Mixed Assembly of Lead-free Solder Joint: A Short Review

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Abstract. The transition from lead (Pb) to Pb-free solder has arisen the need for the development of the reliability of mixed assemblies solder joint research. Mixed assemblies are defined as solder joints that joint together with different compositions or solder forms for example Ball Grid Array (BGA) and solder paste. During the transition period of solder materials, mixed assemblies are still used in electronic packaging. In addition, Pb-free manufacturing has been forced to release some of the product categories since legislation banning the use of lead solder in electronic assemblies. This phenomenon causes health and environmental concern of the Pb solder used in electronic assembly. Hence, some electronic assemblies will continue to use traditional eutectic Sn–Pb solder paste while others will use Pb-free solder paste. This situation indicates that the use of mixed assemblies in electronics manufacturing is still inevitable. This paper presents a projection of the reliability of mixed assembly’s Pb-free solder joint.

1 Introduction

In recent years, electronic technology has been striving to minimize the use of lead in their manufacturing and production [1, 2]. Since the motivation of most industries are driven towards less usage of lead, lead-free solders have been introduced in order to abolish the application of lead in electronic goods once and for all. The introduction of lead-free solders and BGAs also contribute to the waste electrical and electronic equipment (WEEE) by reducing the environmental risks.

Assembling Pb-free ball grid arrays (BGAs) with Sn–Pb surface mount is known to be mixed alloy, backward compatible or mixed metal processing. The mixed solder assembly has been an effective option for manufacturers as complete conversion to lead-free manufacturing is not possible [3]. The sudden ban of lead-containing components made many industries move along the transition of lead-free manufacturing. Since it is not possible for a complete change all at once, industries are force to apply backward-compatible (BC) or mixed solder assemblies. This assembly’s technique also needs to be established especially the performance or reliability of the solder joint formed [4].

Previously, electronic industry widely used the combination of lead-free such as BGA Sn-Ag-Cu (SAC) solder with Sn-Pb solder paste as mixed assemblies. Analysis of mixed assembled of SAC/Sn-Pb solder joints done by Kinyanjui et al. reveal that package size, solder ball volume, printed circuit board (PCB) surface finish, time above liquidus and peak temperature influence the solder joint reliability [5]. Study done by Wang et al. found that the reflow soldering profiles significantly affect the degree of mixing between SAC solder ball and Sn-Pb solder paste [6]. Besides that, it is also influencing the solder joint microstructural homogeneity.

However, there are still lack on the data regarding of lead-free mixed solder assembly available. Hence, this paper discusses the recent lead-free mixed assembly solder that used in electronic packaging. The solder system and reliability study of lead-free mixed assembly solder was also reviewed.

2 Recent mixed assembly Pb-free solders system

Nowadays, Sn-Bi/Sn-Ag-Cu lead-free solder alloy system was extensively used in mixed assembly for electronic packaging. The selection of Sn-3.0Ag-0.5Cu solder alloy is due to the good performance of this solder alloy which is it has high thermal cycling reliability compared with the traditional Sn-Pb solder joint [7]. However, SnAgCu

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system has faced some challenges due to the high Ag content (Ag larger than 3%) can cause poor drop-impact performance [8] and expensive cost of silver. Hence, some researchers develop new compositions which is the low Sn-Ag-Cu solder alloy such as Sn-1.0Ag-0.7Cu [9] and Sn-0.3Ag-0.7Cu solder alloy [7].

Sn-Bi solder paste is widely applied for BGA package. Adding Bi on the SnAgCu solder alloy has shown an improvement in the mechanical performance [10-12], increasing solder joint tensile strength [13], thermal fatigue resistance and also increase the drop impact performance [14]. Hence, SnAgCu solder mixed with Sn-Bi is believed to improve the reliability of the solder joint during the actual service.

Varying peak temperature during reflowed process significantly influenced the microstructure formation and also the Bi distribution. The plausible reason is that the microstructure formation and Bi distribution are governed by the different diffusion rates of each element for example Sn and Bi during the reflowed process. During the reflowed process, as the peak temperature increased, the growth of Sn-Bi area was promoted due to the high temperature providing enough energy for the Bi to diffuse into the Sn-Ag-Cu BGA solder as illustrated in Fig. 1.

![Schematic illustration of microstructure formation of solder joint on different condition: (a) and (b) low peak temperature and (c) and (d) high peak temperature.](image)

3 Reliability study of mixed assembly Pb-free solder joint

3.1 Thermal fatigue life

An investigation of thermal fatigue life of eutectic various solder materials for example: Sn-Bi, Hybrid Sn-Bi/SAC and SAC solder alloy BGAs was done by Cai et al. The fatigue life of mixed assembly of Sn-Bi/SAC was found undergo early crack at the interface between Sn-Bi and SAC. The crack emerges and propagate when the cycle just reaches 1000 times. These phenomena indicate that shortest fatigue life of mixed assembly when compare to the other two solder alloy which are Sn-Bi and SAC solder. For the mixed solder assembly, the failure mechanism occurs mainly at the interface between the SAC solder sphere and Sn-Bi solder paste. These phenomena occur due to the propagation of crack cause failure of the joints [16]. Fig. 2 shows the illustration on the mechanism that occur on mixed solder assembly that resulting in the failure of the solder joint.
3.2 Effect of current stressing

The SnAgCu/SnBiAg (SAC/SBA) mixed assembly solder joint microstructure that subjected to reliability test of current stressing at 820 hours with the constant electric current was investigated by Hadian et al. It was found that with upward electron flow direction, the distribution of Bi tends to precipitates near to the component interface for solder joints. Meanwhile, a major amount of Bi found to segregate at the interface with IMC at the board side as the direction of the current downward. The current flow significantly influences the Bi distribution on the SAC/SBA mixed assembly solder joint. Increasing stressing time resulting more Bi diffused towards the component interface for upward electron flow and the increase amount of Bi distribution for downward electron flow. There are two factors that cause the Bi atoms movement in the mixed assemblies solder which are electron wind (electromigration) and concentration gradient [17]. The concentration gradient (Fig. 3) become major effect on the Bi diffusion in mixed assembly solder joint especially when the joint subjected to the current stressing condition.

Fig. 2. Solder joint failure occurred. (a) Crack propagate along the interface between Sn-Ag-Cu BGA solder and Sn-Bi solder paste and (b) failure that cause by the crack.
4 Conclusion

Lead-free mixed assembly using SAC as a solder ball and Sn-Bi as a solder paste is commonly used. Currently, Sn-Bi solder paste was extensively used to replace the application of Sn-Pb solder paste in the mixed assembly. Many reliability tests were performed to study the behaviour of the solder in actual working condition. However, some reliability performance of mixed assembly SAC/Sn-Bi solder still needs to improve. In addition, the data of lead-free mixed assembly solder still require more studies to explore the performance of these assemblies in actual service condition.

The authors wish to express their sincere gratitude to the Ministry of Higher Education Malaysia and University Malaysia Perlis for their financial support (Research Materials Fund (RESMATE) 9001-00628) throughout the research project.

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