随着在制造设施中无铅过程的增加，返工的重要性也会提高。无铅合金较高的焊料溶化温度和明显缩小的过程窗口势必导致更多产品进入返工部门。因此，寻求建立无铅制造过程的初始设备制造商（OEM）和电子制造服务（EMS）供应商必须确认他们同时指定适用的返工机器。这些机器必须能够为无铅组装连续提供必要的热性能，以保证过程真正的稳定性。

Thermal Repeatability in Lead-Free Array Rework

Craig Brown

A recent study on thermal repeatability shows how even small changes in process variables can have a significant impact on the end result in lead-free array rework.

The introduction of lead-free soldering technology into electronics manufacturing has raised many questions and generated much debate in the global industry. Many manufacturers are still deciding how best to embrace the technology, as the switch over to lead free requires a new set of engineering knowledge and processes to be learned.

One thing is certain, however: Lead-free soldering is putting a squeeze on the available process window, as higher melting points demand tighter control over the thermal profile if damage to the board and devices is to be avoided.

But as lead free takes off in manufacturing facilities, so will a rise occur in the importance of rework. The higher solder melt temperatures of lead-free alloys and the significantly smaller process windows, with melting points as close as 5°C to a device's upper temperature specification as compared to 40°C for eutectic tin-lead, will inevitably lead to more products reaching rework departments.

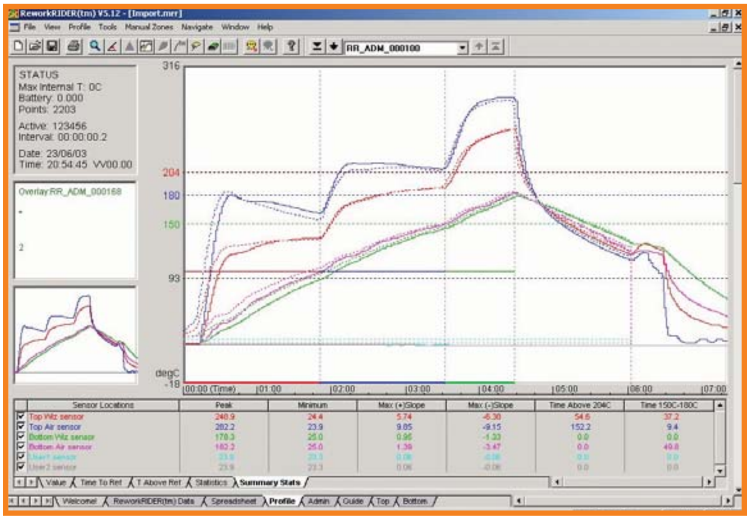
Therefore, original equipment manufacturers (OEMs) and electronics manufacturing services (EMS) providers seeking to establish lead-free manufacturing processes must ensure they also specify applicable rework machines. These machines must be capable of delivering the necessary thermal performance for lead-free assemblies on a repeatable basis to guarantee true stability of processes.

The Demands of Rework

A typical rework process means putting the board and its components through at least two additional thermal cycles, as a defective device is first desoldered and then a replacement attached in its place. The whole process must be performed in a controlled way to prevent any possibility of damaging the assembly, which typically means replicating the original reflow profile as closely as possible.

For standard eutectic tin-lead solders, a typical reflow thermal profile shows solder joint temperatures reaching a maximum 200 to 210°C for 30 to 60 seconds, with die temperature no more than 245°C. Temperatures under the component should reach a maximum of 170°C, while the overall board temperature is at least 120°C with ±10°C across the corners.

But in a lead-free solder process, the thermal conditions are generally much harsher and significantly closer to the upper tolerances of the board and component materials. The process requirements for a typical lead-free assembly are for solder joint temperatures up to 230 to 235°C for 30 to 60 seconds—much closer to the die's maximum temperature of 245°C. The temperature under the component also rises to a maximum of 210°C, and the overall board tempera-



ECD

FIGURE 1: The baseline temperature profile (represented by solid lines) and random samples from the capability cycles (represented by dotted lines).

ture still needs to be a minimum of 120°C ±10°C across the corners.

