

RESEARCH ON DELAMINATION FAILURE OF PLASTIC IC PACKAGES IN COMPONENTS REUSE PROCESSES

Xiaoyu Ding, Dong Xiang, Jiping Yang, Guanghong Duan

Department of Precision Instruments & Mechanology, Tsinghua University, Beijing, 100084, China

e-mail: dingxy06@tsinghua.edu.cn

Xueping Liu

Graduate School at Shenzhen, Tsinghua University, Shenzhen, 518005, China

e-mail: liuxy@sz.tsinghua.edu.cn

Abstract:

This paper describes the technological process for waste IC components reuse and studies its effect on the reliability of plastic IC components through some experiments. Results show that the high temperature thermal shock during printed circuit board (PCB) disassembly and appearance repair could lead to interfacial delamination and subsequent popcorn cracking in plastic IC packages. In the end of the paper, the generation mechanism and preventive measures are discussed, and a concrete technological process with PCB-baking for plastic IC components reuse, is proposed.

Key words: component reuse, PCB disassembly, plastic package, delamination, popcorn cracking

1 Introduction

In recent years, due to environmental problems, the reuse of end-of-life electrical and electronic equipments (EEE) has been attracting broad public attention and seized the initiatives from legislative agencies. The EU Directive on Treatment of Waste from Electrical and Electronic Equipment (WEEE) has set precise reuse and recycling rates of components, materials and substances for 10 categories of EEE. The reuse techniques of end-of-life EEE have been developed over years. One important research focus is how to reuse those still functional and usable components mounted on scrapped or rejected printed circuit boards (PCBs). Some analysis indicated that many components still have high reusability and reliability in spite of the failure of PCBs function. Therefore, the research on reuse of components is of vital realistic significance to the saving of energy and protection of environment.

In addition, components reuse also has some potential economical benefits. Firstly, the components from production rejects of assembled electronics are all “new”, and do not have been used. Though they have experienced high-temperature from SMT production, some of them still might be reused after PCB disassembly without doing damage to them. Secondly, considering increasing short innovation cycles of electronic products, many old type products could not be maintained because there is not a components stock

keeping for repair. At this time, those components from the same or similar products could be used. Actually, the second-hand market of “old” components is very flourishing in China. Components disassembled from PCBs are playing an important role in some low-value applications like toys and DVD/VCD players. This market is pressing to be regulated by law, and also needs reuse technology to give support.

In order to reuse components mounted on PCBs, we have to disassemble them from PCBs, renovate their appearance and test their functions. Moreover, these reuse processes are not supposed to do any damage to components, which is necessary to ensure their reusability. To date, some PCB disassembly systems have been developed by some research institutions [1, 2]. However, there is few analysis in the effects of disassembly and renovation processes on components’ reliability. This paper describes delamination failure in common plastic IC components which happens during reuse processes, and proposes some countermeasures.

2 General process flow for IC components reuse

Typical reuse processes for IC components should include three steps: PCB disassembly, appearance renovation and function test, which is shown in Fig. 1. This paper focuses on reliability of plastic IC components when they are treated with reuse processes. (It should be noted that in this paper, whenever the term component is used, it refers to plastic IC component.) The most common plastic packages of IC components are PBGA(Plastic Ball Grid Array), PQFP(Plastic Quad Flat Package), PSOP(Plastic Small-Outline Package) and PDIP(Plastic Dual In-Line Package). They all could be disassembled, renovated and tested under process flow described in Fig. 1.

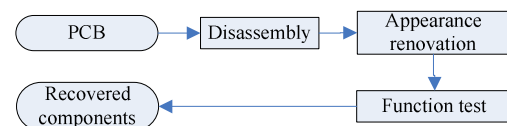


Fig. 1 General process flow for IC components reuse

2.1 PCB disassembly

PCB disassembly is the first and a key step to realize components reuse. If disassembly method is not

appropriate, it will destroy components reliability, thus subsequent renovation and test work are useless. To date, as far as we know, all of those practical PCB disassembly apparatuses use high temperature to melt solder, and then remove components by other external forces.

2.2 Appearance renovation

The main purpose of this step is to repair the shape and solderability of leads or pads. The specific work of this step include: visual inspection, residual solder removal, cleaning and leads repair. In addition, reballing is necessary for components with BGA packages.

2.3 Function test

Components have to be tested after appearance renovation because the function of components might be destroyed during disassembly or renovation. Tab. I lists some component failure modes induced by the above reuse processes.

