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สถาบันวิทยบริการ
จุฬาลงกรณ์มหาวิทยาลัย

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

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คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

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ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

BLADE BREAKAGE REDUCTION IN CSP SINGULATION PROCESS

Mr. Prakorn Vijchulata

A Thesis Submitted in the Partial Fulfillment of the Requirements

for the Degree of Master of Engineering in Engineering Management

The Regional Centre for Manufacturing Systems Engineering

Faculty of Engineering

Chulalongkorn University

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สถาบันวิทยบริการ
จุฬาลงกรณ์มหาวิทยาลัย

ประกร วิชชุลตา : การลดปัญหาใบมีดแตกในกระบวนการตัดของซีเอสพี
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การวิจัยนี้มีวัตถุประสงค์เพื่อลดปัญหาการแตกหักของใบมีดที่ใช้ในกระบวนการตัดของซีเอสพี (Chip Scale Package) ที่นำไปสู่การสูญเสียผลผลิตในอุตสาหกรรมการประกอบ IC (Integrated Circuit) การแตกหักของใบมีดนอกจากทำให้อัตราการใช้ใบมีดอยู่ในเกณฑ์สูงแล้ว ยังก่อให้เกิดการสูญเสียชิ้นงาน สูญเสียเวลาในการซ่อมเครื่องจักร และยังส่งผลให้เวลาในการส่งมอบผลิตภัณฑ์ให้กับลูกค้าไม่ได้ตามเป้าหมาย

การวิจัยนี้ได้ทำการศึกษา ณ. บริษัท เอเอ็มดี (ไทยแลนด์) จำกัด เครื่องจักรที่ใช้ในการตัดมาจากบริษัท Intercon Technology รุ่น DS 8800

ขั้นตอนการวิจัยเริ่มต้นด้วยการจัดตั้งกลุ่ม QC (Quality Circle) ประกอบด้วยฝ่ายวิศวกรรม ฝ่ายซ่อมบำรุง ฝ่ายผลิต ผู้เชี่ยวชาญจากผู้ผลิตเครื่อง โดยมีการระดมความคิดเพื่อหาสาเหตุของปัญหา โดยใช้แผนภูมิก้างปลาและ FMEA (Failure Mode Effect and Analysis) เพื่อวิเคราะห์อย่างเป็นระบบ จากนั้นดำเนินการหาประสิทธิภาพของลำดับการตัดแบบใหม่ และหัวฉีดน้ำความดันสูงแบบคู่ โดยทำการทดลองแบบ Factorial Design ANOVA (Analysis of Variance) นำมาใช้ตรวจสอบคุณภาพการตัด รวมถึงการวิเคราะห์ความสามารถกระบวนการ (Cpk) หลังจากที่ได้นำแนวทางการแก้ไขปัญหาไปใช้จริงในสายการผลิต

จากผลการทดลองสรุปได้ว่า การใช้ลำดับการตัดแบบ 4 ทาง สามารถขจัดปัญหาใบมีดแตก ส่วนหัวฉีดน้ำความดันสูงแบบคู่สามารถลดปัญหาความสูญเสียชิ้นงานอันเนื่องจากเศษการตัดที่ค้างอยู่ซึ่งมาจากการตัดแบบ 4 ทาง ปัญหาใบมีดแตกได้หายไปหลังที่ได้นำแนวทางแก้ปัญหานี้ไปใช้ในระยะยาวในสายการผลิต ผลการวิเคราะห์ ANOVA ยืนยันได้ว่าไม่มีปัญหาต่อคุณภาพการตัด (Prob Value <0.05) ความสามารถกระบวนการ (Cpk) ของพารามิเตอร์สำคัญก็ได้ค่าเกิน 1.5 ซึ่งเป็นไปตามเป้าหมาย

ผลจากงานวิจัยคือ สามารถปรับปรุง MTBA (Mean Time Between Assist) เพิ่มจากเดิม 12 เท่า ลดปัญหาการซ่อมบำรุงและการหยุดการทำงานของเครื่องจักร 60% ลดชิ้นงานเสีย 63% เพิ่มอายุการใช้งานของใบมีด 2.3 เท่า โดยรวมสามารถประหยัดค่าใช้จ่ายได้ถึง 147,201 เหรียญสหรัฐต่อปี ผลพลอยได้อื่นที่ตามมาคือกำจัดปัญหาการหยุดของเครื่องจักรซึ่งนำไปสู่การชะงักงันในสายการผลิตของ ซีเอสพี ลดเวลาแก้ไขชิ้นงานที่มีปัญหา ลดเวลาในการส่งมอบผลิตภัณฑ์ให้กับลูกค้า และผลประโยชน์ที่สำคัญที่สุดคือลดความเสี่ยงที่ชิ้นงานเสียอาจหลุดไปยังลูกค้าของบริษัทผู้ผลิต IC

ศูนย์ระดับภูมิภาคทางวิศวกรรมการผลิต	ลายมือชื่อนิสิต..
สาขาวิชา การจัดการทางวิศวกรรม	ลายมือชื่ออาจารย์ที่ปรึกษา......................
ปีการศึกษา 2543	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม................

##4171613621: MAJOR ENGINEERING MANAGEMENT
KEY WORD: CSP SINGULATION/DICING/FBGA

PRAKORN VIJCHULATA: BLADE BREAKGE REDUCTION IN CSP SINGULATION PROCESS. THESIS ADVISOR: ASSOC. PROF. CHUVEJ CHANSA-NAGVEJ, Ph.D. 124 pp., ISBN: 974-347-226-6

This study aims to reduce blade breakage problem in CSP (Chip Scale Package) singulation process. Blade breakage problem at CSP singulation process leads to major yield loss contribution to the IC (Integrated Circuit) assembly production. The high rate of blade breakage post several problems such as increased reject rate, higher blade usage, increased machine down time, and production cycle time not meeting expected target.

The research is conducted by using CSP saw singulation process of AMD (Thailand) Ltd. as a case study. The equipment used in singulation process is Intercon Tools Solid BGA Sawing System Model DS-8800 Series made by Intercon Technology.

The methodology of the research was to set up a quality circle team consisting of members from process engineering, preventive maintenance, production operators and technicians, and vendors. The team participated in a brainstorming session to identify possible causes of blade breakage by applying a cause and effect diagram and FMEA (Failure Mode Effect and Analysis). The potential solutions and various alternatives were developed and implemented in sequence to solve the chronic problem. The methodology also involves the use of statistical tools such as factorial design to study the effectiveness of a new saw sequence and a new high water pressure nozzle design and ANOVA (Analysis of Variance) was also applied to confirm on the cutting quality. Process capability analysis (Cpk) was performed to determine the variation of CSP singulation process after the developed solutions were implemented.

The conclusions from factorial design of experiment suggested that implementing a new 4 channel cutting sequence had successfully eliminated the blade breakage problem and together with a new dual high-pressure nozzle design had minimized dented ball rejects caused by scrap remains. There was zero blade breakage after long production run. Furthermore, ANOVA analysis indicated there was no impact on cutting quality from the changes. The Cpk of critical parameters such as package dimensions and ball array offsets also met the expected goal of 1.5

The tangible benefits of the thesis include an improvement of MTBA (Mean Time Between Assist) 12 times, reduction of maintenance time by 60%, reject reduction by 63%, blade life improvement by 2.3 times, and estimated total cost saving to be worth US$ 147,201 per year. Other benefits are elimination of spindle seizure that can cause CSP production line to shut down due to AMD Thailand operating as a modular production line, reduction of reworking effort, supporting ball inspection sampling project, technical skill improvement in dicing dynamics and shorter cycle time. The most critical benefits of all is minimizing potential catastrophic issue where package or die crack units could escape final inspection and released as good product to IC manufacturer customers.

The Regional Centre for Manufacturing Systems Engineering Student's signature…………….

Field of study……Engineering Management……..Advisor's signature……………

Academic year……2000……..Co-advisor's signature…………

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สถาบันวิทยบริการ
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CHAPTER 1

INTRODUCTION

1.1 Background of Research

Globalization is made possible by the infrastructure of todays information technology. Telecommunication and networking devices have grown to be a highly competitive market. Therefore, by playing an important role, semiconductor industries has rapidly expanded to support the great demand.

Fast rising sales of consumer products such as cellular phones, digital still cameras, Internet audio devices, handheld computers and set-top boxes are propelling the flash memory market to record heights. The market for flash memory chips is so robust that suppliers cannot keep up with demand. Cahners In-Stat Group (2000) forecasts that flash memory shipments will exceed $6 billion for 2000 and unit shipments will surpass 1.6 billion. By 2004, the total flash memory market will skyrocket to $16 billion with a compound annual growth rate of 20.5 %.

One of the recent IC packages that has emerged in early 2000 according to Koller [9] is the FBGA (fine pitch ball grid array) as the new chip scale package (CSP) of choice for flash memory devices. A “CSP” is an integrated circuit package with dimensions equal to or slightly larger than those of silicon chip size. The CSP package is usually approximately 20% larger than chip size. The traditional package used for flash memory devices was mainly TSOP (thin small outline package) which are leaded package with a larger size compared to the FBGA. FBGA packages delivered so many advantages, it put a fork in the package roadmap for flash memories automotive, telecom, and new consumer product applications (e.g., cellular phones, pagers, hand-held computers, etc.). The FBGA smaller form/fit factor saves considerable board space and provides a lower profile – all of which is needed when trying to cram more memory capacity onto ever smaller motherboards, or in product striving to fit into the palm of your hand.

Many large semiconductor enterprises spread their manufacturing bases world wide including in Asia during the past decade. Labour cost is one of the influencing factors that made these companies set sight to have assembly manufacturing base in Asia. Likewise, AMD Thailand is one of the offshore microchip assembly plants for Advanced Micro Devices Incorporation, a US based microchip manufacturing company. The major volumes for the assembly manufacturing plant are flash memory devices. AMD Thailand manufacturing process will be used as a case study for this thesis.

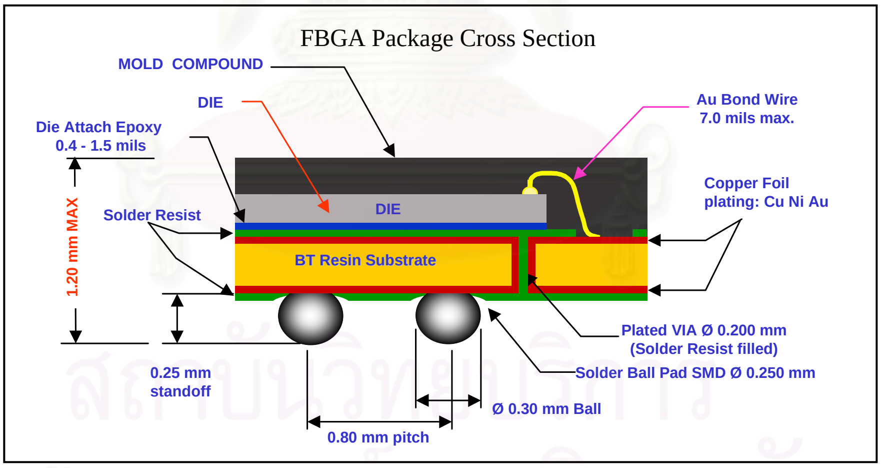
AMD corporate is one of the world leading supplier of integrated circuits (ICs) for personal and networked computing and communications. Founded in 1969, AMD today is the second-largest supplier of Microsoft® Windows® compatible PC processors. AMD revenues totaled $2.9 billion in 1999.

Deriving more than half of its revenues from international markets, AMD has more than 13,000 employees worldwide and manufacturing facilities in the United States, Europe, and Asia, as well as sales offices in major cities around the globe.

AMD provides Windows compatible processors, flash memory devices, and communications and networking products that enhance the power and utility of PCs as information-processing and communications tools.

The cross-section of an FBGA package is illustrated in Figure 1.1. The assembly manufacturing process for FBGA packages starts by attaching die onto an organic substrate of BT (Bismaleimide Triazine) resin. The BT resin is embedded with copper traces used for routing the signals from the die to the external terminals. Next the die is wire-bonded with a gold bond wire to the substrate and then overmolded with epoxy. The molded substrate is then flip over to attach the solder balls and pass to a reflow oven to ensure that the balls are secured in place. The substrate is then brought to a saw singulation process where the substrate is cut into individual units as final product. Finally, a fully automatic ball inspection machine is used to inspect package dimensions and ball quality of the product. The assembly manufacturing process is completed at this stage, but the FBGA product will still have to be process through test, mark and pack operations before shipping to customers.

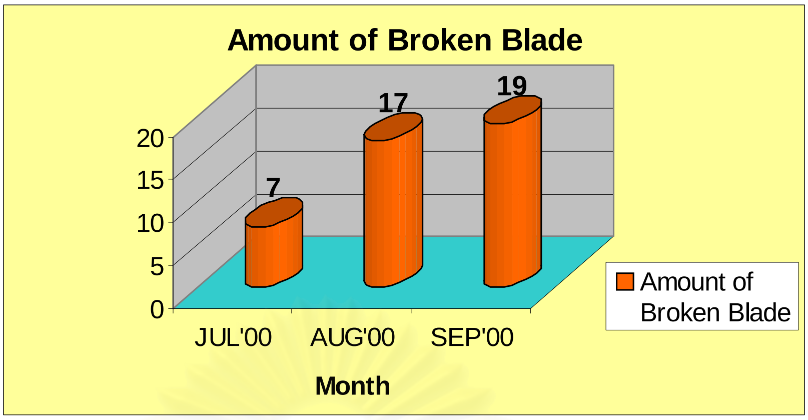
Figure 1.1: Cross-Section of an FBGA Package (FBGA User's Guide, 1999)



1.2 Statement of Problem

The FBGA assembly manufacturing process in AMD Thailand started to ramp up during the second quarter of 2000. The major yield loss contribution to the assembly production was at saw singulation process where there was high rate of blade breakage. Figure 1.2 illustrates that blade breakage frequency was getting higher as the FBGA volumes started to pick up during the second quarter of 2000.

Figure 1.2: Blade Breakage Rate at CSP Singulation Process



The CSP saw singulation system consists of a dicing saw integrated with a handler. A dicing saw basically consists of a blade to cut parts mounted on a high speed rotating spindle shaft. Molded FBGA substrates are carried in a nest, and placed onto a vacuum 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 FBGA units. The handler of the fully automatic system then transfers the sawn parts to a washing and drying chamber, and picks and places (offloads) the units into shipping trays.

During the cutting process once a blade breakage problem is encountered then a broken blade detector sensor would trigger for the machine to stop the process – Refer to Figure 1.3. The broken blade needs to be replaced with a new blade in order to continue the cutting process.

In the event of blade breakage there is usually high vibration from the broken blade causing a twitching force towards the substrate. The partially sawn parts in the area where blade breakage occurs are pulled out of position from the vacuum saw chuck – Refer to Figure 1.4. All the FBGA parts sitting on the saw chuck will then move out from the correct position due to the vacuum that supplies through the viton rubber pads come from a single vacuum source. These partially sawn parts needs to go through a manual reworking process where the final FBGA units have high potential of being rejected ie. package dimension failure after completing the reworking process.