Not only are the temperatures higher, but the different metallurgy necessitates stricter control of heating and cooling gradients. Also, different wetting characteristics demand stricter control of flux activation.

Comparing the thermal values for a lead-free process to those for standard eutectic tin-lead shows that lead free has a much narrower process window, producing an increased need for process control. And for rework, this narrower process window demands a system that offers a high degree of precision and repeatability.

However, the higher processing temperatures of lead free are not the only factor putting pressure on the process window. Technology trends show that future assemblies will feature thinner and more complex bare boards, an increase in array package usage, higher I/Os per assembly and a reduction in pad/solder ball pitch—all of which reduce the margin for error even further.

Process control and repeatability are set to become a controlling step in both rework as well as mainstream manufacturing. Even with low defect per million (DPM) rates, as the number of solder joints increases, the amount of rework could still increase.

Is Your Rework Process Capable?

Against the background of a demand for tighter process control in lead-free array package rework, a rework machine process capability study was developed. The aim was to show

Ad Index

Advertising Sales

North America: UP Media Group, Inc.
2018 Powers Ferry Road, Suite 600
Atlanta, GA 30339

National Sales Manager:
Susan Jones, **(404) 822-8900**
email: sjones@upmediagroup.com

Europe: **Star Media:** Steve Regnier, Tim Anstee
+44 1732 366 555
email: sales@starmediaservices.co.uk

Asia: Jan Vardaman, TechSearch International Inc., **512-372-8887**
email: jvardaman@upmediagroup.com

Korea: Young Media, **82 2 756 4819**
email: ymedia@chollian.net

just how important key variables are in the process and how even small deviations can have a significant effect in the smaller process window of lead free.

A 50-cycle study was developed based on an array package rework system and a thermal profile measurement tool. The array package rework system offered the repeatability, accuracy and thermal control essential for reworking with leading-edge components and solders, including lead free. The thermal profile measurement tool was based on a board-like pallet with ball grid array (BGA)-like sensors that can be put through a complete rework thermal cycle to measure and record the times and temperatures actually delivered.

The study was developed to examine the effects on the rework process of introducing known variables and to quantify the effect of changes to the process, namely different-sized vacuum cups, changes in nozzle height and changes in air flow at the nozzle. These could then be compared to an initial, standard, capability study.

The array package rework system was used to put the thermal profile measurement tool through a typical rework cycle, while measuring the critical parameters of the minimum, maximum, average and standard deviation of the topside temperature (air and mass), bottom-side temperature (air and mass) and time above 204°C for the topside mass. These parameters were chosen as their results can be plotted and the interactions between them studied. By identifying their interactions, fault diagnosis can be conducted and failure modes assigned.

The rework system was initially set up with a 1.4 in. [35 mm nozzle at a height of 0.75 mm (30-mil)] above the sensor,

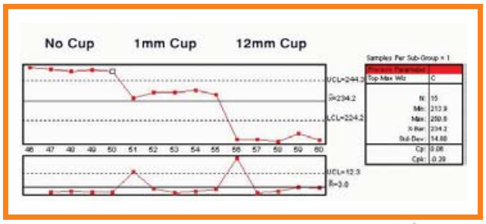


FIGURE 2: The effects of different-sized vacuum cups on the thermal signature.

and measurements were recorded using a scan profiling unit. This procedure produced a baseline temperature profile that could be used to compare against subsequent measurements (Figure 1), and it followed the industry-standard pattern of preheat (up to 177°C), soak (at 177°C) and peak zones (above 204°C), followed by cooling.

After over 50 cycles, temperature measurements on the topside showed standard deviations of 0.88 for the sensor and 1.11 for the maximum air temperatures, while the bottom-side figures were 1.07 and 1.02, respectively. These figures are all well within three sigma, showing that the rework system was statistically capable of repeated high performance.

