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Unique Fiducial Designs for CSP Singulation Process

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Abstract

This paper describes the invention of unique designs of fiducial marks on the ball pad side of substrates for different CSP (Chip Scale Package) integrated circuit package types and sizes. These unique designs on the substrates are related to the saw singulation process in the assembly of this type of packages. The distinct, unique fiducial designs enable the PRS (Pattern Recognition System) of the saw singulation equipment to differentiate between different molded CSP substrates, and stop the operation when the saw program of the equipment doesn't match the expected fiducial design on the substrate. These unique fiducial marks provide an error free solution that prevents loading wrong saw programs or feeding incorrect CSP substrates/packages into the saw singulation equipment. The benefits are that different type and sizes of CSP packages will not be sawn with the wrong dimensions, and that expensive saw singulation equipment parts will not get damaged.

1. INTRODUCTION

The saw singulation process in the assembly of CSP integrated packages involves singulating the CSP molded substrates, with solder balls attached, into individual units—i.e., the final, physical products (*Refer to* Fig. 1 CSP Singulated Unit.)

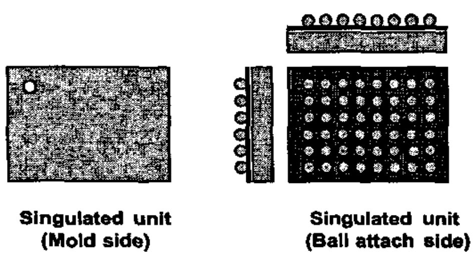


Fig. 1 CSP Singulated Unit

The CSP saw singulation system consists of a dicing saw integrated with a handler. Molded CSP substrates are carried in a nest, ball side up, and placed onto a saw chuck that holds down the substrates during cutting. The saw chuck feeds the substrates towards the rotating blade that cuts through the molded substrates, and separates them into individual CSP units. The dicing saw basically consists of a blade mounted on a high speed rotating spindle shaft to cut the parts (*Refer to* Fig. 2 Saw Singulation System, and Fig. 3 CSP Singulation Concept.) Accurate cutting (accurate package dimensions) at a standard saw singulation operation is ensured by a PRS (Pattern Recognition System) integrated in the singulation system, and fiducial marks (cross design) located on the surface of the substrates (*Refer to* Fig. 7 Identical Fiducial Designs for Different CSP Package Types.) The PRS basically reads the cross designs of the fiducial marks for the equipment to perform the desired alignment to obtain the correct dimensions of the final product.

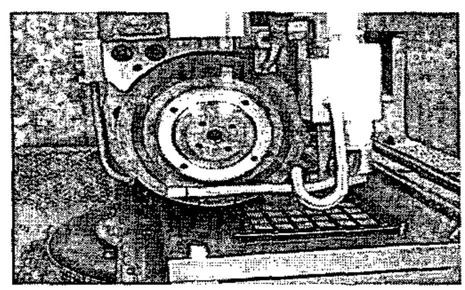


Fig. 2 Saw Singulation System

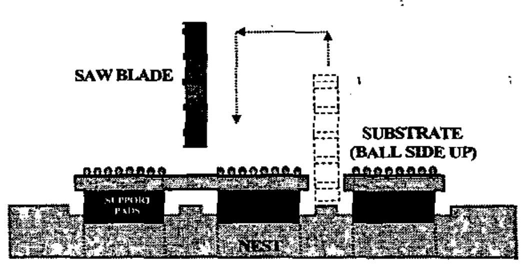


Fig. 3 CSP Singulation Concept

Since a large number of different CSP package types and package sizes are being manufactured, different saw programs are required for each package type or size. In a manufacturing environment where frequent machine conversions (saw programs) between the different package types and sizes takes place, errors of loading the wrong program or substrates are prone to occur. If the incorrect saw program is selected, or the wrong substrate type is loaded into the machine, the pattern recognition system is not able to detect these problems, and the equipment proceeds with an unsuitable cutting process. This results in damage to the support pads that support the substrate on the saw chuck during cutting (*Refer to* Fig. 4 Damaged Support Pads) and a final product with the wrong dimensions (*Refer to* Fig. 5 Package Dimension Rejects.)