Figure 1.3: Broken Blade Detector

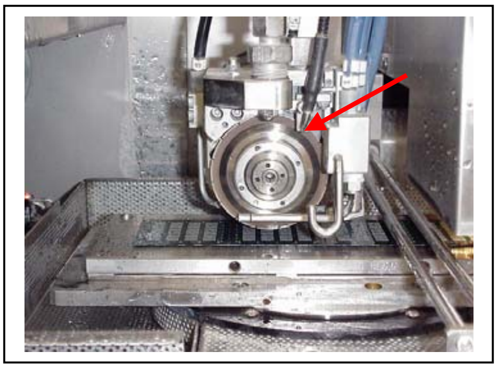
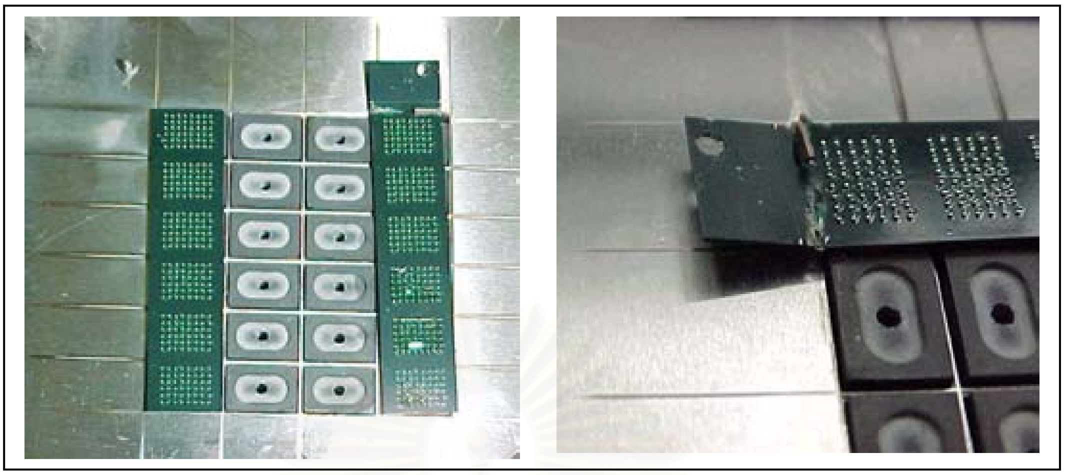


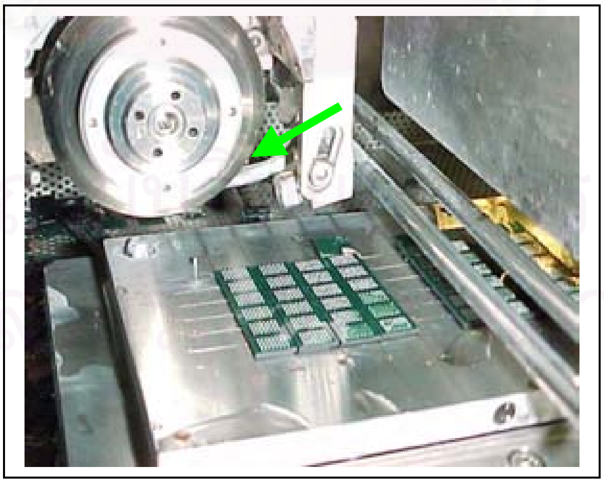
Figure 1.4: Partially Sawn Parts on Vacuum Chuck



The impacts on quality and productivity related to the high rate of blade breakage encountered at the CSP singulation process can be broken down as follows:

1. Rejected FBGA units – The location on the molded substrate where blade breakage occurs will have high potential of being rejected. Reject mode includes package chip, package crack or wrong dimension of the final product. This contributes to high yield loss for the singulation process with continuity of frequent blade breakage problem. Figure 1.5 shows the event of a blade breakage where the FBGA units are damaged resulting from the problem.

Figure 1.5: Broken Blade and Damaged FBGA Units

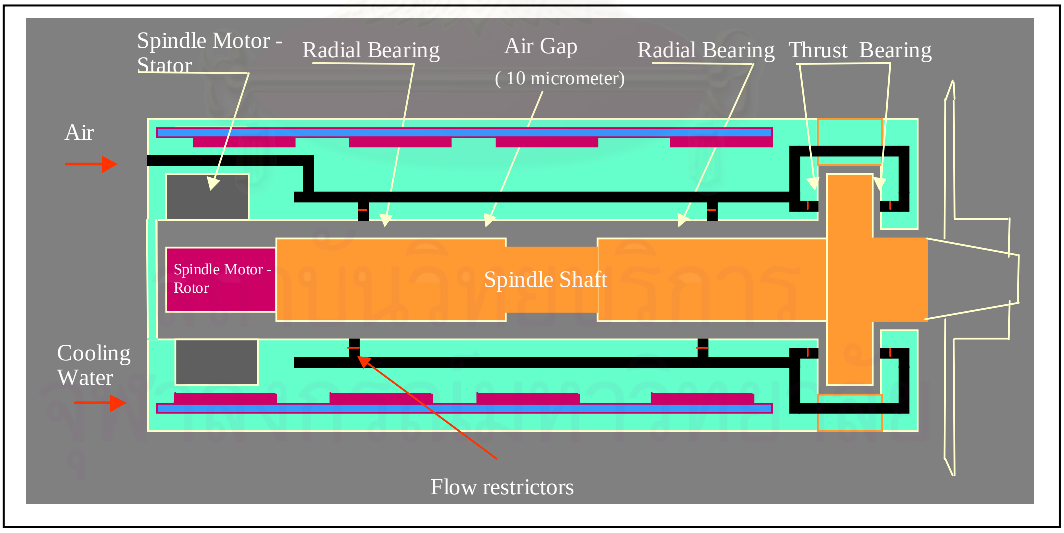


2. High blade usage – FBGA saw blade is one of the highest indirect materials cost ($US 89 per piece) and with shorter blade life resulting from frequent blade breakage will impact to the overall operating cost for the FBGA assembly process.

3. Increased machine downtime – In the event of a blade breakage production has to be interrupted. The blade has to be replaced and machine setup is required. The substrate that was incompletely cut also needs to be reworked which this process takes more time than normal cutting process. Furthermore, partial breakage of a blade causes unbalance loading on the spindle shaft, and with a very small air gap of 10 microns between the spindle shaft and the spindle assembly, the spindle seizes to rotate, in this case the spindle requires rework—Refer to Figure 1.6: Schematic Drawing of Spindle Cross-Section. In a worst case scenario, the whole spindle assembly needs to be replaced, at a cost of up to $USD 13,000. The consequence of this particular problem is that the machine is down for a longer period of time, maintenance time is increased and production cycle time in shipping out the FBGA product does not meeting the expected target.

The impact of blade breakage problem could extend further up to where the loading of the broken blade could generate a micro crack origin on the FBGA package or the internal die. This fine hairline crack has high potential of escaping final visual inspection at the assembly process and released as good product to subsequent process or even to customers. The stress applied on to the package from later processes or transportation may caused the crack to propagate even further and at some point the device would not be functional or fail in the field. The result from this situation posts product reliability concern and can become a catastrophic customer issue for the assembly manufacturing plant.

Figure 1.6: Schematic Drawing of Spindle Cross-Section



1.3 Objective of Research

The objective of the research is to reduce blade breakage problem in CSP saw singulation process.

1.4 Scope of Research

The research is conducted at FBGA saw singulation process of AMD (Thailand) Ltd. The original equipment manufacturer is from Intercon Technology, based in California, USA. The equipment used at singulation process is Intercon Tools Solid BGA Sawing System Model DS-8800 Series. The Dicer that is hooked up with the Intercon handler is a Disco Model DAD641 dicing saw.

A fully automatic ball inspection equipment, ICOS CI-8250, is used for measuring the cutting quality outcome from the singulation process. The system can provide print out measurement data so that they can be used for further analysis in optimizing the singulation process.

The first phase of the research focuses on selection of dicing blades and cutting application of CSP. The evaluation is carried out prior to production start up of CSP Singulation process. The second phase of the research involves a team work effort with participants from related department and vendors to find solutions in solving yield problems at the singulation process after CSP has gone through continuous assembly production . Resolving blade breakage problem is the major issue that this research focuses on.

1.5 Methodology of Research

The methodology of research are listed as follows:

1) Study related literature such as CSP publications, statistical principles, statistical software tools, equipment operating manuals, AMD specification, dicing principles, and dicing process optimization techniques.

2) Perform dicing blade evaluation both at supplier and AMD site. Cutting sequence for CSP application needs to be evaluated prior to production. Package chip and package dimension are measured to determined the cutting quality outcome.

3) Data collection of existing problems from yield reports and gather blade life historical data through on-line input from production operators during continuous prodution run.

4) Setup a quality circle team consisting of members from process engineering, preventive maintenance, production operators and technicians, and vendors from Intercon and Disco corporation.

5) Brainstorm among team members to identify possible causes of blade breakage by applying a cause and effect diagram, and FMEA (Failure Mode Effects Analysis) for in dept technical issues.

6) List down potential solutions and prioritize action plans.

7) Review results of blade breakage rate after performing each corrective action and then identify further action plans.

8) A Factorial design experiment is carried out to study the impact of a proposed new saw sequence, and a new high water pressure nozzle design and to determine if interaction is present. Analysis of Varaince (ANOVA) is applied to confirm the cutting quality, while a process capability analysis is performed to determine the variation of the FBGA singulation process after the project implementation. Statistical software tools eg. JMP version 3.1 is used to carry out statistical calculations.

9) Implement the proposed recommended solutions and monitor results.

10) Discuss the results together and summarize the benefits.

11) Provide conclusion and recommendation for further development plans.

12) Prepare thesis report and final examination.

1.6 Expected Results

The expection of this research is to have an appropriate dicing blade as well as to reduce blade breakage problem in CSP Singulation process. The benefits from the research should be able to reduce the rejects caused by blade breakage, improve the blade life, reduce machine maintenance time and potential of spindle seizure, meeting production target schedules, and most critical of all to minimize the chance of having any crack or micro crack FBGA package escapes to the AMD customers. The cost impact from this research should be able to save the IC (Integrated Cicuit) manufacturer at least 100,000 USD per annum.

1.7 Research Schedules

The research was initiated in May 2000 and completed in April 2001. The research tasks and schedules are presented in Figure 1.7

Table 1.1: Research Schedule for Blade Breakage Reduction

		2000								2001			
Step	Task Name	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
1	Literature survey	■	■										
2	Dicing blade evaluation	■	■										
3	Data collection of blade life history			■	■	■	■	■	■	■			
4	Setup a quality circle team				■								
5	Brainstorm with team members to idenify possible causes				■								
6	List down potential solutions derived from cause & effect diagram and FMEA					■							
7	Setup experiment and implement action plans					■	■	■					
8	Proposed recommended solutions and monitor results							■	■				
9	Discussion and summarized benefits									■			
10	Conclusion and recommendation									■			
11	Prepare thesis report and examination									■	■	■	■

CHAPTER 2

LITERATURE REVIEW

2.1 Flash Memory Review

The flash memory market has been growing rapidly in year 2000. Flash memory, or flash RAM (Random Access Memory), is a solid-state (it has no internal moving parts), non-volatile (stable), removable and re-writable memory chip that works like a combination of RAM and a hard-disk drive. It gets its name because the microchip is organized so that a section of memory cells are erased in a single action or ‘flash’. Flash memory stores bits of electronic data in memory cells, just like DRAM (Dynamic RAM) and SRAM (Static RAM), but unlike those chips, flash data stays in memory when the power is switched off.

The optimistic outlook for Flash memory is based on several key factors that include technological superiority over many existing products, increasing popularity of consumer electronic items, and much greater demand than can be presently met.

According to Frauenfeld (2000) flash memory is in big demand because it enables wireless appliance manufacturers to increase their products’ functionality, reliability, and durability. The unique feature of Flash memory is that it combines extremely rapid access times (hundreds of times faster than accessing a hard drive) with high transfer rates. Additionally, these chips are very durable, meaning that they are able to withstand severe shock or vibration. No data is lost even if the power is turned off. While maintaining high reliability, these chips also have very long life expectancies. Solid-state memory chips are also miracles of miniaturization, making them usable in small devices. Additionally, the low voltage of the chips requires very little power, resulting in extended battery life.

2.2 CSP Package Development

One of the recent IC (Integrated Circuit) packages that has emerged in early 2000 according to Koller (2000) is the FBGA (fine pitch ball grid array) as the new CSP (Chip Scale Package) of choice for flash memory devices. A “CSP” is an integrated circuit package with dimensions equal to or slightly larger than those of silicon chip size. The CSP package is usually approximately 20% larger than chip size. The traditional package used for flash memory devices was mainly TSOP (Thin Small Outline Package) which are leaded package with a larger size compared to the FBGA as shown in Figure 3.1. The evolution of IC packaging from DIP (Dual in line Package) to CSP has consisted of a progression of incremental changes. Area array concepts in play presently offer significant advantages over their peripherally leaded predecessors. Figure 2.1 also represents the evolution of IC packaging trend from DIP with pin leads, TSOP with gull wing leads, and CSP with ball grid array.

Ever since the first integrated circuits became commercially available in the sixties, integrated circuit packaging has undergone significant developments. Package types evolved from Thru hole-type Transistor Outline Cans and Transistor Outline Two Twenties in the sixties, to Pin Dip packages in the seventies. In the eighties, Surface Mount Technology, or SMT, was developed. Examples of SMT package types include PLCCs (Plastic Leaded Chip Carrier) and PQFPs (Plastic Quad Flat Pack). More recently in the nineties, Grid Array-type PBGAs (Plastic Ball Grid Array) and CSPs, have further reduced package size and increased performance.

The size of an AMD CSP package for memory devices can be estimated by comparing with the size of an American coin as shown in Figure 2.2. Chip Scale Packages, which do not exceed the size of their silicon dies with more than 20 percent, have been packaged in several different constructions – Refer Figure 2.3 mainly: µBGA s, or micro ball grid array devices, which are not encapsulated in a mold compound, FBGAs, which are still packaged in mold. And stacked dies, which have 2 or more dies in FBGA package such as Flash on top of DRAM.

The FBGA package provides a highly reliable, easy to design with, small form factor package. It is smaller than all FLASH packages expect for µBGA for any one die. The FBGA package is also easy to manufacture with, since it is transparent to die size changes and uses industry standard footprints and package materials. The FBGA package also allows for second sourcing and can take advantage of smaller, lower cost die without changing form factor.

