Dropping Simulation Induced by BGA Position in Printed Circuit Board for Optical Module Application

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Abstract. To obtain higher reliability of printed circuit board (PCB), finite element analysis on dropping state was introduced to point out the influence factors of BGA solder joints. The parameters of simulation included drop angle and location of chip. The results indicated that PCB dropping at 180° had greater damage to solder joints than that at 0° drop since the former case could result in direct ground contact of PCB, thereby causing larger deformation. In addition, compared to chip located in side and corner of PCB, chip located in the center exhibited good reliability during dropping simulation both at 180° and 0°.

Introduction

Since the quality of the interconnection become more critical to portable electronic equipment, solder joints play an important role in the interconnection reliability of printed circuit board (PCB) [1]. Recent years, researchers paid more attention to the analysis of the solder joints especially in the shape, height of the pad and the materials in order to obtain higher reliability of PCB [2]. However, the sensor is hard to be arranged in key position to monitor the whole dropping process during board level tests [3]. Thus, finite element analysis was introduced as especial method to simulate above dropping process [4] and evaluate the stress value of each solder joint.

In this paper, chip was placed in different position of PCB to investigate the influence of chip location to solder joints. Furthermore, dropping simulation of PCB at the angle of 0° and 180° were set to analyze the impact of drop angle.

Experiment

The model was regarded as three-layer structure including ball grid array (BGA), solder ball array and PCB from top to bottom. The solder balls with diameter of 0.7 mm were arranged in a 6×6 regular matrix. Moreover, the center distance and the height of the solder balls were 4.5 mm and 0.48 mm respectively. Figure 1. showed the grid model of PCB and solder balls. PCB assembly was 185 mm×102 mm×1.5 mm in dimension. In order to simplify the model, the properties of material and substrate for simulation were linear elastic while PCB used anisotropic materials [5] and the related parameters were displayed in Table 1. Dropping level of PCB assembly was simulated to obtain effects of BGA chip position and PCB dropping direction on the reliability of the connection of PCB and BGA chip. BAG position and dropping direction of PCB assembly were shown in Figure 2.
Results and Discussion

The influence of Drop Direction

In the actual situation, 0° drop and 180° drop were most common. As displayed in Figure 3, the stress distribution of the solder joint array was simulated for PCB dropping at 0° and 180° for the case of BGA in center, corner and side of PCB, respectively. 180° drop for PCB resulted in worse damage to solder joint, compared to 0° drop even though the chip location in PCB was different. Thus, 180° drop was the most destructive way to the reliability of solder joints. However, the stress distribution for 0° drop was nearly the same, regardless of the design change of chip position. On the other hand, the degree of damage was tiny for the case of 0° drop. The reason for above difference was that the chip contacted to the ground firstly and the speed reduced to zero in the same time when 180° drop of PCB happened, but PCB kept moving and then deformation was caused.

(a): Grid model of solder balls

(b): Grid model of PCB

Figure 1. Grid model diagram of the PCB.

Table 1. Material parameters of this model.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Density(g/cm³)</th>
<th>Elastic modulus(Gpa)</th>
<th>Poisson ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB</td>
<td>1.15</td>
<td>25</td>
<td>0.39</td>
</tr>
<tr>
<td>BGA chip</td>
<td>2.33</td>
<td>131</td>
<td>0.30</td>
</tr>
<tr>
<td>Solder joint(SnAg0.5Cu)</td>
<td>7.5</td>
<td>43</td>
<td>0.34</td>
</tr>
</tbody>
</table>
The Influence of Location of Chip

- Though BGA location certainly influenced the dropping level, current research on the drop test paid more attention to the shape and height of the solder joint. Therefore, three kinds of location of the chip were simulated to achieve the effect of the chip location on dropping level. From the simulation, the maximum stress distribution was located in the edges of solder joint allay, as shown in Figure 4, so the first line of each chip location was selected to plot the maximum stress distribution as shown in Figure 5 and Figure 6. As demonstrated in Figure 5, the stress of each chip in PCB side was larger than that in PCB center and corner when the chip was located in PCB corner after 180° drop which could reach 3.835×10^8 N/m^2. While BGA chip was located in the corner of the PCB, its stress was smaller than those chips in the side of PCB. Obviously, when chip was located in the center of the PCB, the value of stress of solder joint was much smaller than two other cases and the lowest value was 2.042×10^8 N/m^2. The result indicated that the most dangerous layout was that chip was located in the side of PCB when 180° drop happened. In contrast, the most safety layout was that chip was located in the center of PCB.
Figure 3. (a), (b), (c) Stress distribution of the solder joint array when chip located in center, corner and side of PCB respectively at 0° drop. (d), (e), (f) Stress distribution of the solder joint array when chip located in center, corner and side of PCB respectively at 180° drop.

Figure 4. Stress distribution of solder joint array.

As displayed in Figure 6, it illustrated the maximum value of stress of solder joint in 0° drop. BGA chip located in the center of PCB was the optimal choice since its each solder joint was smaller than other layouts. Such result was similar to that for 180° drop and its lowest value was 2.025×10^8 N/m². On the contrary to 180° drop, solder joints in the first row of BGA chip in the corner had a greater stress distribution than that in the side which could reach 3.491×10^8 N/m². However, the opposite simulation result of the stress distribution was found in the last two rows of solder joints. Chip in PCB side benefited to decrease the dropping-induced stress. From the above analysis, it was found that chip located in the center of PCB could contribute to the good reliability of each solder joint after dropping simulation at different angle. Thus, when designing the layout of PCB, designer should take the priority into the consideration.
**Conclusion**

This paper developed a method to calculate the stress value of solder joint and investigate the factors that affect the reliability of solder joints. According to the simulation results, it was confirmed that 0° drop had much more stress value than 180° drop because BGA chip directly contacted to the ground to result in deformation in the condition of 0° drop. It was also found that chip located in center of PCB was the most optimal layout both in the condition of 0° and 180° drop. Nevertheless, the results also demonstrated that chip located side of PCB was the most dangerous design for the case of 180° drop while chip located in the corner of the PCB had higher stress value than chip located in the side when 0° drop occurred.

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