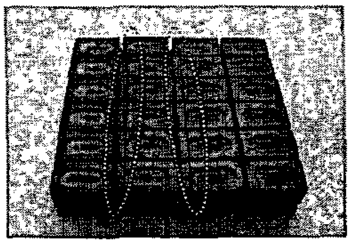


Fig. 4 Damaged Support Pads

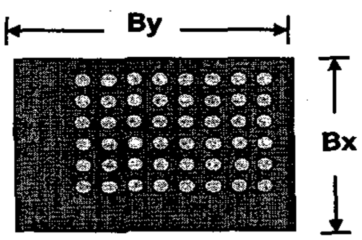


Fig. 5 Package Dimension Rejects

Fig. 6 Error Scenarios in CSP Singulation Process explicitly summarizes the error scenarios that are potential catastrophic issues in a CSP singulation process. It is therefore desirable to develop a methodology where no cutting process would proceed with the wrong program or the wrong substrate in place.

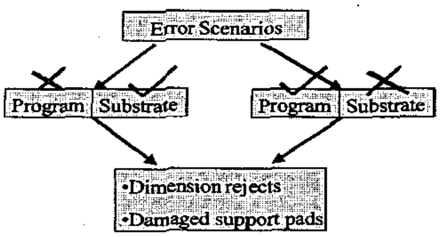


Fig. 6 Error Scenarios in CSP Singulation Process

2. Problem Description

If we take the example of two typical CSP packages that have different dimensions—Package X and Package Y—we see that the bottom fiducial marks normally used as reference to acquire accurate cutting positions are both identical cross designs for these two packages—*Refer to* Fig. 7 Identical Fiducial Designs for Different CSP Package. The PRS of the singulation equipment always searches for these fiducial marks for proper alignment and cutting. Since the fiducial marks of the two packages are identical, an identical cutting process will take place, although the dimensions of these two packages, and the machine setup (e.g., rubber pads on the saw chuck) are actually different. The result is a package cut in the wrong dimensions, and most likely damaged rubber pads where the blade cut the pads instead of running through the groove. Ideally, the PRS should be able to detect the difference between the two CSP packages, and stop singulation if the cutting setup does not match the one required for the particular package type on the cutting chuck—i.e., the singulation system should have error detection capability.

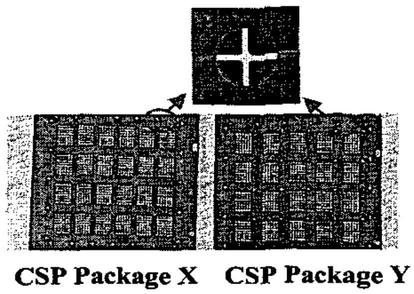


Fig. 7 Identical Fiducial Designs for Different CSP Package Types

3. Unique Fiducial Designs for Different CSP Packages

Since the PRS of a saw singulation machine is capable to recognize and differentiate between different fiducial designs, and the system is equally capable to make decisions concerning alignment based on information received from the PRS—i.e., the cutting software program—we proposed to use unique fiducial designs for each CSP package at the bottom of the substrates to provide saw singulation systems with detection capability of the type of package on the cutting chuck. Basically, if the fiducial design detected on the substrate did not match the one expected by the particular cutting program loaded, the system would not proceed with cutting and alarm the user. This would provide an error free CSP saw singulation process, since loaded substrates and the customized sawing program would have to match for the cutting process to proceed. (*Refer to* Fig. 8 Singulation Process with Unique Fiducial Marks.)

Other solutions such as using mechanical detection, or applying sensors, to detect different package types require substantial modifications of either or both the substrates and the saw singulation equipment, at relatively high cost. These solutions also require continuous monitoring and maintenance of the mechanical features, adjustments of the sensors, etc., to maintain the detection capability. On the other hand, the concept of having unique fiducial designs for different CSP package types requires no additional cost and maintenance.

We therefore believe that the concept of using unique fiducial marks for different package types and sizes would be the best solution for an error free singulation process for CSPs As more, new CSP packages come into production, new unique fiducial designs could be adopted.