Figure 2.1: Evolution of IC Package

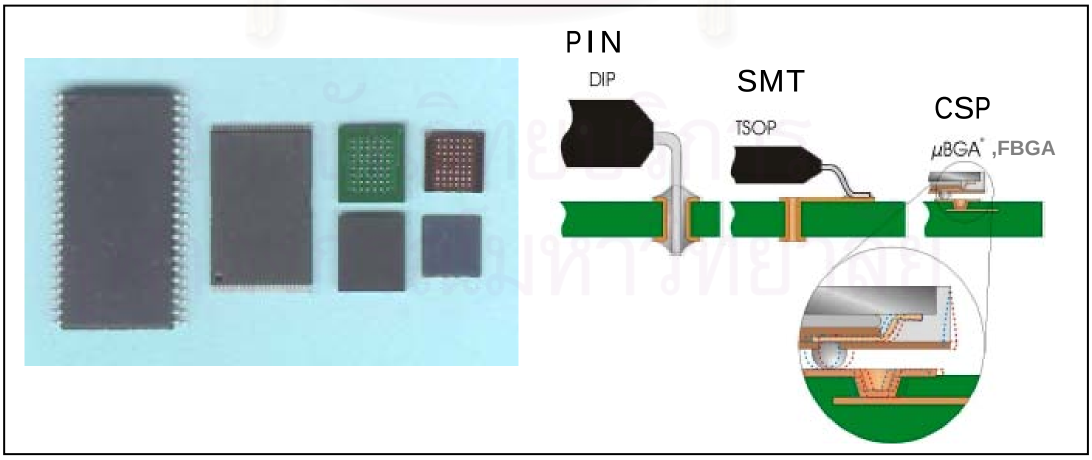
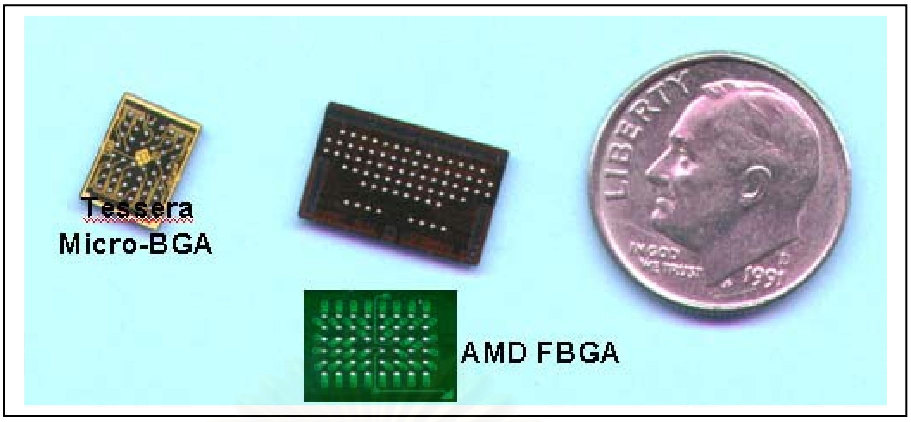
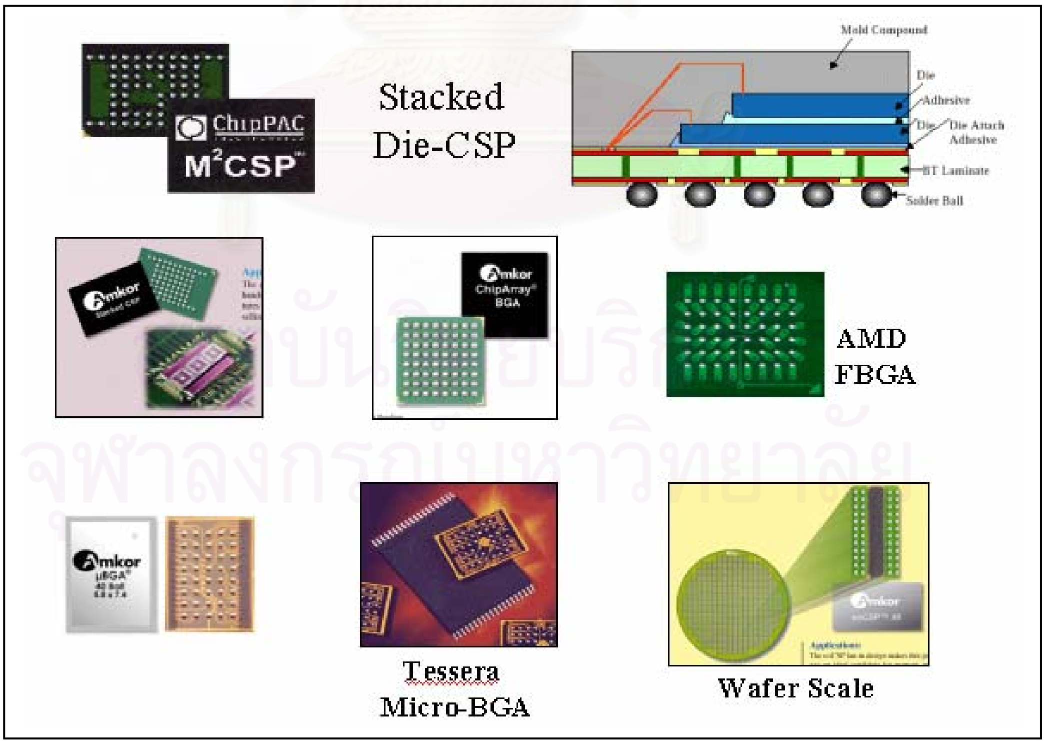


Figure 2.2: CSP Package Size



AMD began offering FBGA design that afforded so many advantages, it put a fork in the package roadmap for flash memories automotive, telecom, and new consumer product applications (e.g., cellular phones, pagers, hand-held computers, etc.). The FBGA smaller form/fit factor saves considerable board space and provides a lower profile – all of which is needed when trying to cram more memory capacity onto ever smaller motherboards, or in product striving to fit into the palm of human hand. Developing CSP technology is nowadays the preferred solution to meeting semiconductor packaging needs well into the twenty-first century.

Figure 2.3: Alternative of Chip Scale Packaging (CSP)



2.3 Drivers for Product Miniaturization

The drivers for product miniaturization can be of these examples (Figure 2.4):

1) Consumer: Electronic games, computers/peripherals, power tools, camera, video equipment and appliances
2) Communications: Cellular telephones, radio transceivers, pagers, message system, personal communicators
3) Automotive: Engine controllers, transmission controllers, monitoring and safety system, entertainment equipment

Figure 2.4: Drivers for Product Miniaturization (AMD Non-Volatile Memory, 2001)

2.4 FBGA Construction

The cross-section of an FBGA package – Refer to Figure 2.5. Materials used in the packaging of FBGAs include:

- Wafers of silicon dies,
- Rigid substrates made up of a BT resin core, with copper traces which connect the lead fingers at the top, with the solder ball pads at the bottom through vias.
- Epoxy to adhere the dies to the substrates.
- Gold wires to bond die pads to lead fingers.
- Molding compound for encapsulation, and solder spheres, which shall form the connection between the packages and the printed circuit boards.

The assembly manufacturing process for FBGA packages starts by attaching die or chip onto an organic substrate of BT (Bismaleimide Triazine) resin. The BT resin is embedded with copper traces used for routing the signals from the die to the external terminals. The BT resin material properties is referred in Figure 2.6.

The die is then wire-bonded with a gold bond wire to the substrate and then overmolded with epoxy. The molded substrate is then flip over to attach the solder balls and pass to a reflow oven to ensure that the balls are secured in place. The substrate is then brought to a saw singulation process where the substrate is cut into individual units as final product. Finally, a fully automatic ball inspection machine is used to inspect package dimensions and ball quality of the product. The assembly manufacturing process is completed at this stage, but in order to shipped to customers the FBGA product will still have to be process through test, mark and pack operations.

Figure 2.5: Cross-Section of an FBGA Package

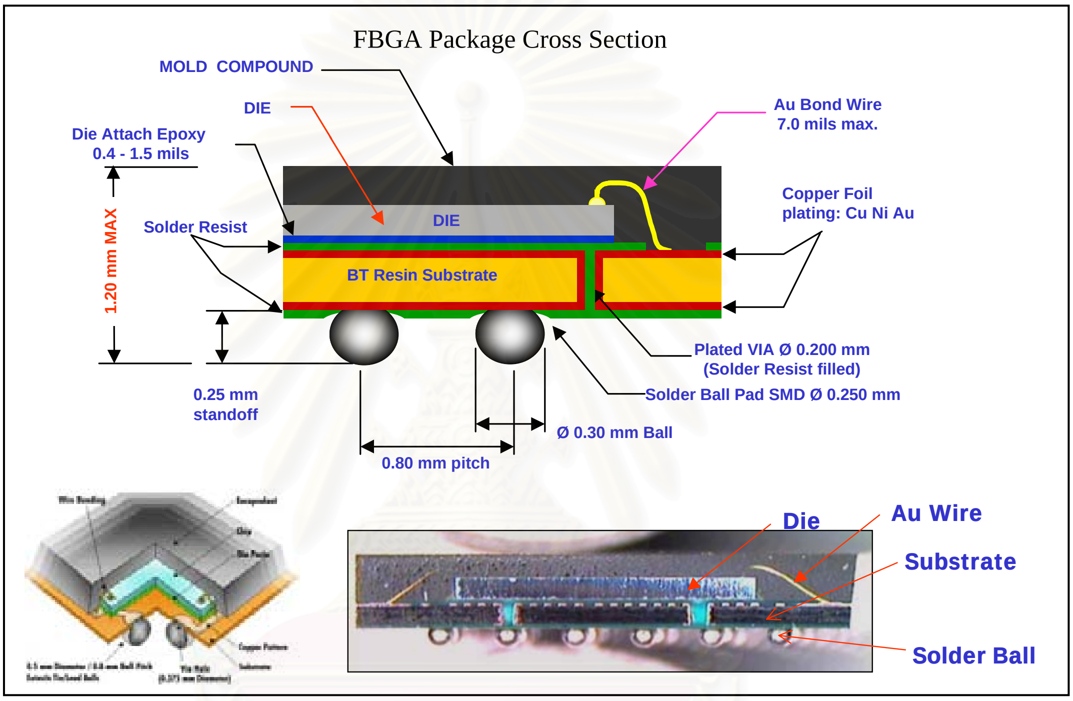


Figure 2.6: BT Resin Properties

2.5 FBGA Process in AMD Thailand

The FBGA process in AMD Thailand started up with a capacity of 300,000 units per week. The capital investment for the project was $4,000,000 USD. The total capacity for FBGA could increase up to 400,000 units per week by putting two additional wire bonders. The reliability level of AMD FBGA package meets JEDEC (Joint Electron Device Engineering Council) level 3 with 240 degrees reflow peak temperature. The process and material set was duplicated from AMD Penang, which is one of AMD sister plant. AMD Thailand started up by qualifying 2 package sizes – 6x9 mm (8 Megabyte) and 8x9 mm (16 Megabyte) body sizes.

The existing manufacturing facility of AMD needed an expansion to support this new package volume. The first module for FBGA supported a volume of 300K units per week, but for maximum capacity the plant area could support up to 2000K units per week. The location of new FBGA equipment can be referred in Figure 2.7. The FBGA assembly production started up since January 2000. The assembly process flow for all FBGA equipment is illustrated in Figure 2.8.

Figure 2.7: Assembly Plant Layout

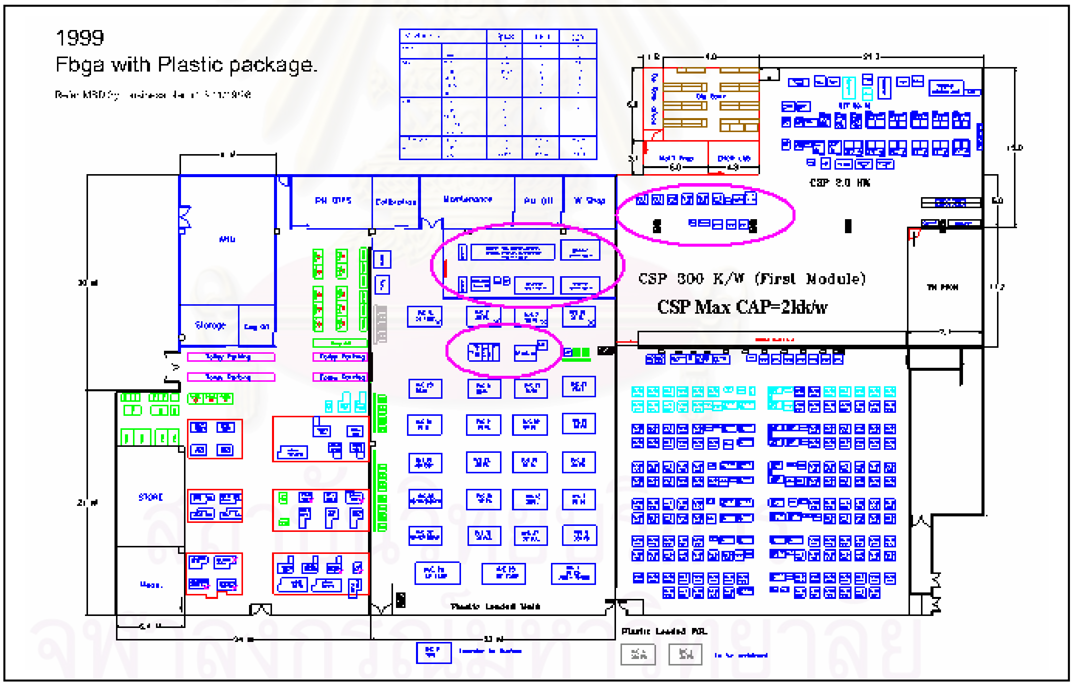
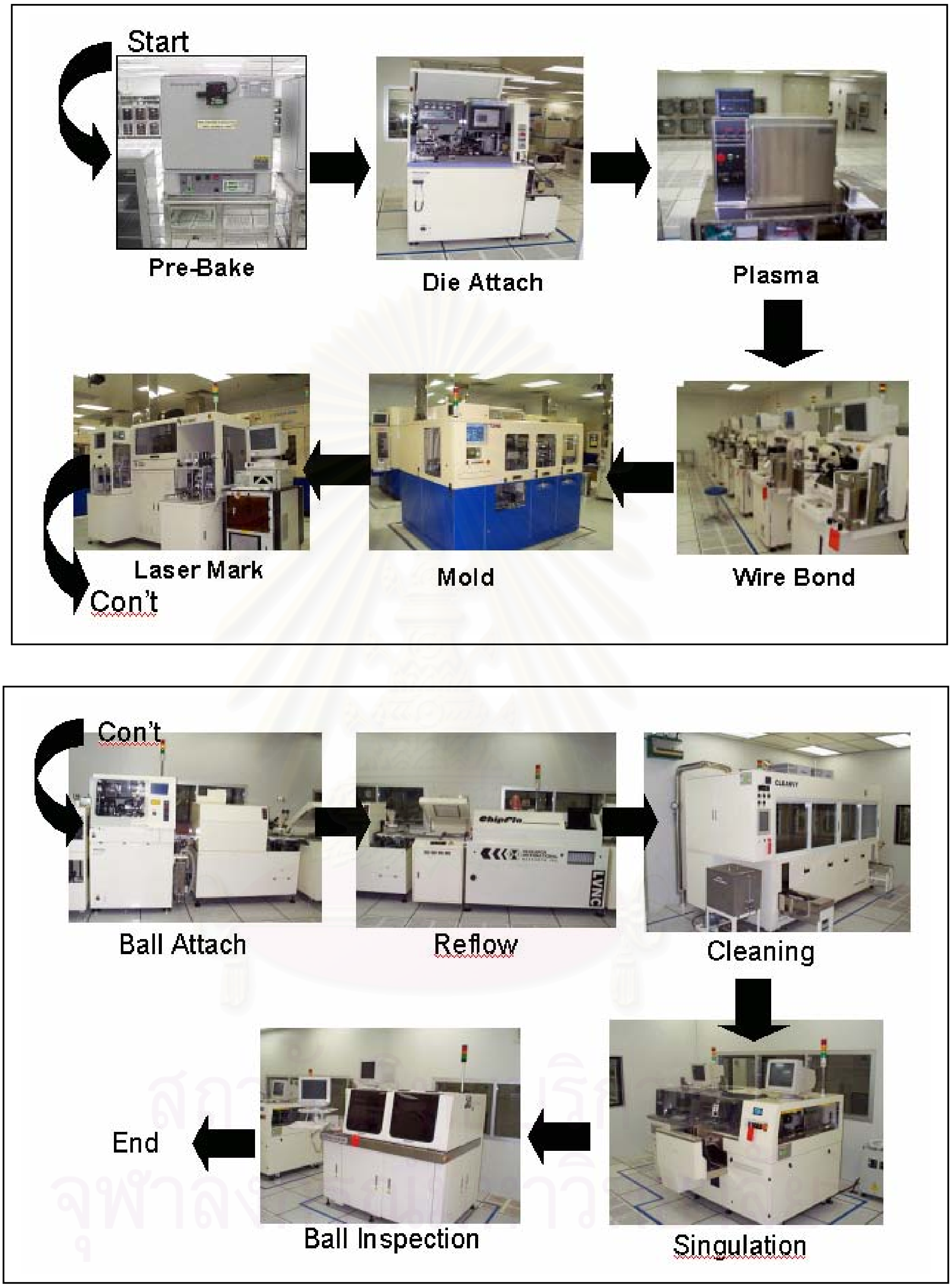


