The Finite Element Analysis of Factors affecting Deformation of Solder Bumps

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Abstract

Deformation of components in IC die packages has been found more often due to the reduction of IC die package size in hard disc drive (HDD). Therefore, this research aims to study and analyze the factors affecting deformation of solder bumps in the IC die package. Particularly, the position of simple solder bumps is studied asymmetrically. The finite element method is a significant tool in this study for analyzing the stress and strain in solder bumps, which is affected by the heat reflow process. The results show that position and density of solder bumps in an IC die package are the significant factors affecting deformation of solder bumps.

Keywords: finite element method, deformation, stress, solder bumps

Introduction

Problem of deformation of components in IC die packages has been found in the manufacturing process of hard disc drive (HDD). Many computer manufacturing companies including the Belton Thailand Company Limited are facing this problem. In order to solve the problem, the finite element method is used to analyze the possible cause of deformation by focusing on the stress and strain in solder bumps

Many research literatures have been dedicated to IC package packages. Charles (Charles et al.,1998) exhibited the influence of geometry solder bump profile to the fatigue life during temperature cycle. Teo (Teo.,1998) investigated the influence of solder bump material, chip size, pad options and underfill material under effected conditions, such as temperature cycle, power circulation, stable temperature, humidity test and high temperature test. Significantly, the research has shown that the fatigue damage in solder bump was caused mostly by the loading temperature. Furthermore, Liu (Liu et al.,2000) proposed the novel technique which is named hybrid method. Their technique is a combination between analytical algorithm and energy-based method to forecast the force balanced surface profile and restoring forces of solder joints in multiple pad shape area package. Jong (Jong et al.,2005) investigated the geometrical effects of bumps on the fatigue life of flip-chip package by Taguchi method and found that the influence of climbing height of underfill was significant to the fatigue life assessment of flip-chip bumps and the width of the solder bump was the most important factor.

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Case study

Normally, the arm coil of hard disk can be divided to two main parts, i.e., flip-chip (which operates in the part of flex) and hook up (which operates in the process of combining the flex into bracket and joining the arm coil assembly). In this research, the top of flip-chip package in the figure 1 is particularly focused. The figure 2 shows the simple actual dimension of IC die components which consists of three parts: preamp, bump and flex.

The major components of IC die package consist of preamp, solder bump and flex. Figure 2 shows the dimensions of IC die package and table 1 shows the characteristics of IC die package including height, width, length, radius and weight that are considerably used as simulating data. Preamp is normally made from silicon (Si). Solder bump composite has several formulas. In this study, SAC 405 is studied. Normally, flex is made from pure copper (Cu).

Figure 1 shows the IC die package with unsymmetrical bump position, which is studied in this research. The actual solder bump position can be in several types depending on a circuit designer. The unsymmetrical bump position has been normally found in an IC die package. Figure 3 and 4 show the schematic and 3D view of solder bumps in this study. The ANSYS version 11 is the major finite element program for analysis because it has the potential and well recognized for analyzing affect of stress, strain, and temperature on material.

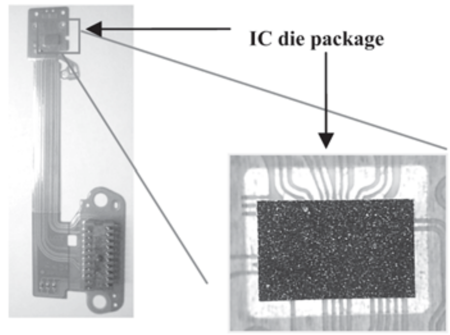

Figure 1 The simple IC package for this study.

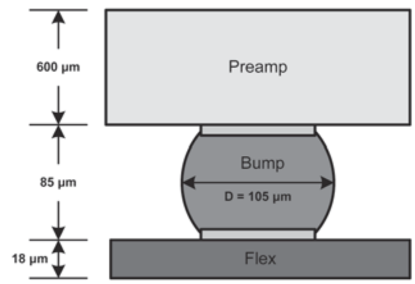

Figure 2 Dimensions and geometry of the IC die package.

Table 1 Characteristics of components of a IC die package.