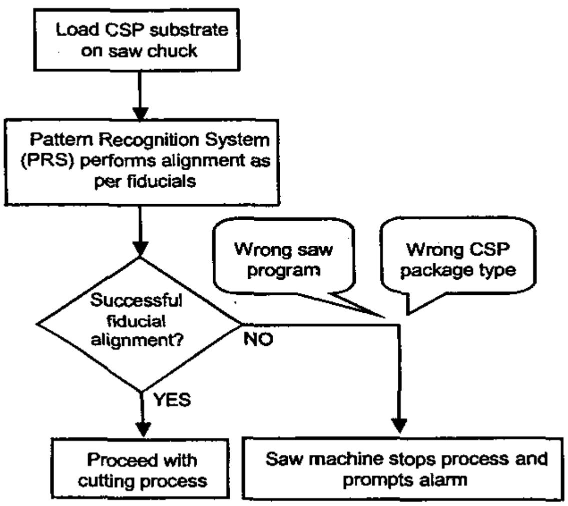


Fig. 8 Singulation Process with Unique Fiducial Marks

4. QUALIFICATION EXPERIMENTS

4.1. Unique Fiducial Design Development

We developed a new, unique fiducial design for substrates to be used with our test vehicle—i.e., a CSP package code named package Y. The new fiducial mark consisted of a "T" design, as opposed to the "cross" design normally found on the bottom (ball side) of standard substrates (*Refer to* Fig. 9 Standard & New Fiducial Designs.)

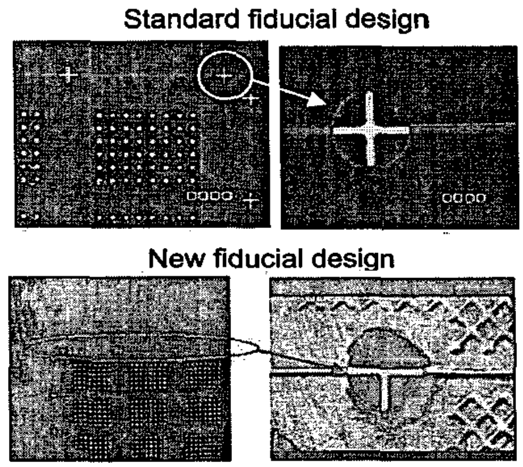


Fig. 9 Standard & New Fiducial Designs

4.2. Detection Capability

Design of Experiment

To qualify our proposal of unique fiducial designs for different CSP packages, we carried out a series of experiments to evaluate the impact on the singulation process (detection capability and saw quality.) The Design of Experiment (DOE) involved 4 runs: Run A, B, C and D. Run A simulated an error scenario with the standard saw program of package X (alignment as per cross fiducial) and package Y standard substrates (with cross design fiducial.) Run B simulated an error scenario with the standard saw program of package Y (alignment as per cross fiducial) and package X standard substrates (with cross design fiducial.) Run C simulated the error scenario of a standard saw program of package X (alignment as per cross fiducial) and package Y with the new T design fiducial. Run D simulated the error scenario of a new customized saw program of package Y (alignment per T-design fiducial) and package X substrates (with cross design fiducial.) (*Refer to* Fig. 10 Simulation of Different Error Scenarios.)

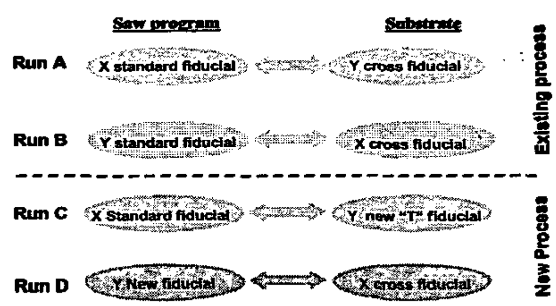


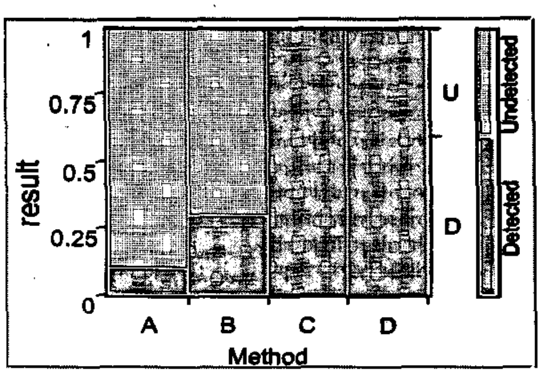
Fig. 10 Simulation of Different Error Scenarios

The experiments involved 20 replicates of each of the different substrates of each run. The response measured was the capability of the PRS of the singulation system to detect the errors, which was monitored on the display of the system—i.e., an "Auto alignment completed" prompt that the saw can proceed cutting as normal (meaning the error was not detected), and a "Not found micro target" prompt that stops the saw operation and activates an alarm (meaning that the error was detected, or the system has error detection capability).