Figure 2.8: FBGA Equipment Process Flow



2.6 FBGA Process Flow Chart

The FBGA assembly process flow at AMD as described by Leong (1999) is illustrated in Figure 2.9

Figure 2.9: Process Flow Chart for FBGA (Leong, 1999)

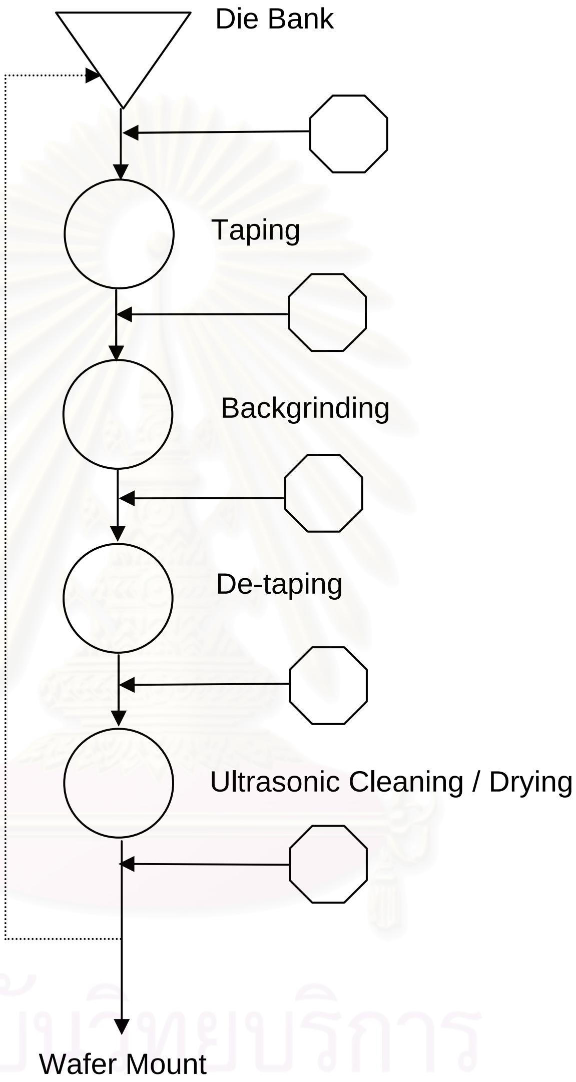


Figure 2.9 (Continue)

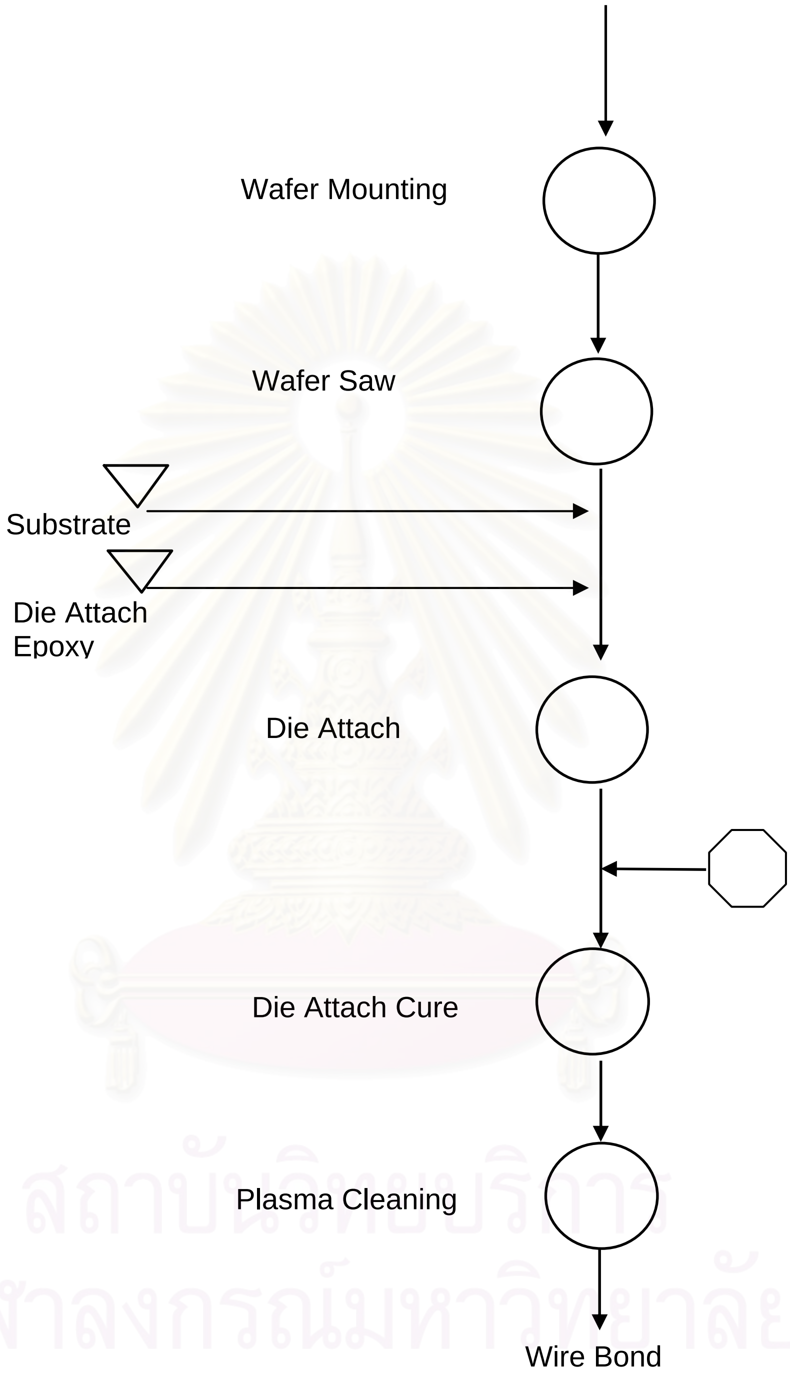


Figure 2.9 (Continue)

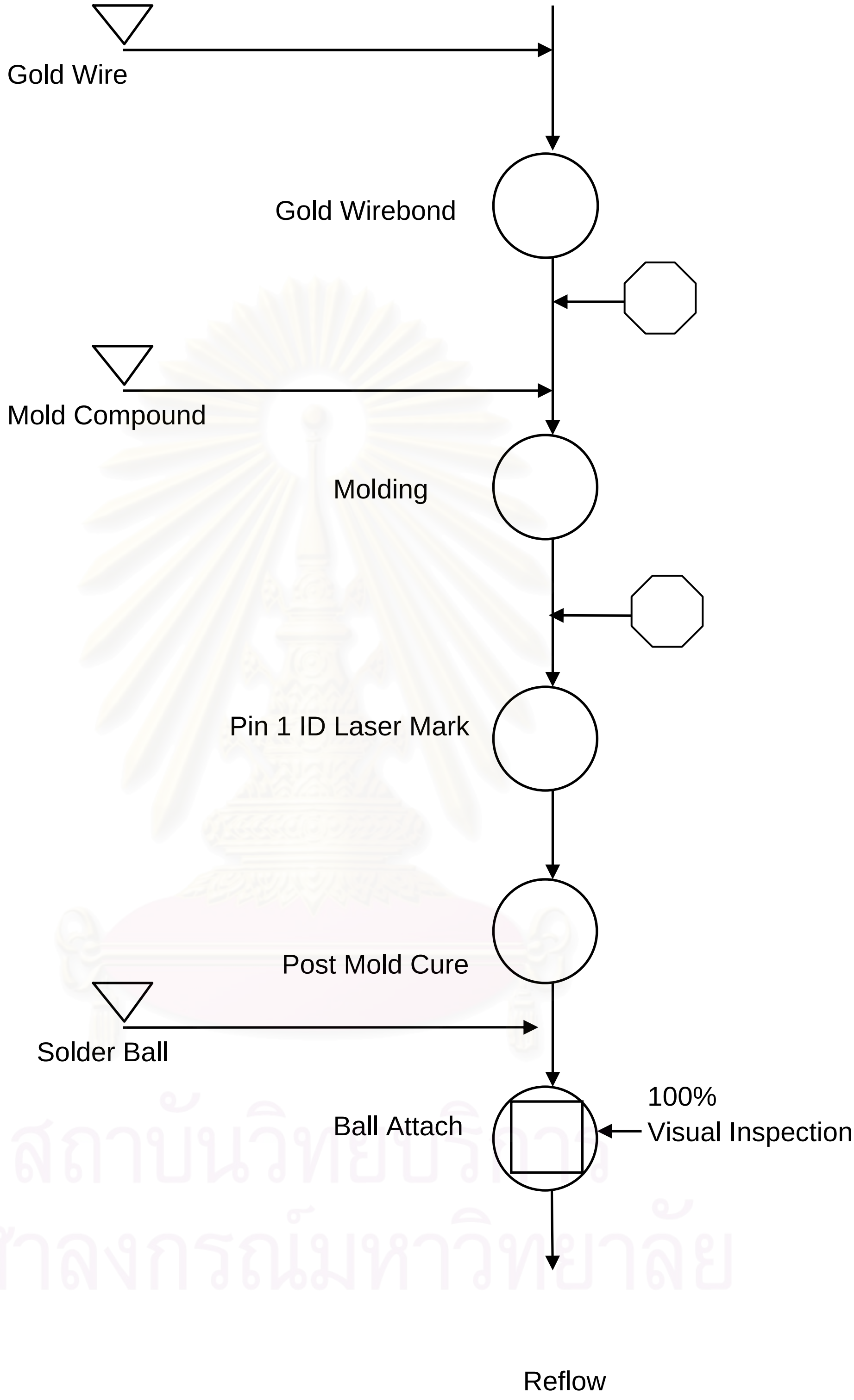
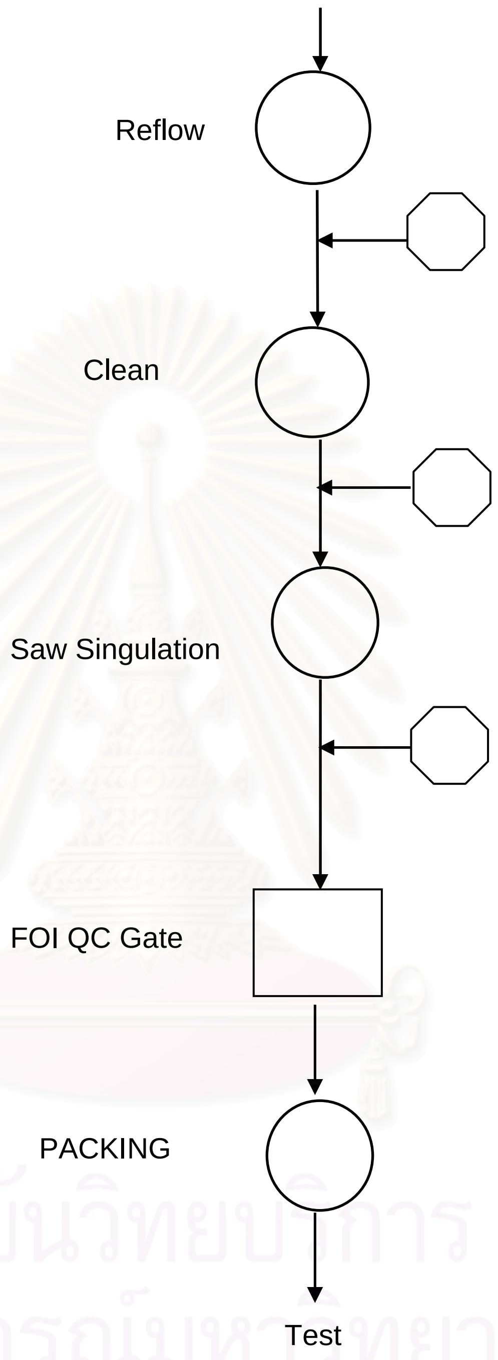


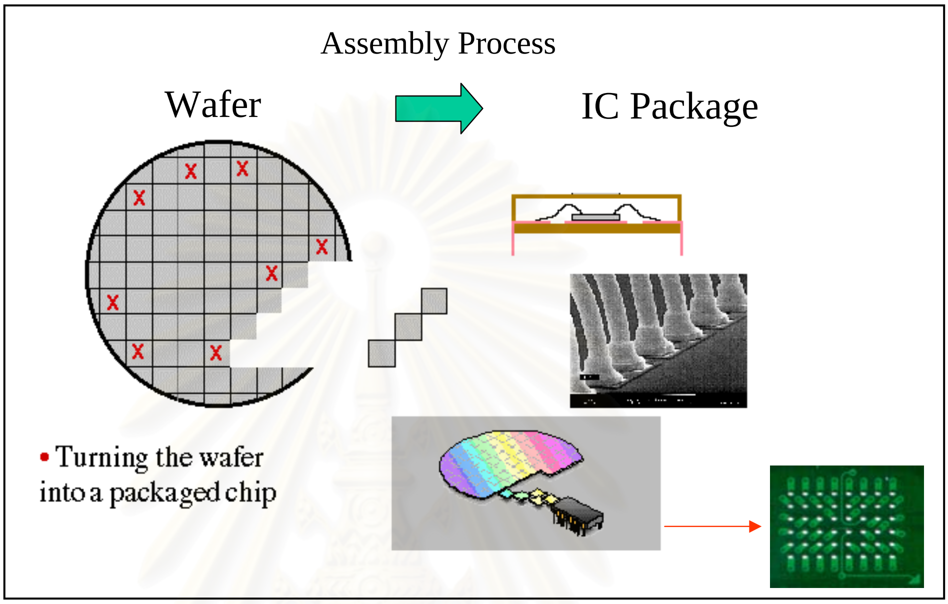
Figure 2.9 (Continue)



2.7 IC Assembly Process

The integrated circuit (IC) assembly is the process of turning a wafer into IC packages such as FBGA. Figure 2.10 shows a graphical illustration of the IC assembly process.

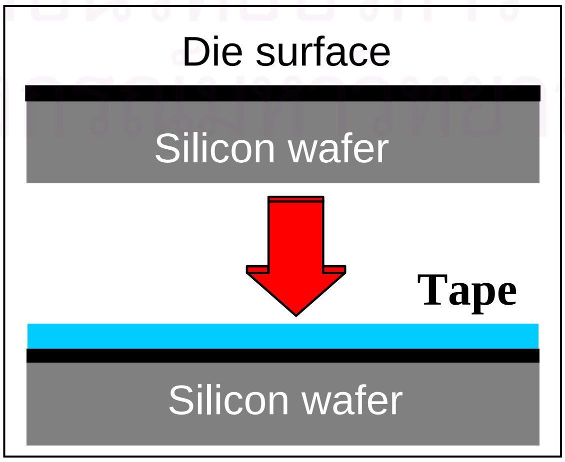
Figure 2.10: IC Assembly Process



2.7.1 Backgrind Process

The FBGA assembly process starts at die bank where all wafers inventory are stored in a controlled environment. The wafers that die bank received are manufactured from wafer fabrication house in Austin, USA and shipped to AMD Thailand for package assembly. Wafers are then processed through a taping process – Refer to Figure 2.11 where an adhesive tape is laminated to protect the topside die surface of the wafers before processing them through backgrinding.