Table I Common component failure modes caused by reuse processes

Process	Failure mode	Reason for failure
High-temperature disassembly	Delamination	Moisture, thermal impact
High-temperature disassembly	Lead or bond damage	Mechanical stress
Appearance renovation	Delamination	Moisture, thermal impact
All	ESD damage	ESD

On one hand, mechanical stress and electro-static discharge (ESD) listed in Table I are easy to be found because serious mechanical stress and ESD could destroy electrical properties of components, and this could be checked out through Analog Signature Analysis (ASA) or other function tests. Thus, the effects of mechanical stress and ESD could be eliminated by improving disassembly methods and anti-ESD measures.

On the other hand, the delamination caused by moisture and thermal impact is often ignored because this failure mode could not be checked out through function test. However, as one primary failure mode of plastic IC components, delamination often lowers the threshold for other mechanical, as well as electrical failure mechanisms, so it should be given enough attention during component reuse processes. Those components with serious delamination should not be reused even if they have passed all function tests.

3 Delamination in plastic IC packages during component reuse processes

During component reuse processes, any procedure using high temperature might cause or aggravate interfacial delamination in plastic IC packages. These procedures are high-temperature disassembly, residual solder removal and reballing. Specific reasons and countermeasures are discussed as follows:

3.1 Delamination induced by moisture in high-temperature disassembly

In order to study the effects of disassembly process on component reliability, some experiments were conducted by using a PCB disassembly apparatus. This apparatus uses hot air to melt solder of the whole PCB and then applies impact or vibration force to remove all components simultaneously. Table 2 is parameters used in an experiment. In this experiment, some components disassembled were treated with ultrasound scanning to check their internal qualities. Results show that high-temperature disassembly could easily induce interfacial delamination in plastic IC packages. Fig. 2 gives a couple of ultrasound scanning pictures of a type of PQFP with 128 leads. It is evident that component showed in Fig. 2a delaminated severely on the interface between die pad and encapsulant. (Red area is the delamination.) Table 3 is the delamination statistics of some different types of components.

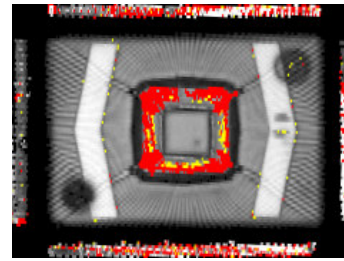


Fig. 2a Component with delamination

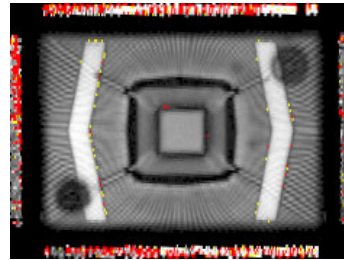


Fig. 2b Normal component

Fig. 2 Ultrasound scanning results of a type of PQFP

Table 2 Parameters used in disassembly experiments

Temperature on PCB surface	206-214℃
Vibration frequency	10Hz
Peak value of acceleration	4g
Vibration time	20s
Amplitude	1cm

Table 3 Delamination statistics of different types of components

IC component type	Number of components with delamination	Number of good components
IT8705F(PQFP)	8	16
RTL8100C(PQFP)	4	12
VT8233(PBGA)	3	12
SIS645(PBGA)	4	9

Delamination is also a failure mode during solder reflow and has troubled SMT producers for a long time. Many researchers have proved that delamination in plastic IC packages is caused by the comprehensive forces from different kinds of stresses. Firstly, the plastic encapsulant naturally absorbs moisture from surrounding environment and expands, while die and leadframe do not. This induces hygrostresses in the package. Secondly, when the package undergoes solder reflow or disassembly process, the sudden vaporization of moisture exerts a pressure on internal surfaces, and the mismatch of coefficient of thermal expansion (CTE) of different constitutes gives rise to thermal stresses. These different kinds of stresses often work at the same time, which leads to interfacial delamination and even cracking of the plastic encapsulant [3, 4, 5].

3.2 Delamination induced by appearance renovation process

In appearance renovation process, residual solder of components is melted by high temperature which might be more than 200°C. This procedure could bring thermal impact to components. In addition, components with BGA package have to be treated with reballing process which will also bring thermal impact. Thus, delamination that started in disassembly process might be aggravated in appearance renovation.

Fig. 3 presents a comparison of a component with BGA package treated with ultrasound scanning before and after appearance renovation. It shows clearly that the delamination in this component became more severe after appearance renovation.

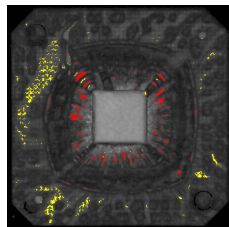


Fig. 3a Ultrasound scanning result after disassembly

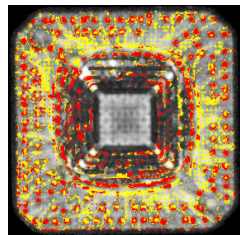


Fig. 3b Ultrasound scanning result after appearance renovation

Fig. 3 Comparison of delamination before and after appearance renovation

Conclusion can be drawn from above experiments and analysis that due to moisture in packages and thermal impact from PCB disassembly, plastic IC packages are easily to delaminate during component reuse processes.