Experiment Results

Data from the DOE were consolidated and statistically analyzed using Chi-Square test (*Refer to* Fig. 11 Chi-Square Test Results.) The "Likelihood ratio" of the test with a value of less than 0.05 inferred that the different scenarios significantly impact the PRS detection results, at 95% confidence level. The bar graph indicated that scenarios A and B do not have total detection capability (10% and 30% respectively), while scenarios C and D had total detection capability (100 percent).

From these results we could conclude that the PRS of a saw singulation machine is capable to detect and identify different fiducial designs on substrates, and that the software of the system is capable of making accurate decisions about the process (saw, or stop the process). Therefore, implementing unique fiducial designs on substrates for different CSP packages enables the singulation systems to identify the particular package, and align and cut at desired dimensions, or stop the process if the wrong cutting program/substrate should be loaded (*Refer to* Fig. 12 Simulation Results with Unique Fiducial Design.)



Tests		
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	70.244	<.0001
Pearson	55.000	<.0001

Fig. 11 Chi-Square Test Results

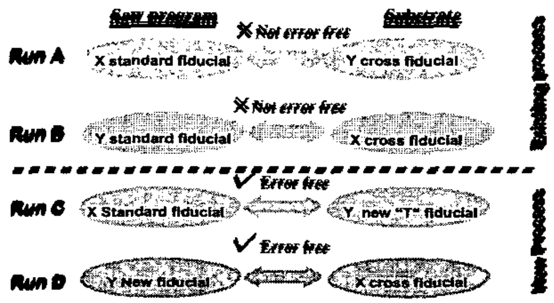


Fig. 12 Simulation Results with Unique Fiducial Design

4.3. Cutting Quality Qualification

Critical Parameters

Due to changes made in the saw program —i.e., alignment according to programming for particular fiducial design—we also needed to confirm the cutting quality by such a modified program. Critical singulation parameters include package dimension (Bx/By, or the length and width of a package) and ball array offset (Gx/Gy, or the offset from the center of the whole ball array compared to the center of the package both in x and y directions.) (*Refer to* Fig. 13 Critical Singulation Parameters.)

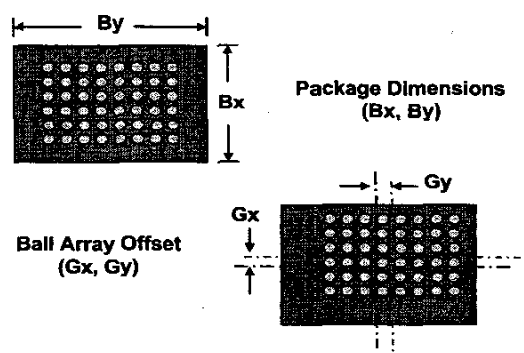


Fig. 13 Critical Singulation Parameters

We collected and analyzed data on cutting quality from units from the different DOE runs using the standard cutting program (e.g., runs A, B, C) and the new program (Run D). The results from T-test analyses inferred that there was no significant difference in package dimensions (*Refer to* Fig. 14 Package Dimension), and ball array offset (*Refer to* Fig. 15 Ball Array Offset) between the 2 cutting programs. The process capability index (Cpk) for these critical parameters well exceeded the typical industry standard of 1.5.