Figure 2.11: Taper Process



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The wafers with laminated tape are then backgrinded on the wafer backside to obtain a specific wafer thickness. The FBGA wafers are grinded from 21 to 10 mils thickness to meet the package design rule as illustrated in Figure 2.12. After backgrinding the laminated tape needs to be removed by the detaping process. Following detaping the wafers are dipped into ultrasonic cleaning and drying tank to wash out any residues, debris, and contamination that be left on the wafer from the tape adhesive. Refer to Figure 2.13 – Ultrasonic cleaning tank.

Figure 2.12 : Backgrind Process Flow

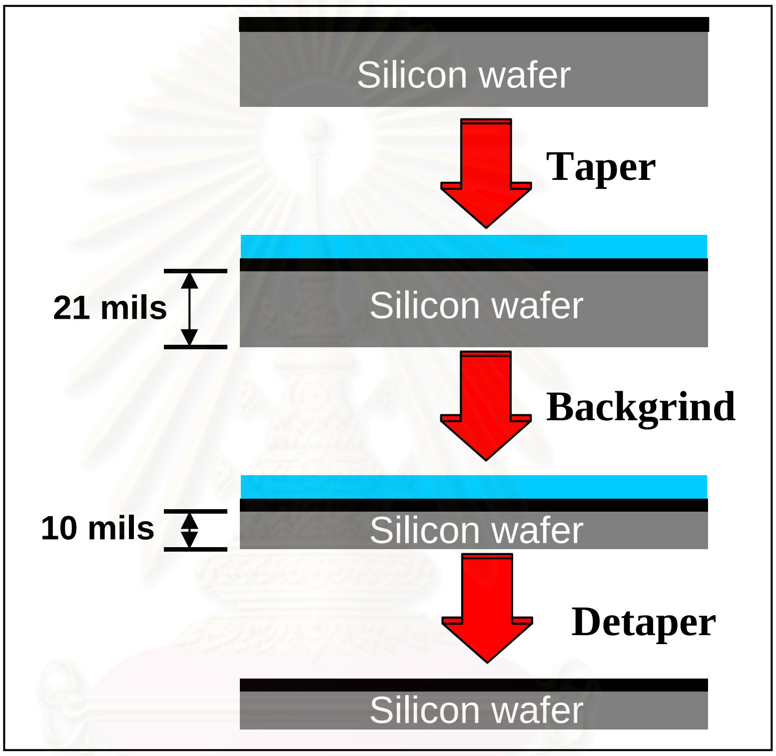


Figure 2.13 : Ultrasonic Cleaning Tank

2.7.2 Wafer Saw Process

Next wafer is processed through wafer mounting – Refer to Figure 2.14. The process is to mount the backside of the wafer onto an adhesive tape so that once the wafers are separated into individual dice they are still intact. A frame ring is a stainless fixture to secure the mount tape. At this stage the wafer is ready for sawing or dicing operation. The wafer saw function – Refer to Figure 2.15 then cuts each wafer into individual die along the designated scribe lines with a high speed rotating speed blade as illustrated in Figure 2.16.

Figure 2.14: Wafer Mount Process

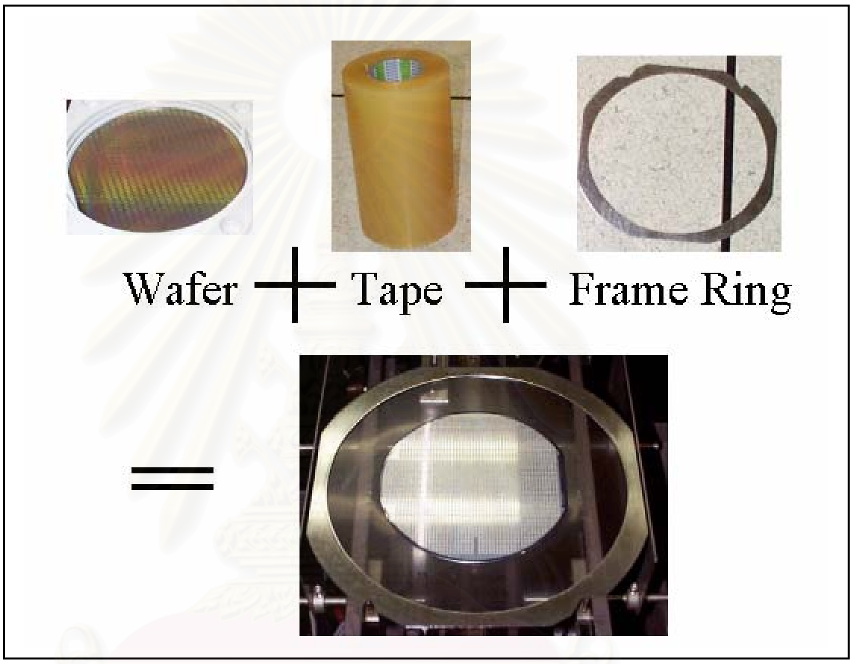


Figure 2.15: Wafer Saw Function

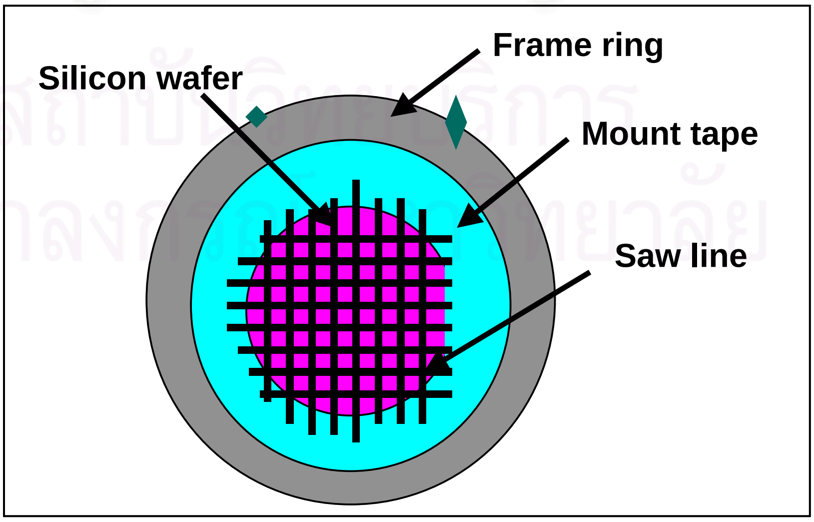
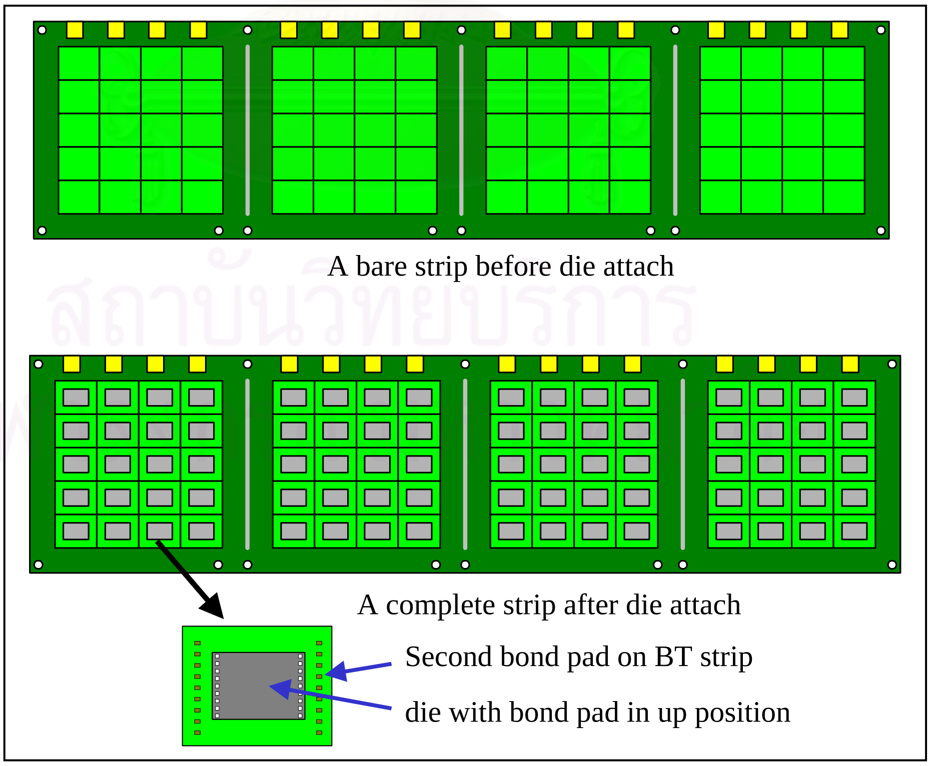


Figure 2.16: Wafer Saw Process

2.7.3 Die Attach Process

The die-attach process picks out each die from the sawn wafer and places the die onto a bare BT resin substrate. A die attach epoxy is used as intermediate adhesion material between the die and the BT resin substrate. A completed substrate strip after die-attach will consist of many FBGA dice, which the amount of die depends on the FBGA package type. Figure 2.17 shows the die-attach process with 96 units per substrate.

Figure 2.17: FBGA Die- Attach Process

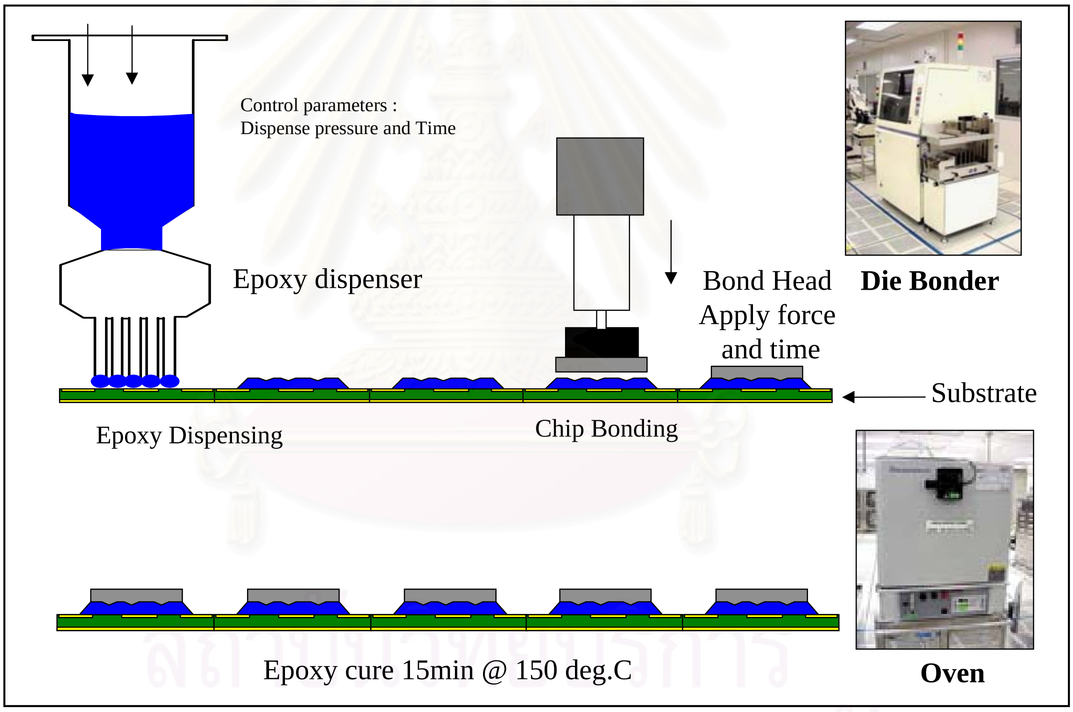


The die attach operation and epoxy curing are shown in Figure 2.18. The die-attach machine dispenses epoxy onto the substrate while the bond head picks up the die and applies force and time so the die is properly attached onto the substrate. The die attach epoxy needs to be cure in an oven so that there is good adhesion between the die and substrate. The die attach epoxy is cured at 150 degrees Celsius with a duration of 15 minutes.

2.7.4 Wire Bond Process

Subsequently the substrates are processed through plasma cleaning where organic contamination (containing carbon and hydrogen) and outgassing can be removed from the substrate surface and on bonding pads surface. The organic contamination is a very thin layer, which result from the resin substrate itself or epoxy outgassing generated during die-attach curing. The plasma process enhances wire bond ability and mold adhesion.

Figure 2.18: Die-Attach Epoxy Dispensing and Curing

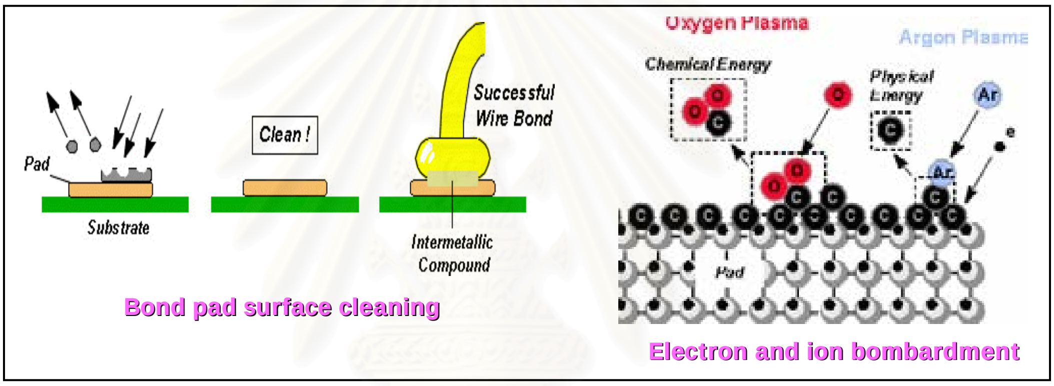


The plasma cleaner uses Oxygen (O_2) and Argon (Ar) to produce plasma in a vacuum chamber which is energized by Radio-Frequency (RF) 13.56 Mhz. The plasma chamber and compressed tank is shown in Figure 2.19.

