Effect of Different Matrix Characteristics on Diamond Saw Blade Lifetime in BGA Substrates Singulation Process

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Abstract

Diamond saw blades for BGA substrate singulation were fabricated and evaluated for the saw blades wear and life. Two kinds of saw blades with different hardness matrices were used to compare the blade wear and life. These blades have the same thickness, the same diamond grit size and the same concentration. The matrix material of one saw blade is hard & dense and the other one is soft & loose. A saw machine was used for BGA substrate singulation. The two kinds of blades used the same sawing parameters. The results show that the hard & dense blade only cuts 2000m, and the soft & loose blade can cut 3300m and more, but the wear of soft & loose blade was larger than that of hard & dense blade. The blade life depends on the edge shape, and the edge shape depends on the edge wear. The hard & dense matrix results in little wear on the blade edge, causing a higher wear at the blade side corners. End of hard & dense blade life is the loss of die size. However, the soft & loose matrix results in a higher wear on the blade edge, and the edge shape keeps even until the blade is worn out. So the soft & loose blade can cut much longer distance than the hard & dense blade.

1. Introduction

BGA (Ball Grid Array) packages are based upon wire-bonded or flip-chipped dies mounted on an FR4/5 or BT resin based laminate. The backside of the die is usually encapsulated in an epoxy resin in which there are many enhanced particles such as SiO_2, Al_2O_3. The package has no leads and connects to the PCB by an array of solder balls. Typical thickness is 0.9-2.0 mm (including solder balls). Most common package sizes are 4×4 to 40×40 mm [1]. BGA packages are singulated from the substrates by a saw device. Diamond saw blades are usually used in the microelectronics industry for die separation and also for fine, accurate, partial and cut-through of very hard and brittle materials. Large-scale production and high productivity rely on low, consistent blade wear and superior cut quality as demanded by today's sophisticated industrial environment [2,3]. The singulation of the BGA substrate into individual packages by diamond saw blade is an important step in the manufacturing process, but there are many problems affect packages throughput and cost, such as chipping, burrs, slivers, protrusions and trace shorts, lip effect, and so on [2]. In these problems, the lip effect causes the loss of package size, and it is the main problem that affects the blade life. This paper will give intensive analysis and research from the saw blade matrix characteristics and formation causation of lip effect to process improvement, and it will give the effective ways to solve the problem of lip effect by choosing appropriate saw blades.

2. Experimental procedures

For evaluation of the blades wear and life, the blades with different hardness matrix were fabricated. Table 1 shows a classified table of saw blades. All blades with 40mm in inner diameter and 58mm in outer one were used to compare the cutting performance. These blades had the same thickness (260 *mm*) and the same diamond grain size (20-30 *mm*). Blades A & B have the same diamond concentration (60%), but their components of matrixes differ from each other. The matrix of blade A is made of the elements of Cu, Sn, Ni, Co, and one of blade B is made of the elements of Cu, Sn and other nonmetals. The hardness of matrixes of blade A and blade B were HRB97 and HRB60, respectively. A sawing machine (DISCO EAD6340K) was used for cutting BGA substrate. The BGA substrates with 220mm of length and 60mm of width and 1mm of thickness were used as workpieces. The cutting street width is 0.26mm, the die size is 14×14mm, and the tolerance limit of the die dimension is within ±0.05mm.

Table 1 Characteristic of saw blades

Sign	Matrix materials	Hardness of matrix materials	Diamond size (*mm*)	Diamond concentration	Blade thickness (*mm*)
A	Cu, Sn, Ni, Co	Hard (HRB97)	20-30	60%	260±3
B	Cu, Sn, nonmetals	Soft (HRB60)	20-30	60%	260±3

Note: 100% diamond concentration is 4.4 carat per cubic centimeter

The outer diameter of flange for fixing sawing blade was 49.5mm. The exposure length of blade was 4.25mm. Turning velocity and feeding rate were 30,000rpm and 100mm/s, respectively. Blade height was 0.35mm, seeing figure 2. The blade height was kept in a constant in BGA singulation process. The wearing shapes and the matrix materials of the blades were inspected by a scanning electron microscope (SEM, JSM-5610LV).

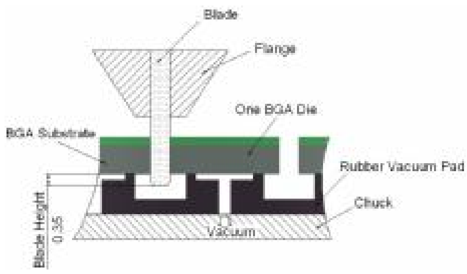
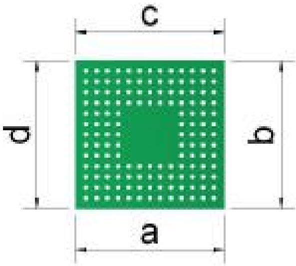


Figure 2. Blade height

Die size is a key factor that determines the service life of the blade. In order to evaluate the blades life, the average die size of 10ea is measured in each cutting length. The measure positions of die size are shown in figure 3.



