高可靠性高的组装件的成功的再加返工是富于挑战性的。但是，通过使用正确的工具和过程序控制措施，可能会更容易、更安全。对成功的焊接工来说，再加工对采用厚高接地层平面而且与对温度敏感的塑料球栅极阵列(PBGA)和陶瓷柱栅极阵列(CCGA)的大型多层聚酰亚胺印刷电路板返工时，要成功焊接是富于挑战性的。大型电路板的物理尺寸可能使其难于精确处理和操作。本文解释再加返工解决方案必须如何适应大型电路板，同时提供高水平的可重复性和过程序控制，并将温度变量控制在最低水平。

High Stakes: Reworking High-Precision, High-Reliability Boards

Franck Bitton

Successfully reworking high-reliability assemblies is challenging, even for the most experienced of operators. However, it can be made easier and safer by deploying the right tools and safeguards.

People's lives rely directly on the quality and reliability of the electronics assemblies installed in safety critical applications, such as in the automotive, aerospace and medical sectors. These applications require a very narrow process control window, with almost zero room for manufacturing error. In a perfect world, where cost is immaterial, any assembly that does not pass quality control testing first time would be scrapped. Yet, what happens if that assembly is worth thousands of dollars?

Scrapping such assemblies would be economic suicide, particularly if the problem is relatively minor and due, for example, to a single failed or insufficiently soldered ball grid array (BGA) device. The challenge is to perform this rework task to a verifiable and traceable standard, while ensuring that no additional manufacturing-related error is introduced that could destroy the quality control and process discipline employed up to that stage.

This challenge is all too real for manufacturers of high-reliability assemblies, who must address the demands of state-of-the-art electronics. Specifically, the rework of high-value, thermally sensitive, array package devices is of particular challenge.

Reworking Large, Multi-layer Boards

While companies try to avoid manufacturing-related errors, problems do occur and are typically detected at either the optical and x-ray inspection or electrical test stage. Reworking a large, multi-layer, polyimide printed circuit board (PCB), which may have high ground planes and high-value and thermally sensitive plastic BGA (PBGA) and ceramic column grid array (CCGA) packages, is challenging to successfully solder. This rework can only be accomplished by skilled manual repairing of the individual component in question.

Rectifying such problems, however, is not an easy task, due to a number of key technical issues. The first stems from the sheer size and thickness of some multi-layer boards. These boards have a very high total thermal mass that for rework purposes demands a very high thermal power.

Unless this power is closely controlled, it could easily inflict major and possibly irreversible thermal damage to the board and assembly, particularly given the number of thermally sensitive BGA components. As much as possible, the manufacturer must limit the maximum temperature within the component package to 160°C, with a peak reflow of 200°C.

BGAs are sometimes located on the edge of the board, providing even further rework challenges. During preheating, the temperature of the outer exposed two sides will generally be

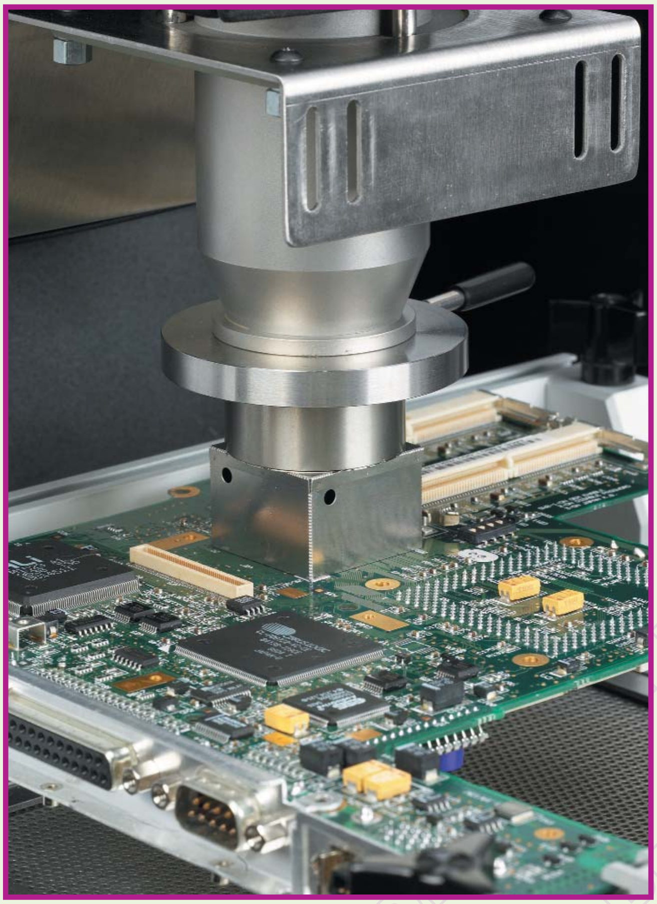

FIGURE 1: Some effective rework systems allow the PCB to remain stationary while a single rework head moves around the board.

greater than the temperature of the inner sides. This result is due to heat being convected and dissipated toward the center of the PCB, which essentially acts as a cool thermal reservoir. Although some heat is naturally radiated away from the exposed edges of the board, the process is far less efficient than the substrate conduction. The net result is an elevated risk of thermal over-stressing issues such as delamination and PCB warpage during rework.