The oxygen plasma will react with organic impurities on the surface to form volatile oxides, which can be pumped out of the system. Argon is ionized gas and its mechanically removes the organic. The bond pad cleaning and electron and ion bombardment mechanism is illustrated in Figure 2.20

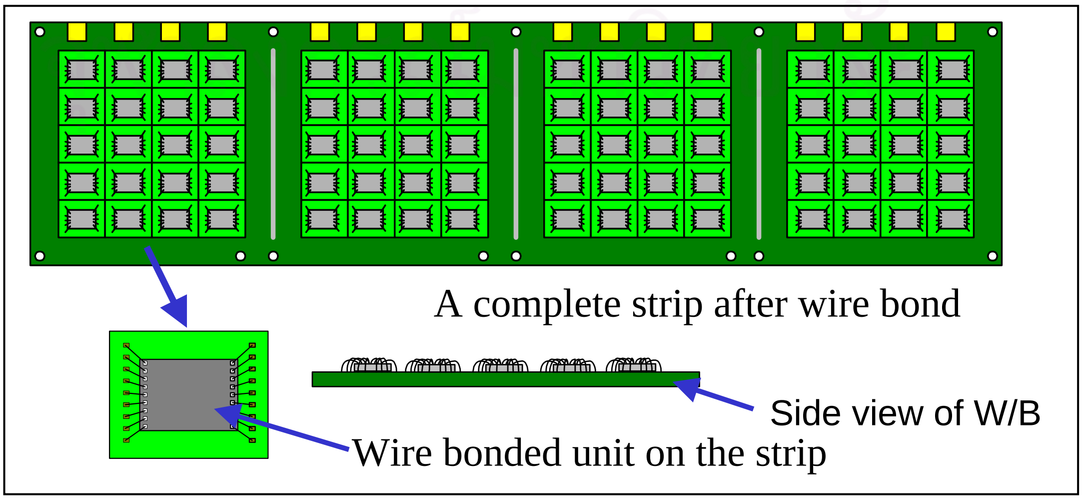
Figure 2.19: Plasma Chamber and Compressed Gas Tank

Figure 2.20: Plasma Cleaning Mechanism



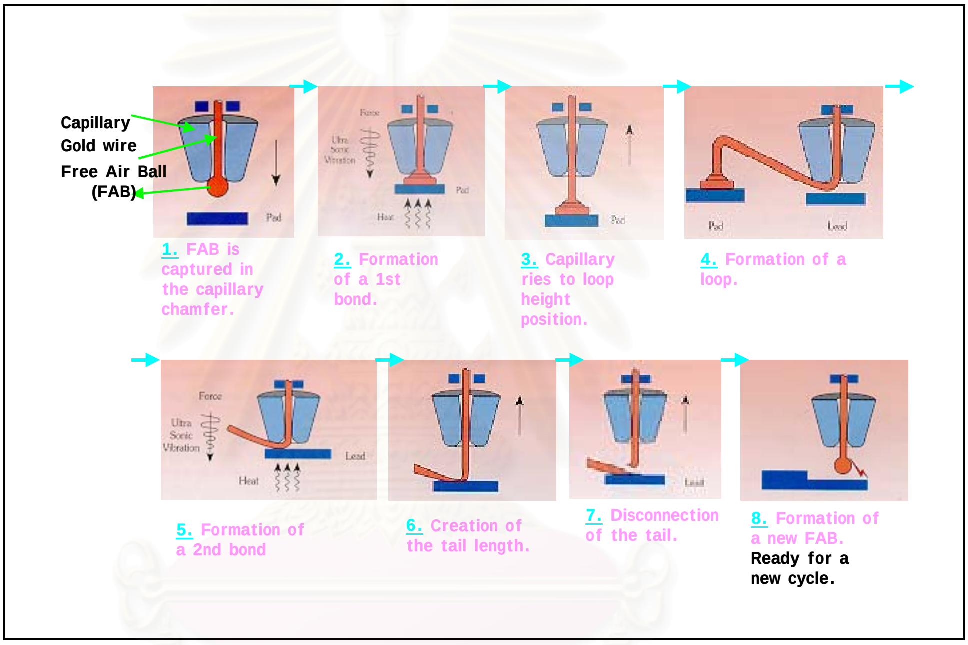
Wire bonding is the next process. Wire bonding is used throughout the microelectronic industry as a means of interconnecting the chips, substrates and output pins. Automatic gold bonding uses heat and ultrasonic energy to form a metallurgical bond. Typically, high purity (99.99%) 1 mil diameter gold wire is used and a ball bond (1^{st} bond) is formed at the bond pad and a stitch bond (2^{nd} bond) at the lead. A completed wire bonded strip is shown in Figure 2.21.

Figure 2.21 : Wire Bond Process



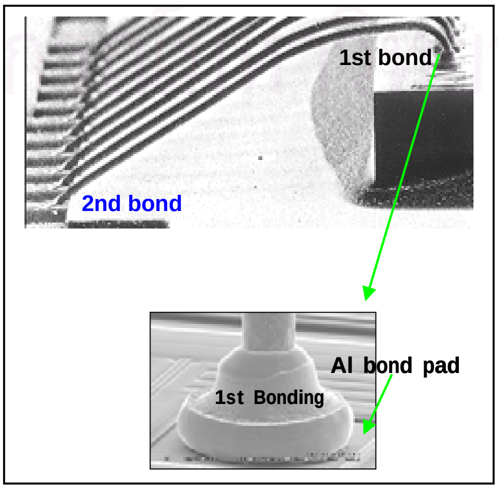
The wire-bond cycle is illustrated in Figure 2.22. The process cycle starts with a gold wire that is inserted through a capillary chamfer. A free air ball is generated at the tip of the capillary. In the 2nd step the first bond is created by ultrasonic vibration together with bonding force and heat from the supporting pedestal underneath. The 3rd step the capillary rises to the loop height position and forms a loop in the 4th step. In the 5th step the second bond is created similar to the first bond but instead of a ball shape a wedge shape is generated. The capillary rises again and generates a tail length in the 6th step. A wire-clamp disconnects the tail of the wire in step 7. In step 8 formation of a new free air ball is created and it is ready for a new bonding cycle. This process repeats until the whole die is wire-bonded and then will move to the next die until the whole FBGA strip is as well totally wire-bonded.

Figure 2.22: Wire Bonding Cycle



In Figure 2.23 shows the first bond on a aluminum-bonding pad of a die and the second bond on a FBGA substrate.

Figure 2.23: FBGA 1st and 2nd Bond



2.7.5 Mold Process

The next process is molding. The transfer molding process or encapsulation is a process of forming components in a closed mold from a thermosetting material. The material is conveyed under pressure, in a hot, plastic state, from an auxiliary chamber, called transfer pot, through runners and gates into closed cavities.

The purpose of molding process is to protect the IC chip from outside environment such as moisture, impurity and heat. The mold provides electrical insulation from outside environment and resistance to thermal and mechanical shock. Figure 2.24 shows a complete FBGA strip after molding.

The overview of mold process is shown in Figure 2.25. A heated wire bonded strip together with tablet mold compound is the required input for the molding process. A single chest of mold cavity can carry up to 2 FBGA strips and together with heat and pressure a molded strip is obtained from the process.

Figure 2.24: Molded FBGA Strip

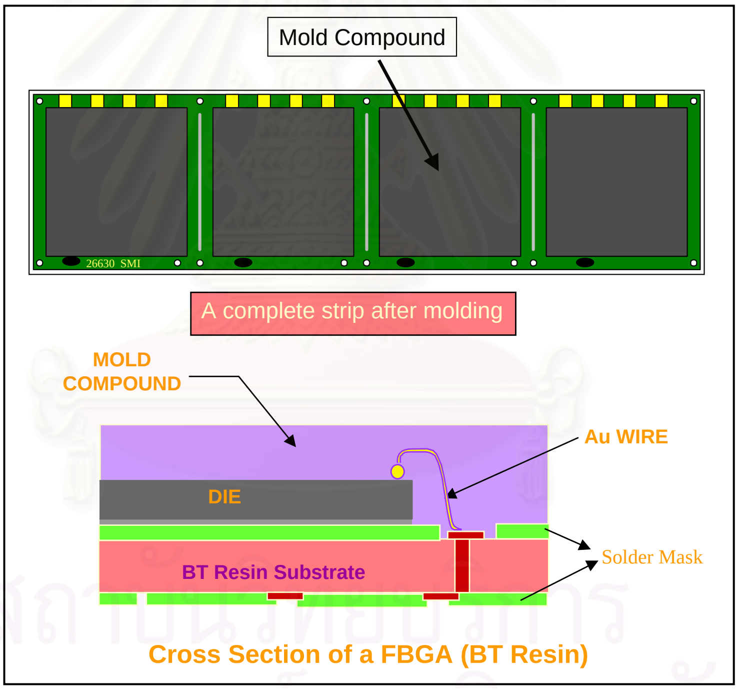
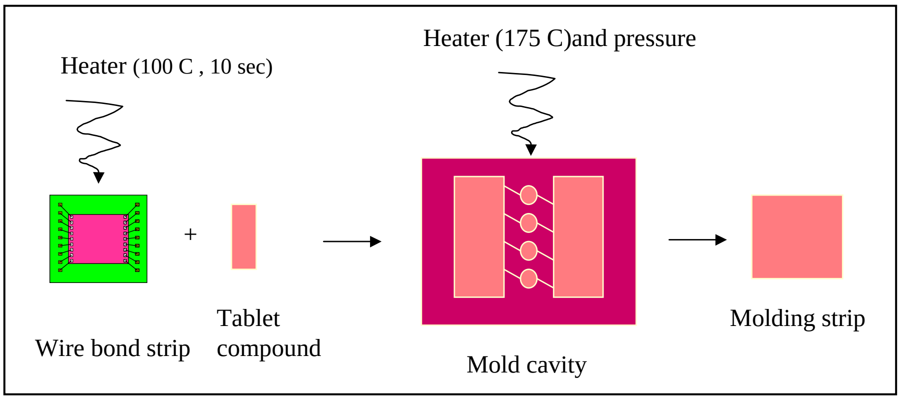


Figure 2.25: Molding Process



The molding process can be subdivided into 9 steps as illustrated in Figure 2.27. First the wire-bonded strips are pre-heated at 100 degrees with a time of 10 seconds. The two substrates are then loaded together with 4 mold compound tablet into the mold cavity. The top and bottom mold cavities are clamped together and the tablet compound is melted by heat. The melted mold compound is transferred into the cavity through the mold gates. Once the mold compound completely fills up the cavity then system will wait for 90 seconds for the compound to set. The complete molded strips with cull are off-loaded and move to degate in order to remove the culls between the two strips as shown in Figure 2.26. In the last stage the FBGA strips are off-loaded into a magazine and ready for pin 1 ID laser marking.

Figure 2.26: Degating of Mold Cull

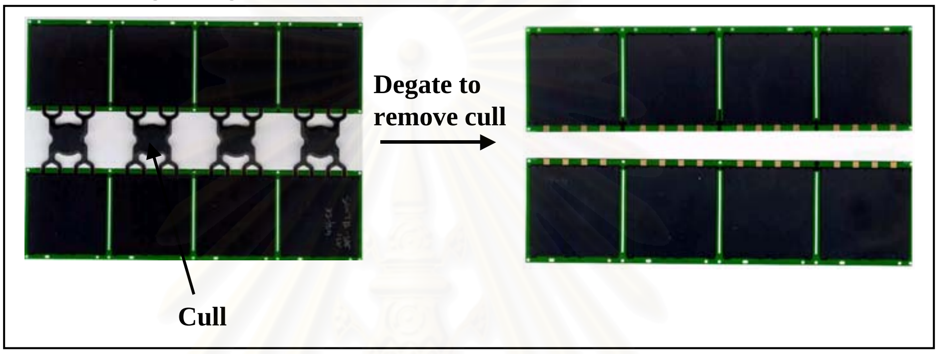
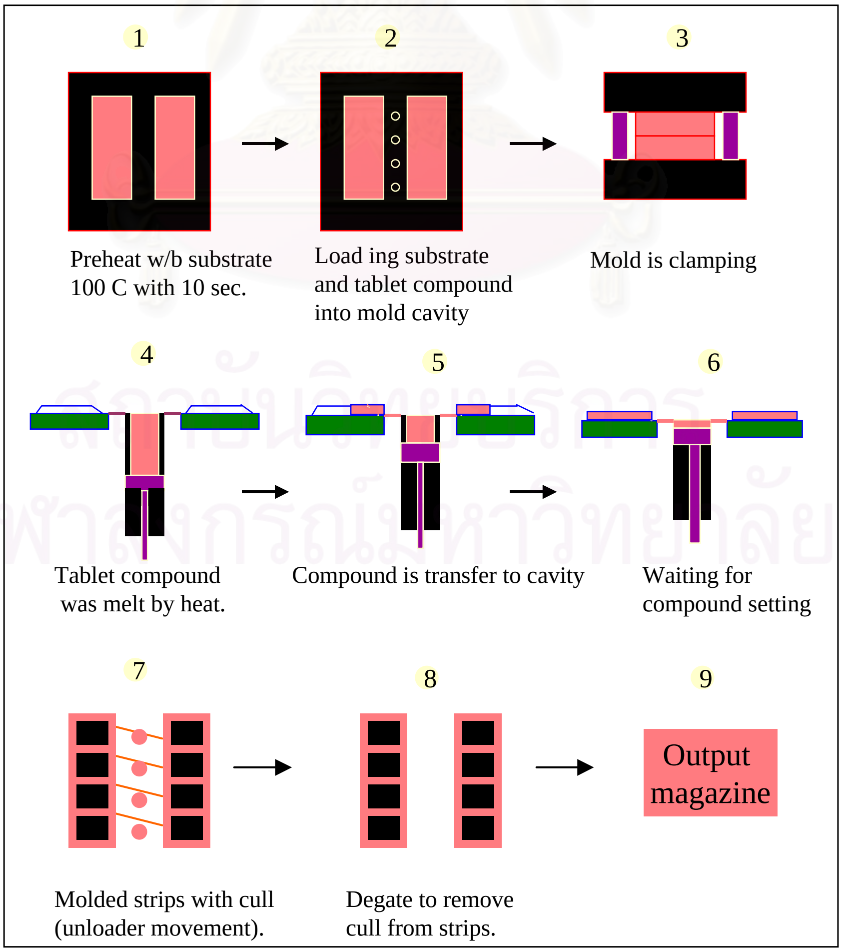


Figure 2.27: Molding Cycle

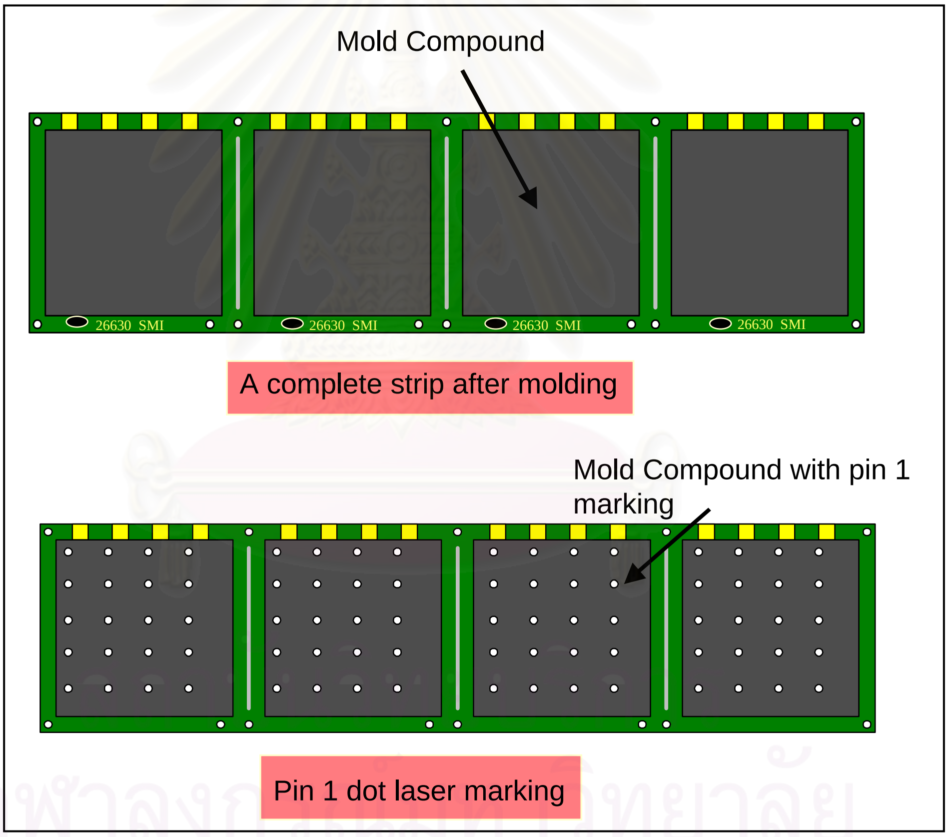


2.7.6 Pin 1 ID Mark Process

Pin 1 ID laser marking is the following process after mold. Pin 1 ID marking is the method of identifying the pin 1 location by using a laser mark machine. The pin 1 ID is engraved into the mold surface so that subsequence process after assembly can identify the correct substrate orientation. The marking of pin 1 ID on the mold compound is shown in Figure 2.28.

