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Experimental Method on Solder Joint of Ball Grid Array Using Reflow Oven

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ABSTRACT. Modern applications need electronic systems to operate at high temperature. Mainly in automotive applications which leads to large temperature differences between ambient and operating temperatures. One of the most critical consequences occurs in dealing with thermo-mechanical stress which are created on solder joints due to mismatch of Coefficients of Thermal Expansion of electronic package and printed circuit board. The thermo-mechanical stress due to temperature cycles plays a fundamental role to increase life of electronic components. This study to investigate the solder joint strength by using Pb free SAC 305 solder paste on solder joint. Experiment has been carried out by IR reflow oven with different types of solder paste and thermal profile. Importantly, SAC 305 was used during the experimental process with different types of thermal profile setting in order to generate optimum results.

Keywords: *Solder paste, Printed circuit board (PCB), Ball grid array (BGA), Solder joint;*

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1. INTRODUCTION

Leading and popular electronics component are very sensitive to the high temperature [1]. Electronic component like solder joint are tend to fail when expose to the high temperature or thermal stress. Such situation happens due to lead-free processes using mixing of tin-lead and lead-free metallurgies [2,3]. Lead-free legislation permits certain products, especially those intended for high-reliability applications. One major concern with these exempt products is that, during assembly or rework, lead-free components will have to be used due to the unavailability of tin-lead components. This will result in the mixing of tin-lead and lead-free metallurgies. The mixing of metallurgies can induce new reliability concerns [4,5]. Present study is focused on enhancing solder joints by using composition of solder paste and nanoparticle. In modern times, CFD is a new area in studying solder joint during reflow oven process to verify the experimental results. Reflow oven process in solder joint can cause damage to the solder joint due to the excessive temperature [6,7]. Reflow oven process which is an alternate heating and cooling of a material of solder joint until they experience molecular reorganization, which tightens or optimizes the particulate structure of the material throughout, relieving stresses and making it denser and uniform thereby minimizing flaws or imperfections. Main issue with Solder joint happens in its microstructure due to thermal loading conditions [8,9,10]. Microstructure do plays an important role in influencing time to failure for solder joints. Several studies have been conducted to investigate strength and reliability of solder joints subjected to several loading conditions and material combinations [11]. Besides that, reflow oven process at solder joint is of the main factor that made solder joint to broke due the excessive temperature and heat [12]. In the actual process, the reflow oven were used to study thermal stress or thermal resistance of solder joint on printed circuit board (PCB) [13]. The parameters considered in this study can be categorized into two main streams: material properties, mainly Pb-contained or Pb-free, and the geometric parameters, typically height of solder joints. A total of three groups (four same samples in each group) of BGA packages subjected to thermal cycling were analyzed [14]. Existing fatigue damage models for the electronic package are mainly based on the thermal-fatigue test and most of them require stress-strain relations in low-cyclic fatigue (LCF, N < 103) to predict life cycle of the electronic board with solder interconnection. Generally, the shapes of the solder joint are random and their sizes range from ten to hundreds of micrometers. Thus, it is impossible to perform direct and accurate measurement of strain on the solder joint surface using the existing methods. Meanwhile, finite element (FE) analysis is used to obtain the stress-strain responses for solder joints with different components [15,16].

2. MATERIAL AND METHODS

The novel approach was presented in solving the solder joint reliability problems during reflow soldering process. Before dealing with numerical techniques, the experimental details for thermal profiling were presented for better understanding in structure and concept of reflow ovens. Furthermore, the procedures of determining the most critical solder joint under ATC were discussed in same section. A batch-type convection-IR reflow oven was designed for reflow the small quantity assembly or for scientific research purpose. The convenience in controlling heating and cooling elements of a convection-IR reflow oven was given the excellent performance in forming a good joint between the PCB and its components. Figs. 1-3 shows an example of experiment setup of the convection-IR lead-free reflow oven. This type of oven was used to validate simulation results for optimization studies of lead-free reflow soldering process.