Changing the Variables

Once the baseline profile in Figure 1 had been established, the study then examined the effects of changes to the vacuum cup size, nozzle height and nozzle airflow. Using the same (35 mm) nozzle throughout, and switching from a 12 mm (0.48 in.) vacuum cup to a 1 mm (0.04 in.) vacuum cup and then no vacuum cup fitted at all, the same series of thermal cycles was performed to see how the thermal signature was affected (Figure 2).

The results show that the choice of vacuum cup has a significant impact on performance. When a 1 mm vacuum cup was used, a drop in temperature around 15°C occurred at the component level, as

The results show that the choice of vacuum cup has a significant impact on performance.

compared to when no vacuum cup was used. The drop, however, is closer to 30°C when a 12 mm vacuum cup was used. Overall, a standard deviation of 14.80 occurred in recorded temperatures with the different vacuum cup sizes, demonstrating that the choice of vacuum cup has a big influence on the thermal profile. The results also illustrate the usefulness of recording rework temperatures for alerting users to this type of error.

The study moved on to look at the effects of varying the nozzle heights above the board. Temperatures on the topside were recorded as the nozzle height was increased in 0.25 mm (10-mil) steps from 0.75 mm (30-mil), and these were compared against the baseline results taken at 0.75 mm.

When the nozzle height was increased by 0.25 mm, the sensor recorded only a small drop in temperature of less than 5°C. But the drop increased to around 10°C when the height was raised to +0.5mm (20-mil) above the baseline and fell by 15°C when the height was raised to +1.0 mm (40-mil) (Figure 3).

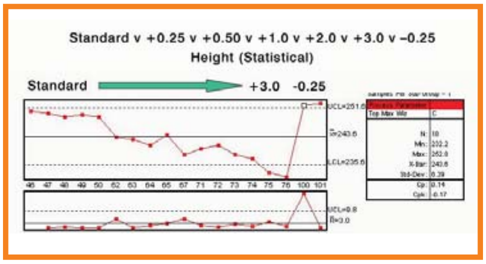


FIGURE 3: The effects of varying the nozzle height on topside temperatures.

Fixing the nozzle height is, therefore, essential for maintaining a repeatable profile, and a programmable or fixed z-axis in the rework station is necessary to achieve optimum results. The results also show that, with the right equipment, detecting nozzle height errors to within ±0.25 mm is possible.

The final series of tests looked at the effect of changes in convected airflow by comparing the baseline setup against lower and higher flows. The results show that, when the airflow was lowered, a drop in temperature of 15°C occurred at the component level across the whole of the temperature profile. Conversely, when the airflow was raised, an increase in temperature of about 10°C occurred at the component level across the profile (Figure 4).

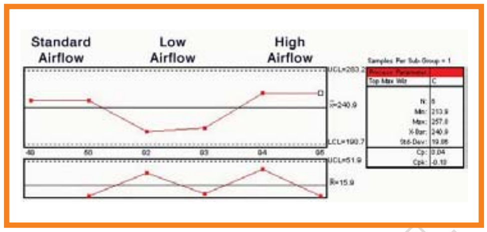


FIGURE 4: The effect on temperature by varying the airflow.

The outcome indicated how the rate at which air passes through a nozzle can greatly affect the temperature profile over its entire length. So having a rework system capable of delivering a programmable airflow rate in each zone increases the flexibility of the machine in terms of the profile it can generate.

Conclusion

Overall, this study showed that minor changes to process variables, such as choice of vacuum nozzle, reflow nozzle height and airflow rate, can have a significant effect on the thermal profile. It also highlighted that the rework machine must accurately control these parameters if consistent results are to be achieved in practice. The results stipulate the use of rework equipment capable of delivering tight process control and high thermal repeatability. ■

***Craig Brown** is European product manager for array package rework at Metcal Division, OK International, Menlo Park, CA; (650) 325 3291; email: cbrown@okinternational.com.*