	Height (um)	Width (um)	Length (um)	Radius (um)	Weight (mg)
Preamp	600	2650	3280	-	10.0139
Bump	85	-	-	105	-
Flex	18	2650	3280	-	-

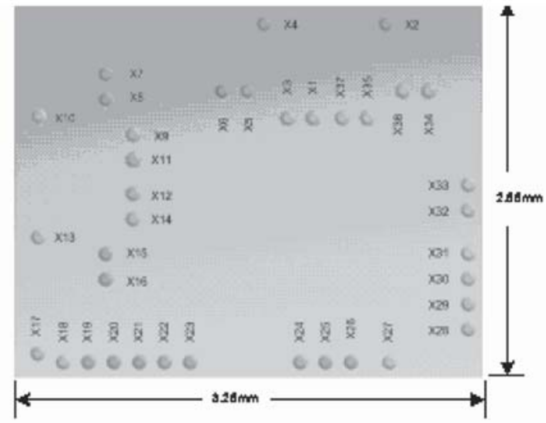

Figure 3 Schematic of solder bumps in the IC die package.

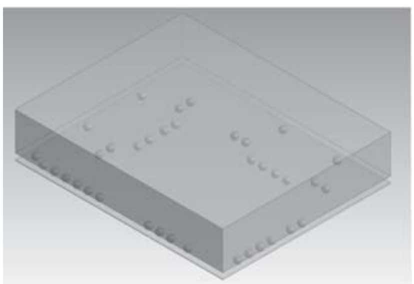

Figure 4 3D view of solder bumps in the IC die package.

Heat reflow profile

Analysis of deformation of bumps consists of two periods of transformation: from solid to liquid and liquid to solid. The researchers aim to analyze the period of solid transformed into liquid because this process is taken place in graphic form which is easily visible. Figure 5 displays the process of heat reflow.

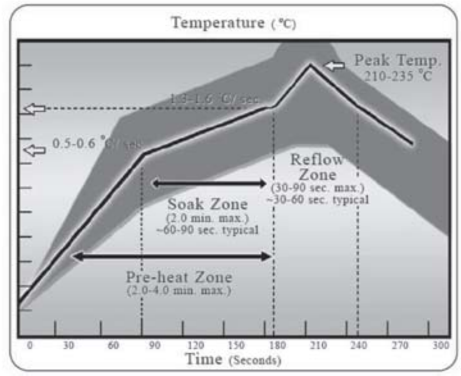

Figure 5 Heat reflow profile.

The period of solid transformed into liquid is the pre-heat zone. This period is taken place in high temperature and has the chemical interaction and the period of liquid transformed into solid is taken place after the pre-heat zone, i.e., the reflow zone. During this period, the component is combined because the temperature is higher than the melting point of components and then the temperature is gradually reduced. Similarly, each component has this kind of the reflow profile and the only difference is the temperature being setting.

Stress and Strain Relationship

Stress is the ratio of outside force coming to the cut surface. This is shown in the following formula:

$$\sigma = \frac{P}{A} \qquad (1)$$

σ is stress (N/m^2)

P is the outside force (N)

A is the area intersected by force (m^2)

As the force enforcing the component is produced by the gravity of the world, the normal stress, which is the force on the surface produced in the vertical intersection with the cut surface, has to be considered. If the force comes from the cut surface, it is called tensile stress. If the force comes to the cut surface, it is called compressive stress.

Strain is the deformation of material when the outside force engenders the strain and results in stress. The deformation of material is an effect of movement within the material. This is shown in the following formula:

$$\varepsilon = \frac{\Delta L}{L_0} \qquad (2)$$

โดยที่ e is Strain

ΔL is the deformed length (L-L_0)

L_0 is the original length of material

The strain can be divided into two main varieties: firstly, the elastic deformation or elastic strain. This is the deformation which material returns its original form when the force is reduced and atoms which move due to the heat generated by strain will return to their own position. Secondly, the plastic deformation or plastic strain is the deformation which material retains its form even though the force is reduced and atoms which move will not return to their normal position. All materials have two deformations depending on how much the force enforced or strained. If the strain exceeds the elastic limit, material will have elastic behavior. On the other hand, if the strain does not exceed the limit, material will be permanent deformation or plastic deformation.

Finite Element Analysis

In the analysis of deformation of solder bumps when the heat is being set to the component, the heat, stress and strain interacting with the component is analyzed by the ANSYS program. For this analysis, the element of the component is divided into three parts: preamp, bump and flex as shown in Figure 2. The deformation of bumps will be the focus of this study.

In the analysis, the heat as shown in Figure 5 is set to the component above and below areas and the heat interacted with the component is observed by the analysis of program ANSYS. It is found that the part above and below of the component mostly received the heat. While observing the heat occurred inside a single bump, the intersection of a single bump shows that the lower area of bump received the heat lesser than the other areas since the flex below has less heat when comparing with the preamp on the above area.