Top view

Cross-section

Figure 3. Measure positions of die size

3. Results and discussions

The components of matrix materials determine the blade characteristics, such as hardness, density, bending strength, and so on. Figures 3 and 4 show cross-sections of blades A & B. Blade A presented a hard and dense characteristics, and blade B presented a soft and loose characteristics due to the pores induced by the volatilization of some nonmetal materials with the low melting point and the interrupting matrix induced by another nonmetal materials with high melting point.

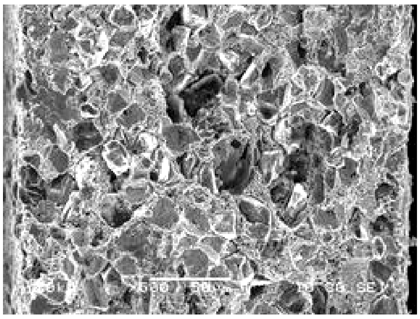


Figure 4. Cross-sections of blade A which has a hard and dense matrix

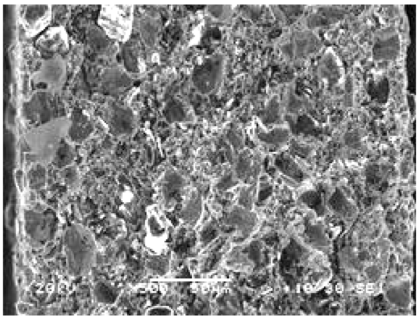
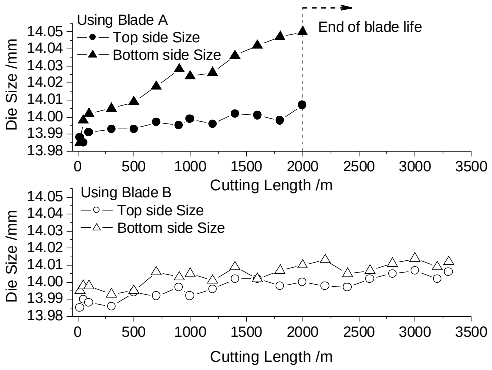


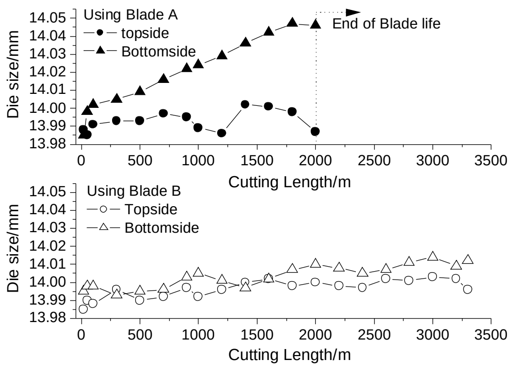
Figure 5. Cross-sections of blade B which has a soft and loose matrix

Figure 6 shows the relationship of die size to cutting length with different blades. The results show that the lifetime of blade B is longer than that of blade A. Blade A demonstrates the total cutting length of 2000m, but blade B does 3300m and more. End of blade A life reason is the loss of die size, but end of blade B life reason is worn out.

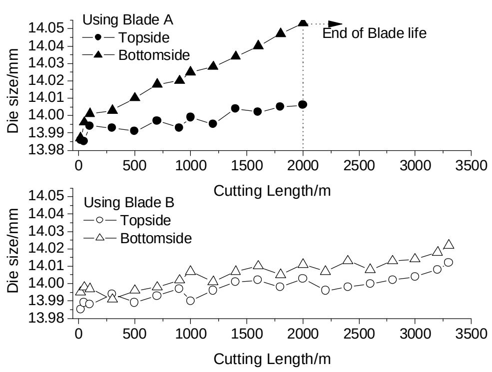
The bottom side size of die on its four sides has been out of the specification in 2000m when using blade A, but the both top and bottom sides size of die on its four sides are still within the specification in 3300m and more when using blade B. The bottom side size out of specification is due to the change of the of blade edge shape. During cutting process, two forces load on the corner of the blade edge. One is the radial force that is loaded on the blade edge along the radial direction, and another is the lateral force that is loaded on the lateral sides of blade, as shown in figure 9. The corner of the blade edge wears out along the direction of resultant force. So the flat shape of blade edge changes into the taper one, as seen in figure 7. The taper-shape induced by imbalance with radial and lateral wear on the blade edge copies its shape to the bottom of die leaving a small lip we call it lip effect, which causes loss of die size, as shown in figure 8. Once it takes place, it results immediately in the over tolerance of the die size and final in termination of the blade life.



