PCB. This must be held firmly and positioned delicately and accurately, as exposure to high temperatures can cause negative effects such as bending and warping.

The Jetronix' high-efficiency IR technology provides sufficient heating energy for all types of applications while its PID closed loop control system maintains this energy within safe limits, preventing danger or damage to the board or components being worked. Additionally, the station's cross-flow cooling fan generates an air carpet that reaches all areas requiring cooling, while preventing any sharp temperature shock which could cause damage or board warping.

Fig.4: Jovy's Jetronix-Eco BGA rework station

The BGA rework station can also be managed by a PC running 'Jetronix-Eco' software, (Or Jovy® PC Suite for other workstations) which provides more control and monitoring functions than the workstation's user interface. Multi-stage control of the process profile can be implemented, and an unlimited number of profiles can be saved and run from the PC. Up to 50 profiles can be imported into machine memory, and profiles can also be exported. Process graphs can be saved for analysis and improvement of process parameter settings.

Conclusions

Handling lead-free PCBs and their components shares the same issues as leaded types, with the particular addition of lead-free solder's higher melting temperatures. At these elevated temperatures, exposure of PCBs and their components to heat energy must be carefully managed to avoid damaging them. Hand soldering tools must achieve the required operating temperatures without overshoot, while BGA rework stations must deliver heat with accuracy in terms of temperature, control, timing and area of distribution. They must also protect the PCBs being reworked while allowing delicate, precise handling and clear visibility of even the smallest components.

This article has highlighted these issues to inform purchasers' buying decisions when selecting re-work equipment for their production or repair facility. For more in-depth or specific help, Cupio's technical support team is available to answer any questions and ensure purchasers make the right choices when adding or upgrading re-work facilities.