Fig. 1 Experiment setup for thermal profiling

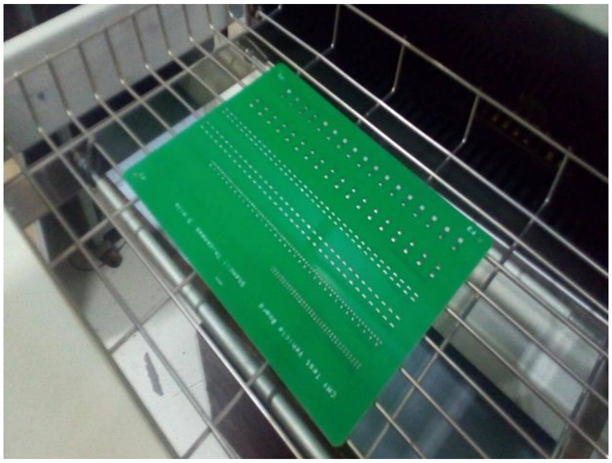


Fig. 2 Location of BGA

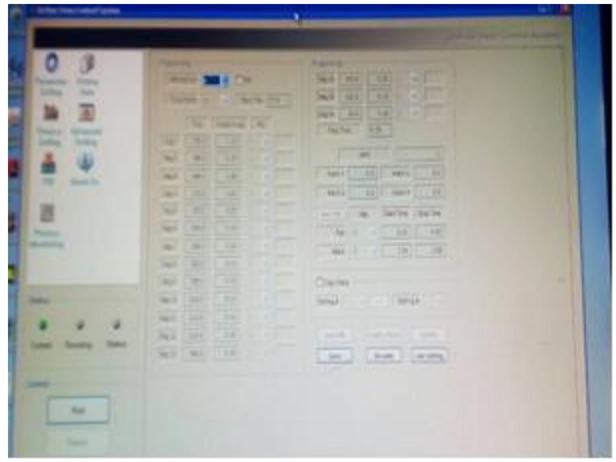


Fig. 3 Thermal profile setting

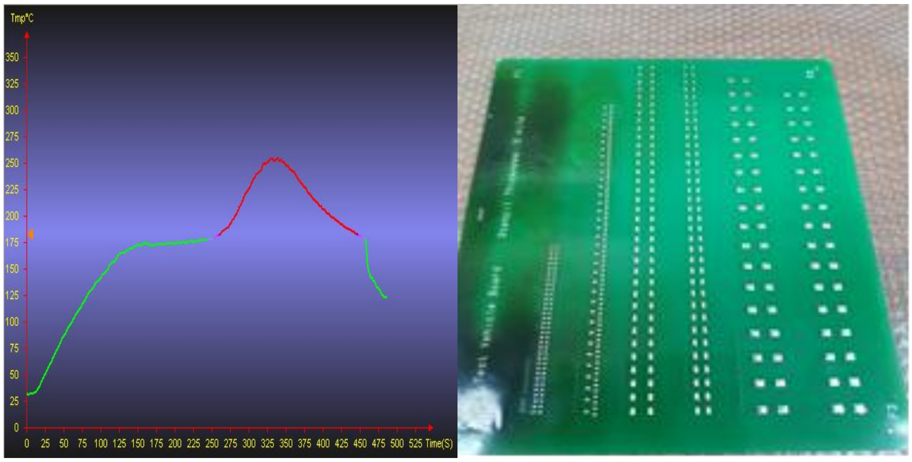
The fundamental three modes of heat transfer which are radiation, convection and conduction occurs in a convection-IR reflow oven. Radioactive heat transfer occurs from the quartz heating tube over the BGA assembly. Hot air circulated by a fan inside the oven contacts with BGA assembly and heat transfer through convection mode. Finally, the heat transfers by conduction within the multi-material BGA assembly. The slope, temperature and dwell times of lead-free reflow profile were technically programmed via computer into the following stages: preheating, soaking, reflow, and cooling stage. Since the batch-type reflow oven was designed in a single zone, the temperature setting was set according to temperature curve that reached the desired temperature in certain time. The example of oven setting temperature in the present study was set according to Table 1.