The subtrates after laser marking are submitted for post mold cure. The post mold cure is required for all epoxy-molding compounds used in molded plastic package. The need to cure is derived from the chemical kinetics of the polymerization reaction and to bring it near 100% chemical conversion. The curing condition for FBGA packages is 175 degrees curing temperature with duration of 5.5 hours.

Figure 2.28: Pin 1 ID Laser Marking



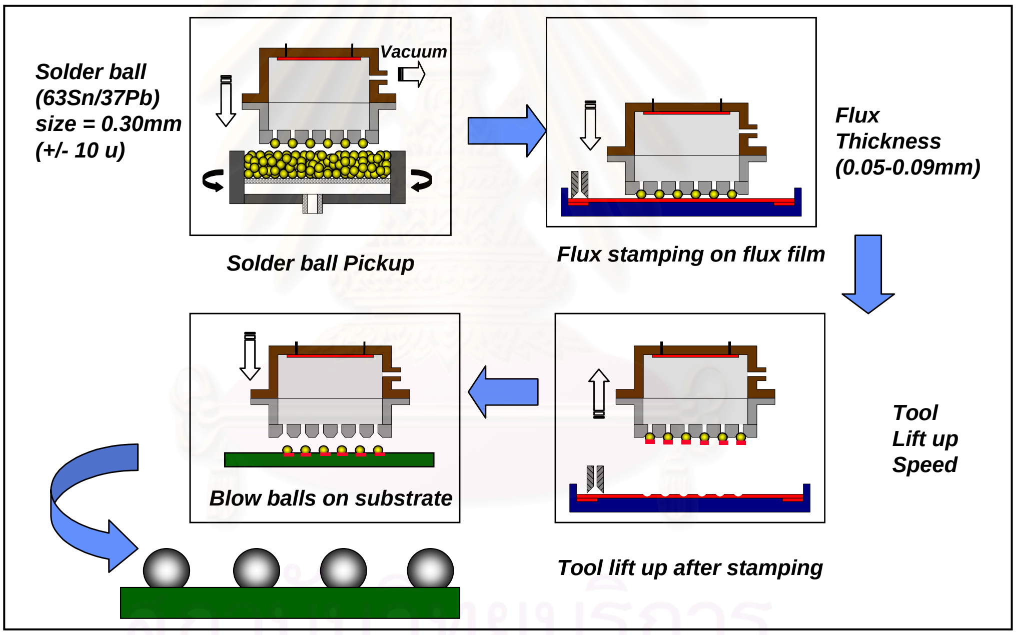
2.7.7 Ball Attach Process

Following post mold cure the substrates will go through ball attach process. The solder balls consist of 63% tin and 37% lead with a diameter of 0.3 mm is attached on to the substrate. The ball-attach process flow as illustrated in Figure 2.29 begins with a vacuum tool head that picks up the solder balls. The solder balls are then carried over for flux stamping. The flux is a thin film with an approximate thickness of 0.05-0.09 mm. The ball-attach tool lift up and then blow the solder balls on to the substrate at a very close distance. The solder balls at this stage are attached to the substrate on the ball pad side.

The ball-attached substrates then flow as a modular line to a reflow oven. The reflow system as shown in Figure 2.30 has a diverter to divert the incoming substrates into 3 lanes before the conveyor belt bring the substrate into the reflow oven. The substrates will pass through a profile of temperature consisting of four heated zones inside the oven chamber. The peak temperature is at 215 degrees (+/- 5 degrees). At the exit of the reflow oven, substrates are then accumulated into 1 lane and conveyed to the unloader where an output magazine is located at the rear end.

The purpose of reflow is to make the solder balls adhere properly with the solder pads of the FBGA substrate. The solder ball height has to meet a specification of 0.2 to 0.3 mm and solder ball shear with a minimum shear strength of 200 grams.

Figure 2.29 : Ball-Attach Process



The next process after reflow is cleaning. The cleaning process washes out remaining flux from ball attach process, residue, loose particles and contamination. The process flow for cleaning is shown in Figure 2.31 where a robot arm carries a basket loaded with FBGA substrates and dips the basket into 5 different tanks. The first tank substrates are cleaned by a special chemical detergent and then pre-rinse with DI ultrasonic water in the 2nd tank. The 3rd and 4th tank substrates are rinsed in DI water by spraying water jet. The 5th and last tank is a hot air blow to dry off the wet substrates.

Figure 2.30: Reflow System

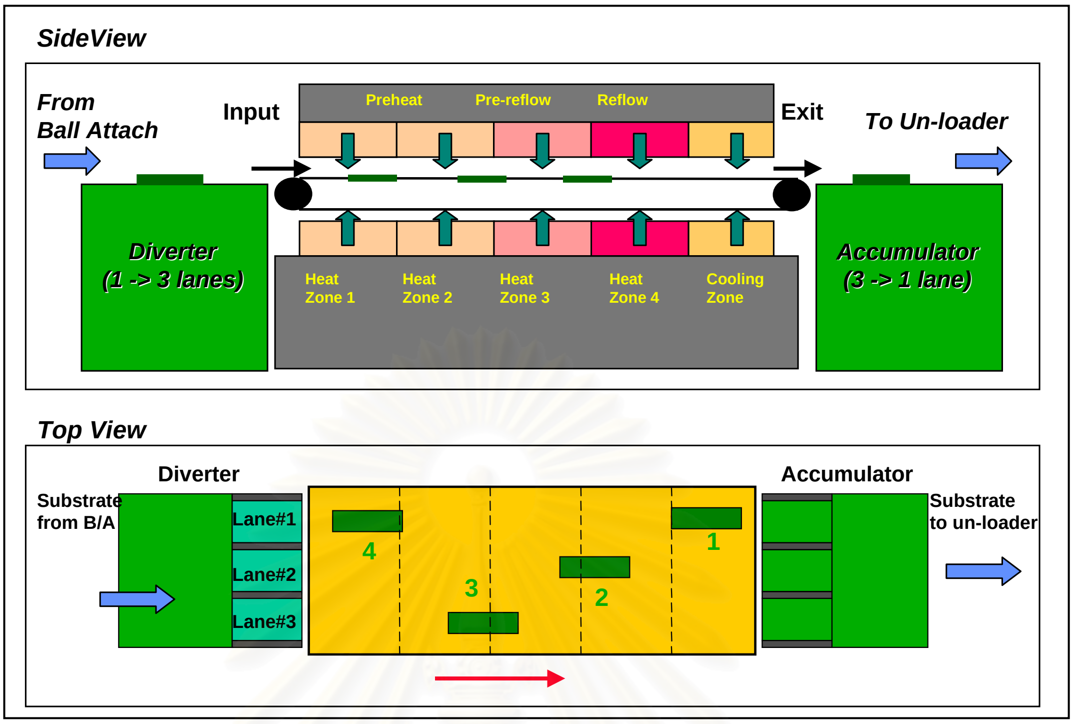
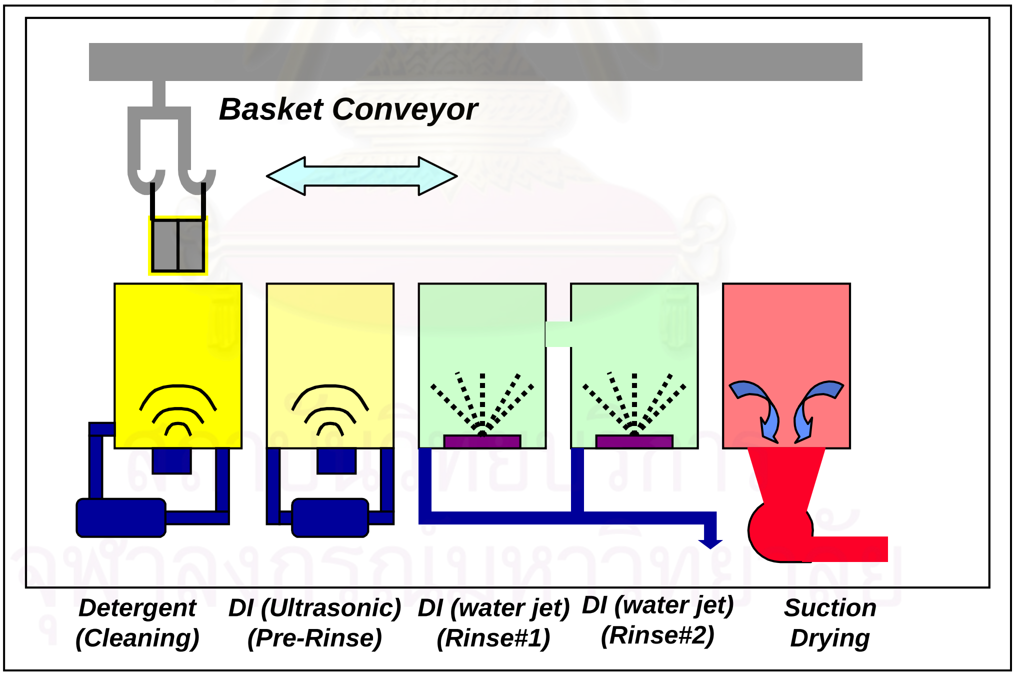


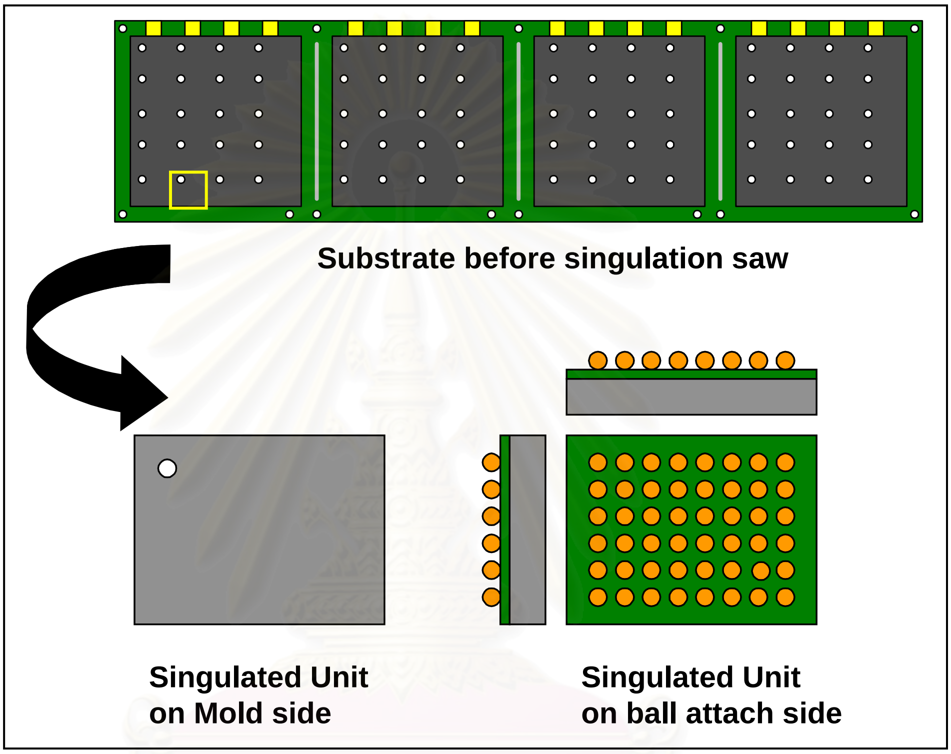
Figure 2.31: Cleaning Process



2.7.8 Saw Singulation Process

The CSP/FBGA saw singulation is the following process after cleaning. The saw singulation process cuts the substrate into several individual units as final product – Refer to Figure 2.32. The Intercon SBS-8800 – Figure 2.33 saw singulation system consists of a dicing machine and a handler integrated together as one fully automatic BGA saw singulation system.

Figure 2.32: Saw Singulation Process

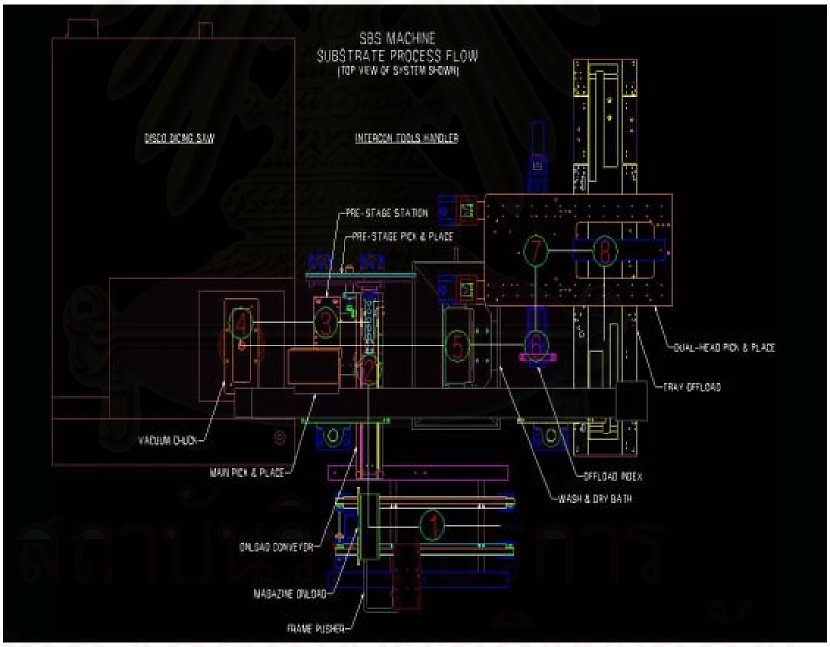


The top view of substrate process flow for the singulation machine is illustrated in Figure 2.34. The process substrate flow inside the saw singulation system according to Intercon Specification Sheet (1999) can be sequentially listed as follows:

(1) Magazine on-load
(2) On-load conveyor
(3) Pre-stage station
(4) Vacuum saw chuck
(5) Wash and dry chamber
(6) Off-load table
(7) Off-load position for pick and place
(8) Tray offload

Figure 2.33: Intercon SBS 8800 BGA Saw Singulation System

Figure 2.34: Substrate Flow in Singulation System (Intercon Specification Sheet, 1999)