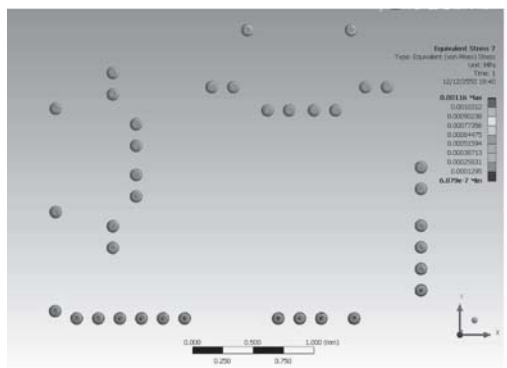

Figure 6. Stress of solder bumps.

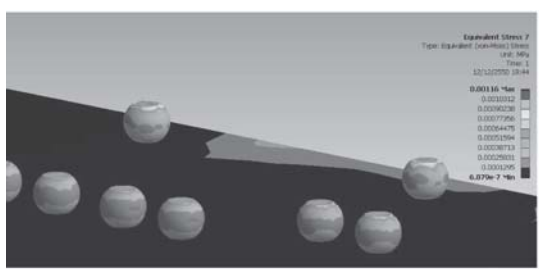

Figure 7. 3D view of stress of bumps.

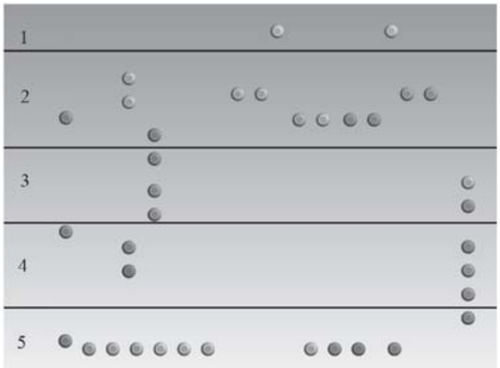

Figure 8. Groups of solder bump.

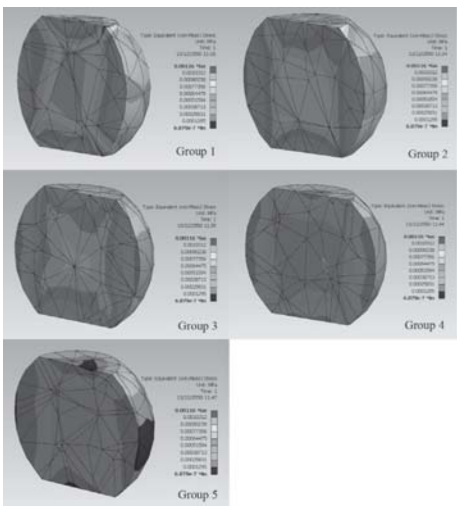

Figure 9. Comparison of stress distribution inside solder bumps.

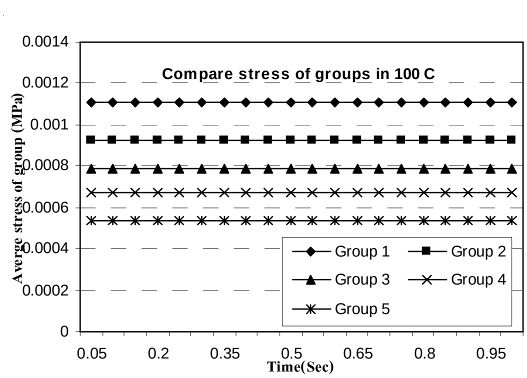

Figure 10. Comparison of average stress levels in solder bump

From analysis of stress interacted with each solder bump, it is found that when set the temperature to 100 degree with the force of preamp, each bump has more value of stress than other areas. This means that it is likely to be deformed more than other areas since the so-called area received the force more than other areas as shown in figure 6. when researchers observed closely to the bump, it is clear that the so called area has more value of stress than other areas as shown in Figure 7.

Since the area of the component has the unequal value of stress, the component is divided into five groups as shown in Figure 8 and Figure 9 shows stress distributions inside solder bumps in each group. It is found that the value of stress of the first group is highest since this group has fewer bumps comparing with other groups. Figure 10 shows the comparison of average stress levels in solder bumps.

Conclusion

The analysis of the ANSYS 11.0 program shows that the position of solder bumps has a significant effect on deformation. Deformation was found at the position with few bumps more than at the position with many bumps. This is because the position with many bumps will support and share the force on the bumps.

Acknowledgments

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