Table 1 Reflow oven setting parameters

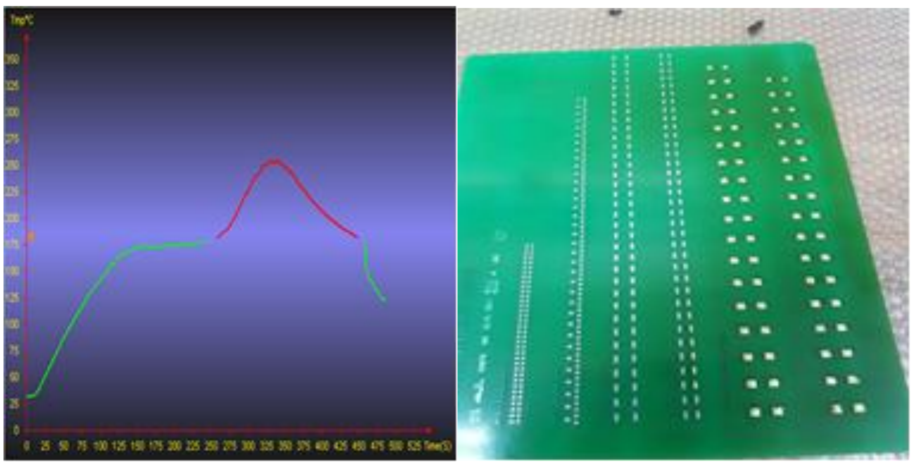
Reflow Oven Setting	Value
Cooling Time	40 s
Preheating Slope (298 K to Soak Temp)	2.5 K/s
Soaking Slope (Soak Temp to 463 K)	0.3 K/s
Ramp Slope (463 K to Peak Temp)	1.5 K/s
Cooling Slope (Peak Temp to 453 K)	-3 K/s
Soaking Temp	433 K
Peak Temp	518 K

3. RESULTS AND DISCUSSION

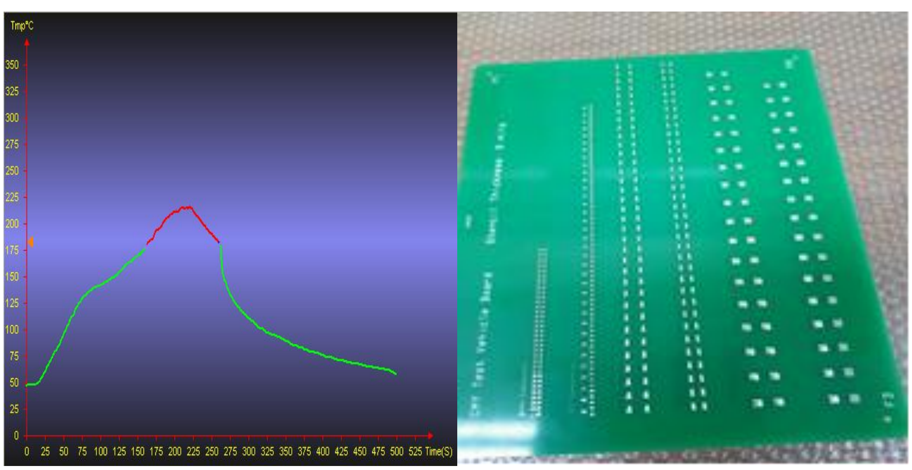
The temperature setting of the reflow oven was compared with three types of setting as shown in Fig. 4(a-c). Significant variations among the temperature setting of ovens were clearly observed, indicating that the structure and mechanism of batch-type were different, which depends on the temperature setting on thermal profile.



(a)



(b)



(c)

Fig. 4 Experiment setup for thermal profiling on Pb free SAC 305 at maximum temperature (a) 275 ºC, (b) 265 ºC and (c) 235 ºC

The temperature setting of the reflow oven was compared with three types of setting as shown in Fig. 4(a-c). Substantial change in temperature setting of ovens were clearly observed, implying the structure and mechanism of batch-type were similar, which depends on the temperature setting on thermal profile. Fig. 4(a-c) indicate thermal profile of PCB at high temperature setting such as 265 ºC and 275 ºC causing the solder paste to melting and overheat. The melting temperature for Pb free SAC 305 is 218.8 ºC. When the temperature is over 218.8 ºC, it will cause SAC 305 to melt and overheat. A suitable temperature setting during reflow oven process was very important to provide good solder joint and to avoid overheat and melting.

4. SUMMARY

Snipped results indicate Pb free SAC 305 solder paste has been carried out by IR reflow oven with different types of solder paste and thermal profile. It was evident that SAC 305 was using high temperature profile and tend to melt and overheat. The temperature different between first two settings was 17.02% and 12.77%. The reflow oven process performed by using different types of thermal profile setting in order to generate optimum results.

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