Even minor deformation could lead to defects, such as cold soldered joints and solder shorts. A normal PBGA stands off the PCB by about 0.020 in. (0.5mm), and lifting by even 0.005 in. (0.1 mm) across the device is enough to cause an open circuit. Another factor is that the larger the device, the more prone it is to these problems. Even if the board/component survives the process with no apparent defect, then the joint will be constantly under strain as the board returns to its normal shape. This result could cause long-term reliability problems that are unacceptable in high-reliability applications.

In addition, plastic devices, such as PBGAs, are generally hydroscopic and absorb moisture during exposure to the atmosphere. If the device is then rapidly heated, the moisture expands, creating a cavity inside the device known as *popcorning*. This defect is characterized by a blister forming, due to internal expansion, on the underside of the component. Avoiding this defect demands a uniform delta T (ΔT) across the assembly that is not allowed to go beyond a maximum of 10°C, so as to avoid spot overheating. That said, as many as 1,000 terminations may be beneath a large BGA component, and one incorrect solder joint can require a second round of component removal and replacement. Therefore, the heating process must also be fast and uniform, as well as safe.

The physical size of large boards also potentially makes them difficult and awkward to handle and maneuver with precision. The rework solution has to be able to accommodate large boards, while still allowing reasonable and easy access to any part of the assembly area.

As with any manual process, the weakest or most vulnerable aspect is human error. Therefore, a semiautomatic system, with closed-loop time, temperature and airflow parameters to maximize repeatability and thermal safety and to decrease operator error, may be the most effective solution.

This requirement translates into a benchtop rework system that provides high levels of repeatability and process control, with minimal thermal variables. Some effective systems allow the PCB to remain stationary while a single rework head moves around the board (Figure 1), instead of moving the board under a fixed reflow head and fixed preheater. Centering the board over the preheater allows a uniform preheating process, with less risk of inflicting thermal damage. Selective heating of an area of the board may inadvertently cause process failure, even when all the parameters appear to be correct.

Component integrity is also helped by the use of low airflow forced convection heating and a reflow head that delivers temperature uniformity. These features provide simultaneous reflow of the component being removed, without disruption to adjacent devices. The BGAs are gradually and consistently heated through the package, so as to reflow the solder connections. Remember, if temperature, ramp and dwell time (2° to 3°C/sec.) are not strictly controlled, simultaneous reflow will not occur and a damaged part is more likely.

Thermal stressing issues, such as warpage, can be avoided by careful consideration of the heating profile settings, particularly

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an insufficient under-board preheat temperature combined with too high a topside temperature. However, boards that are badly balanced thermally can also lead to problems.

The solution to the popcorning problem is to slowly prebake the components and boards prior to reworking them, as this process allows any moisture to escape slowly. Operators should also ensure that only correctly stored devices are used for both assembly and rework. Components are generally supplied in a dry pack that should be resealed after opening.

High-reliability applications are subject to very strict certification requirements, and manufacturers should ensure that the exact soldering and desoldering process specifications from the component suppliers are understood and applied. The rework process should offer a guaranteed uniformity of the reflow head temperature to approximately ±5°C, giving a total ΔT of about 10°C.

Note, however, that other factors, which are out of the control of the actual rework equipment, may influence ΔT on any PCB assembly. One factor is the area to which some solder balls are connected. Commonly, a center array of solder balls on a BGA may be connected to a ground plane specifically to dissipate heat from the component die. These balls may require extra time to reflow.

Meeting Future Challenges

In some high-reliability applications the customer is required to support many of its products over their entire operational life. This requirement may involve being able to safely repair a vast range of PCBs that are 30 years old or more, and it demands both precision and flexibility in the rework process.

In addition, North America is currently exempt from the proposed and well-publicized European Union (EU) directives on Waste Electrical and Electronic Equipment (WEEE) and Reduction of Hazardous Substances (RoHS) that will ban the use of lead in the EU no later than July 1, 2006. Although the U.S. plans no laws on the restriction of lead in the near future, persuasion from the global community and laws banning lead in major export markets will inevitably lead to changes for companies in high-reliability sectors. The elevated 20°C+ temperatures demanded by lead-free alloys, as compared to tin/lead eutectic, will only increase the risk and challenges of high-reliability rework.

In conclusion, successful BGA rework is not a trivial task. It demands a thorough knowledge and understanding of the potential defects and the prerequisite tools to put this intelligence into practice. If proper steps are taken, an assembler may achieve an extremely high yield ratio that avoids unnecessary scrapping while maximizing long-term field reliability. ■

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