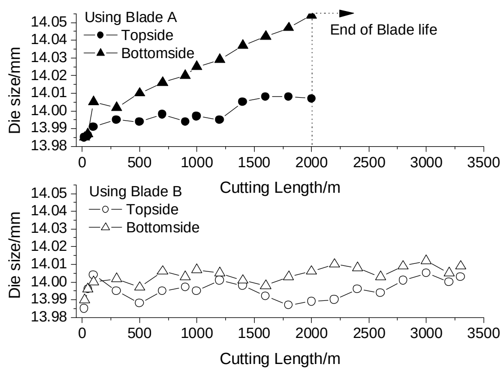
Side a



Side b



Side c



Side d

Figure 6. Relationship of die size to cutting length with different blades

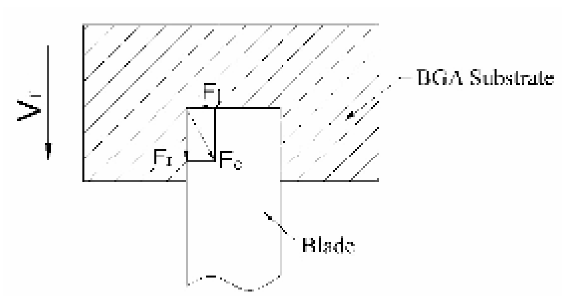


Figure 7. The forces loaded on the blade edge during the cutting process

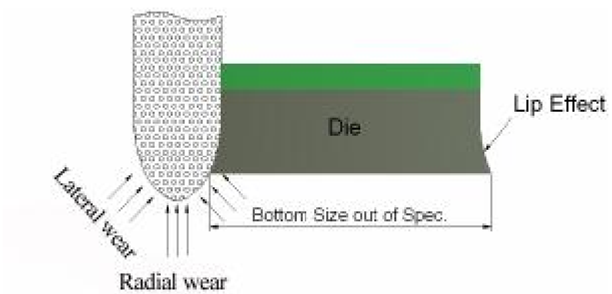


Figure 8. Lip effect

Figure 9 shows the shapes of blade A and B edges after using. The results show that the lateral wear of blade A looks very obvious and results in the taper-shape occurring on the edge. The thickness of blade A becomes gradually thin towards the edge. It is only 0.213mm in the place where the blade height is 0.35mm. Just because the thickness in the place is much thinner than initial one, the bottom side size of die is out of the specification. However, the lateral wear of blade B looks unobvious and the thickness is 0.245mm in the place of blade height that approximate the initial one.

So it can cut more BGA substrates than blade A and the die size tolerance is well within the specification limit for a long time. The thickness of blade in the place of blade height influences the die size. If the thickness in the place of blade height becomes thin, the die size will be increased. The thickness of blade edge is mainly affected by the lateral wear. The blade matrix characteristics dominate the wear of blade. If the matrix of blade is hard and dense, the radial wear speed is slow. If it is soft and loose, the radial wear speed is fast. The faster radial wear can counterbalance the lateral wear that cause the taper shape of the blade edge to maintain the thickness of the blade edge approximating the initial one. Because the matrix of blade A is much harder and denser than that of blade B, the radial wear of blade A is much less than that of blade B, as shown in figure 10. The radial slower wear of blade A induces the formation of taper-shape on the edge. But blade B possess the high radial wear characteristic induced by the soft and loose matrix materials, thus it is good to maintain the flat shape of the blade edge.

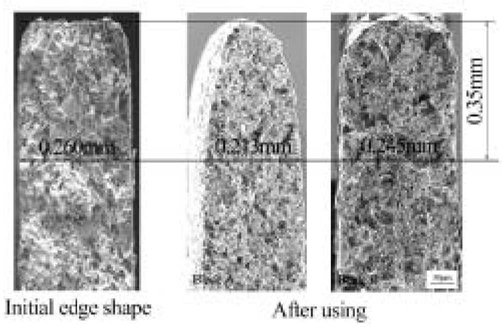


Figure 9. The shape of the blade edges after using

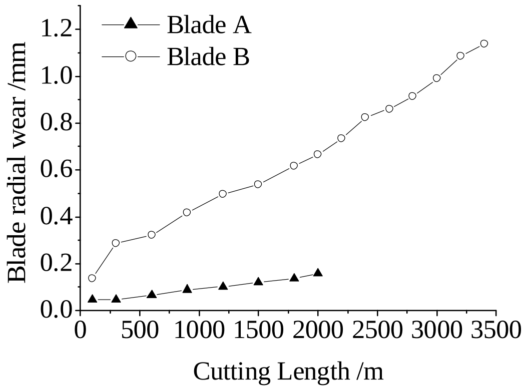


Figure 10. The radial wear of blades

5. Conclusions

(1) The blade matrix characteristics extremely affect the blade life. The soft & loose blade can cut much longer distance than the hard & dense blade.

(2) End of the hard & dense blade life reason is the die size is out of the specification, which induced by change of the blade edge shape. End of the soft & loose blade life reason is the blade is worn out.

(3) The faster radial wear can counterbalance lateral wear to be good to maintain the thickness of the blade edge approximating the initial one.

Acknowledgements

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