4 Countermeasures

In order to eliminate delamination of plastic IC packages during component reuse processes, the moisture which packages absorb from environment has to be driven out. Specific methods are listed as follows:

- 1) Prebake PCBs before disassembly.
- 2) Guarantee dry environment during whole reuse processes.
- 3) After function test, components should be prebaked again and packed in moisture-proof way.

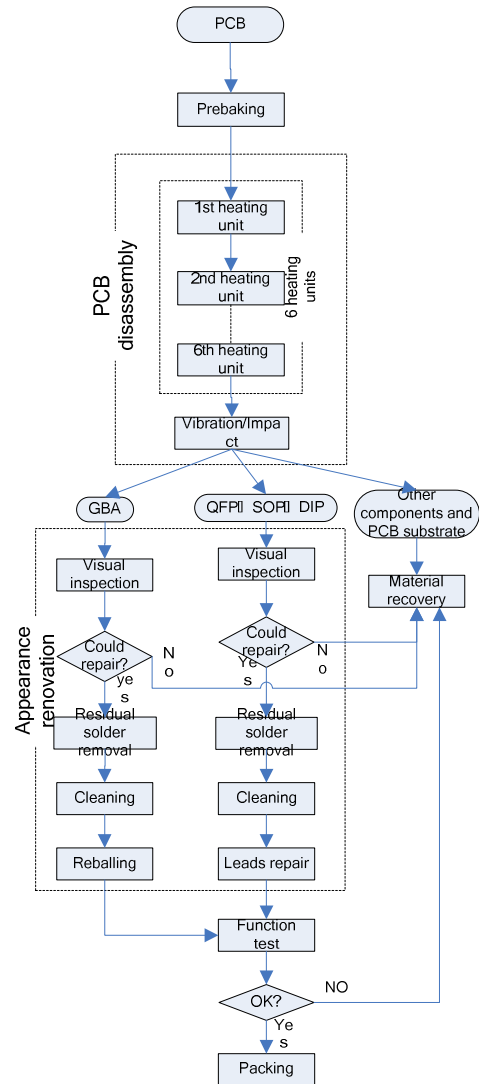


Fig. 4 Process flow structure for plastic IC component reuse

In addition, in order to reduce thermal impact, heating rate should be controlled strictly when heats PCB in disassembly.

Fig. 4 is an improved process flow for IC component reuse in which before disassembly PCBs are prebaked, and six heating units are used to increase PCB temperature step by step, and thus to reduce thermal impact to components.

5 Conclusions

Enough attention should be given to the delamination of plastic IC packages caused by moisture and thermal impact during the component reuse processes.

Those components treated with reuse processes often have moisture saturation due to long-term store and use, and they are easier to delaminate under thermal impact than new components used in SMT production. So prebaking PCB to drive out moisture is necessary to eliminate delamination and make sure component reliability. In addition, when components are heated, the heating rate should be controlled because it could help reduce thermal impact.

However, the specific baking parameters of PCBs and heating rates of disassembly still needs further study.

Acknowledgements

This research was funded by National Key Technologies R&D Program of China “Reutilization technology research and its application on typical home appliance”(2006BAF02A16) and one of the key research projects in Science and Technology in Chongqing city of China “Research on reutilization technology and apparatus for some typical e-wastes”(CSTC, 2007AC2063).

References:

- [1] S. Yokoyama, Y. Ikuta, and M. Iji. “Recycling system for printed wiring boards with mounted parts”, In: IEEE Proc. EcoDesign, pp. 814-817, (1999).
- [2] I. Stobbe, H. Griese, H. Pötter, H. Reichl, and L. Stobbe. “Quality assured disassembly of electronic components for reuse”, In: IEEE Proc. International Symposium on electronics and environment, pp. 299-305, (2002).
- [3] E. H. Wong, S. W. Koh, K. H. Lee, R. Rajoo. “Comprehensive treatment of moisture induced failure - recent advances”, IEEE Electronics Packaging Manufacturing, vol. 25, pp. 223-230, (2002).
- [4] E. H. Wong, Y. C. Teo, T .B. Lim. “Moisture Diffusion and vapor pressure modeling of IC packaging”, In: IEEE Proc. 48thElectron. Comp. Technol. Conf, pp. 1372-1378, (1998).
- [5] J. E. Galloway, B. M. Miles, “Moisture absorption and desorption predictions for plastic ball grid array packages”, IEEE Components, Packaging and Manufacturing Technology, vol. 20, pp. 274-279, (1997).