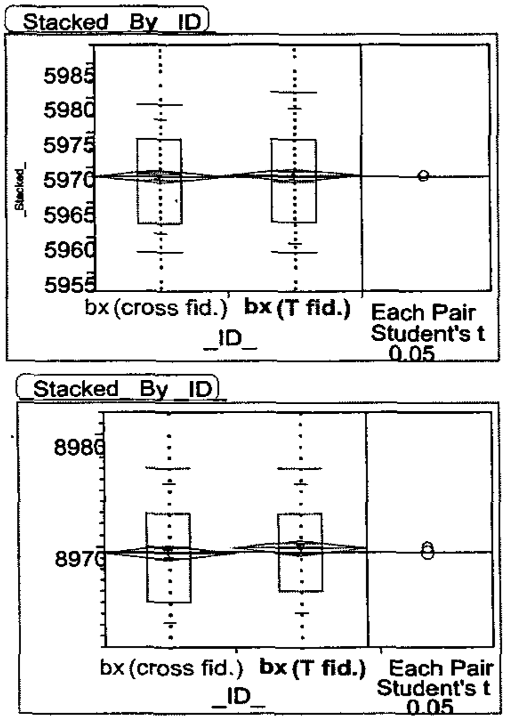


Fig. 14 Package Dimension

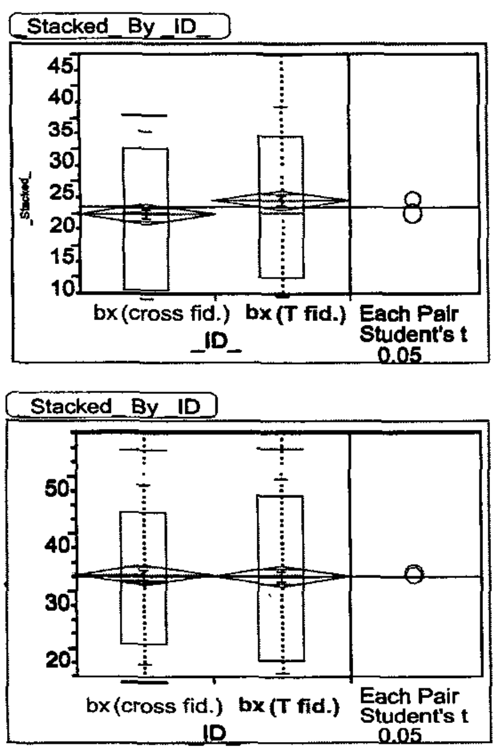


Fig. 15 Ball Array Offset

Productivity (UPH)

Since the change in alignment methodologies from standard alignment (as per standard cross design fiducial mark) to an alignment by a customized cutting program (per fiducial design), we also conducted a study on UPH (Units Per Hour) using the different programs. Results from T-test statistical analysis of UPH data inferred that there was no significant difference in UPH between the two alignment methodologies (*Refer to* .Fig. 16 Alignment Time.)

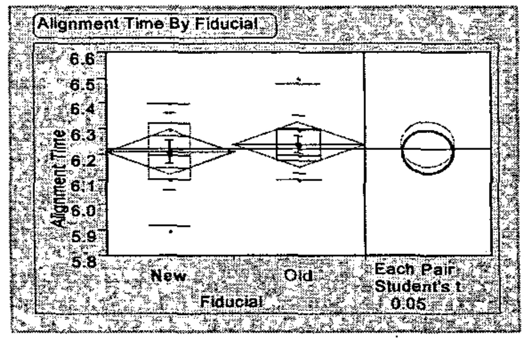


Fig. 16 Alignment Time

5. CONCLUSION

From our experiments, and a large number of fiducial designs that we have implemented in our production processes, we can conclude that a system of unique fiducial designs for different package types offers an error free CSP singulation process as far as cutting substrates with the wrong program is concerned. The cutting process simply does not proceed with the wrong saw program, or the wrong substrate in place. Thus, different types and sizes of CSP packages are never sawn in the wrong dimensions, and expensive saw singulation equipment parts do not get damaged as a result of sawing with the wrong program.

Alignment by a program based on a particular fiducial mark has no impact on cutting quality and productivity (UPH), nor on any other related processes.

The concept of having unique fiducial designs on the substrates for different CSP package types requires no additional investment cost on the part of the IC manufacturer, just coordination with the vendor of substrates to produce products with the desired fiducial marks.

The concept is applicable to all types of CSP packages, and since an almost limitless number of fiducial designs can be developed, is applicable to all new future packages — *Refer to* Fig. 17 Fiducial Designs.

Many more CSP packages are forecast to ramp up in the flash market. More CSP packages means more equipment conversions and an ever-growing variety of CSP substrates. With this comes ever-growing risk of human error in loading products and programs. Across the board implementation of unique fiducial designs for all types of CSP packages would therefore be much desired.

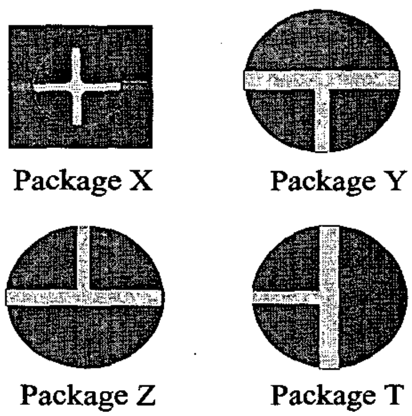


Fig. 17 Fiducial Designs

6. REFERENCES

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