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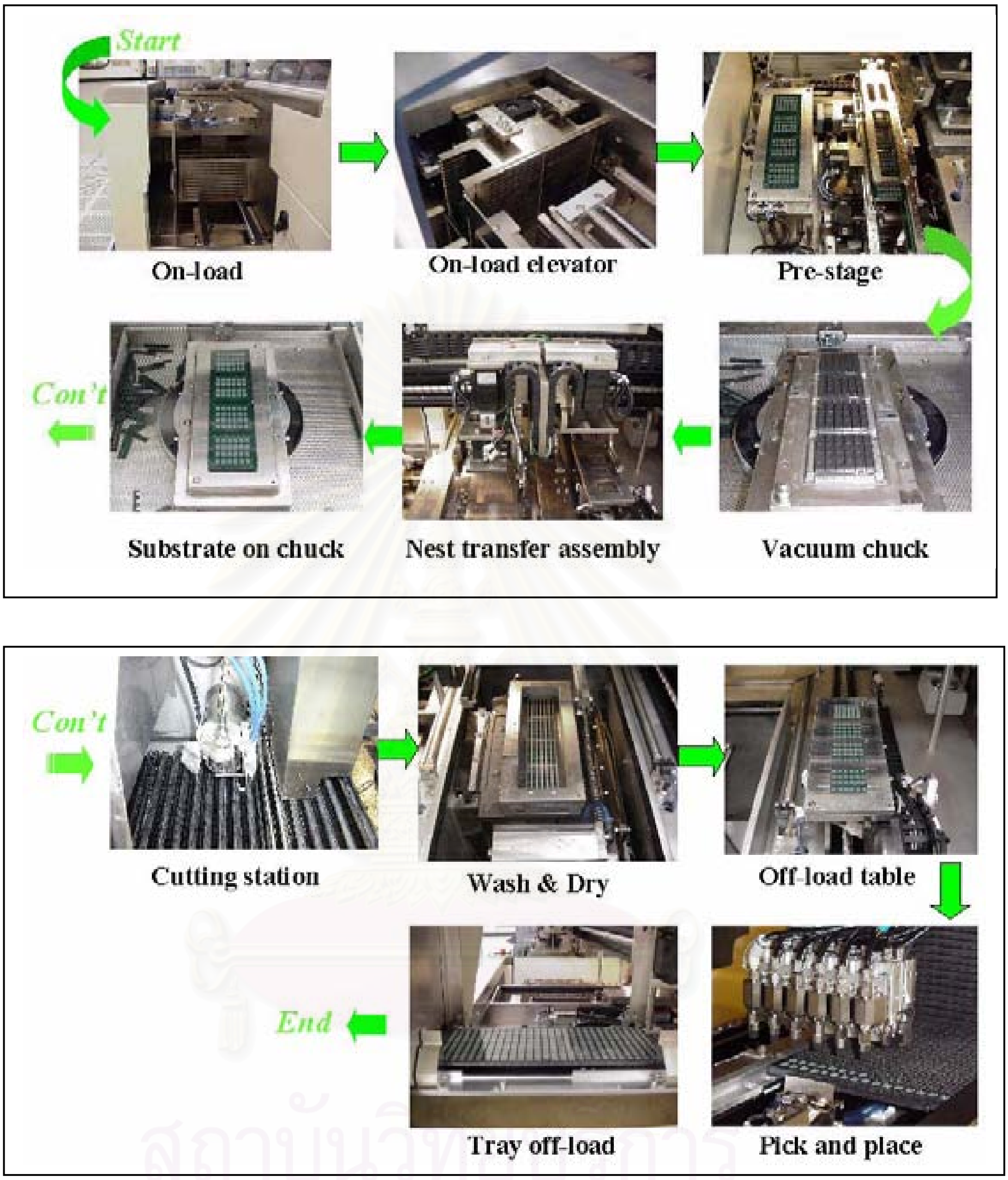
The CSP/FBGA saw singulation process in Figure 2.35 begins with the magazine on-load station. Magazines filled with FBGA substrates are manually loaded by operator into the input magazine on-load. A conveyor belt brings the magazine onto an on-load elevator where the magazine is clamped and lifts up to a docking position on the Intercon handler.

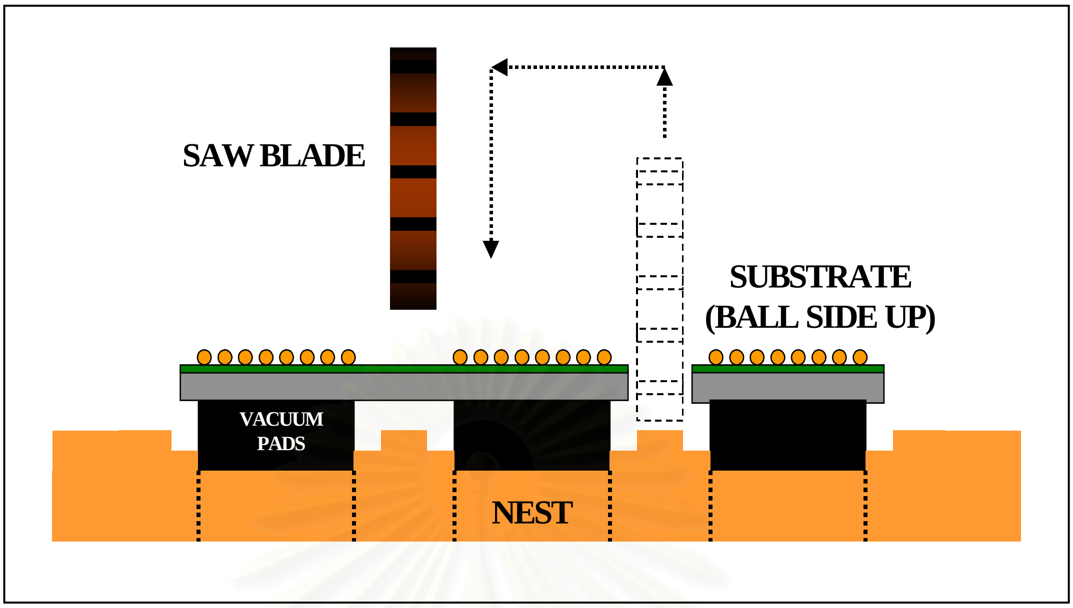
Figure 2.35: CSP/FBGA Saw Singulation Process Flow



The next step, a substrate frame pusher pushes out the top substrate into a conveyor track and then a robotic pick head with vacuum pads picks up the substrate and load the substrate onto a nest at the pre-stage station.

The vacuum saw chuck located at the dicing machine portion consists of matrix arrays of viton vacuum rubber pads. The viton rubber pads are used to support the mold side of a substrate and hold down the singulated FBGA units during the cutting process. The nest jig saw singulation concept can be described in detail as shown in Figure 2.36.

Figure 2.36: Nest Jig Saw Singulation Concept



The nest jig carries the FBGA substrate ball-side facing up. A robotic arm or the nest transfer assembly carries the nest jig from the pre-stage station to the vacuum saw chuck. The nest jig cavities allows the nest to go through the viton rubber pads and stops at the flat saw chuck surface beneath. Viton rubber pads hold up the substrate on molded side so vacuum does not leak during cutting.

A dicing saw basically consists of a blade to cut parts mounted on a a high speed rotating spindle shaft. The saw chuck feeds the substrates towards the rotating blade that cuts through the molded substrates, and separates them into individual FBGA units.

The nest transfer assembly of the fully automatic system then puts a nest cover over the nest to secure the parts for washing. The sawn parts are carried to a washing and drying chamber. The purpose of this station is to clean sawing debris, particle or any type of contamination that could result from the cutting process.

The nest transfer assembly picks up both nest and nest cover together and places them on to an off-load table. The nest cover is lifted away by the nest transfer assembly leaving the nest with sawn parts on the off-load table. A pick and place system picks up the units and places them into shipping trays. The pick and place performs the cycle until a full tray is completed and the system unloads the complete tray into a tray offload stacker. The FBGA trays are stacked up for operators to remove them.

2.7.9 Final Outgoing Inspection

The singulated FBGA units are required to go through Final Outgoing Inspection (FOI QC Gate). The FOI process includes ball inspection equipment combining with gross defect visual inspection. The ball inspection equipment measures variable data such as missing balls, package dimensions, ball array offset, ball diameter, coplanarity, etc. While gross defects are inspect under low magnification microscope to screen out defects such as package chips, cracks, foreign material, mold debris, substrate contamination, exposed solder resist, etc.

A fully automatic ball inspection equipment, ICOS CI-8250, is used for measuring the cutting quality outcome from the singulation process as well as ball present/quality from ball attach process. Refer Figure 2.37 – ICOS process flow chart.

A graphical depiction of the actual ICOS process flow is shown in Figure 2.38. The process start with input trays loaded into X1 tray onload station. A dual pick and place head picks two units at a time and brings them for inspection at the ball inspection module. The camera vision system consists of two cameras, one for 2D and the other for 3D angled at 45 degree from the 2D camera– Refer Figure 2.39. A ring light illumination is used to illuminate the solder balls and together with the 3D camera the system is able compare the distance difference between theoretical ball location and real ball position. The 3D computation results will give readings on ball height, coplanarity, package warpage, etc. The basic 2D camera will provide readings on package dimension, ball diameter, ball -array offset, etc.

A tray transfer module (TTM) transfers the inspected tray to surface mold inspection module (SMI). SMI camera vision inspects for chip, crack, scratch, and pin ID marking. Next, the system with a single vacuum nozzle head, sorts to X2 tray offload for good units, X3 tray offload for ball rejects, and X4 tray offload for surface mold/pin 1 ID rejects. The system is capable of performing parallel inspection between ball inspection and surface mold inspection.

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Figure 2.37: ICOS Process Flow Chart

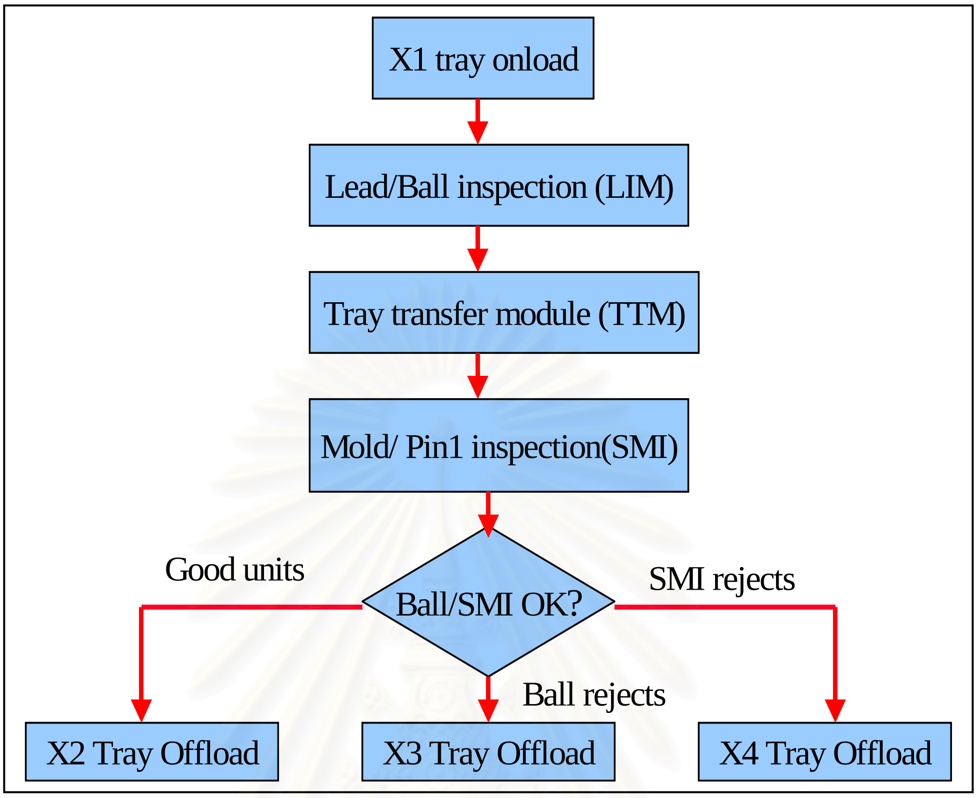
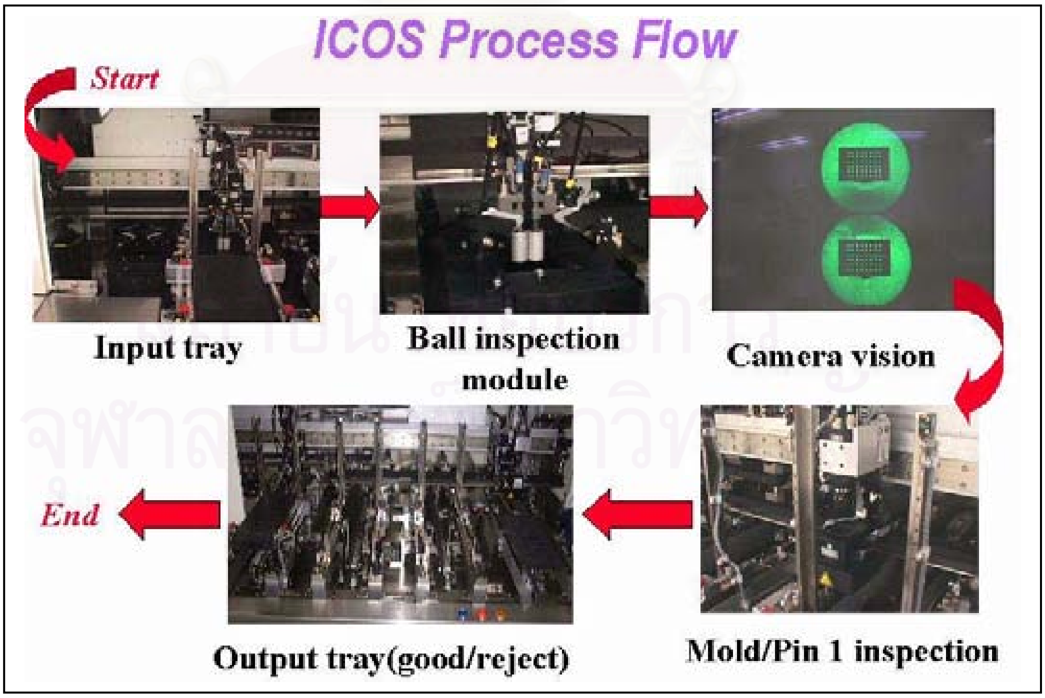
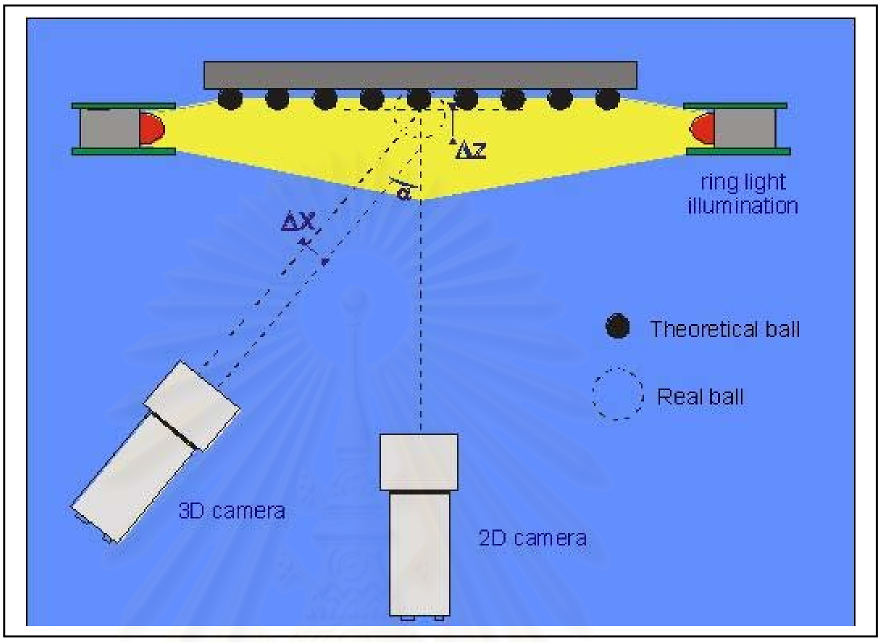


Figure 2.38: ICOS Process Flow



The last process step after final outgoing inspection is packing. The finished good products are strapped into a bundle of stacked FBGA trays, wrapped with foam and packed into carbon coated boxes. The FBGA assembly process is completed at this stage and units are ready for testing.

Figure 2.39: ICOS Cyberstereo Measurement Technique



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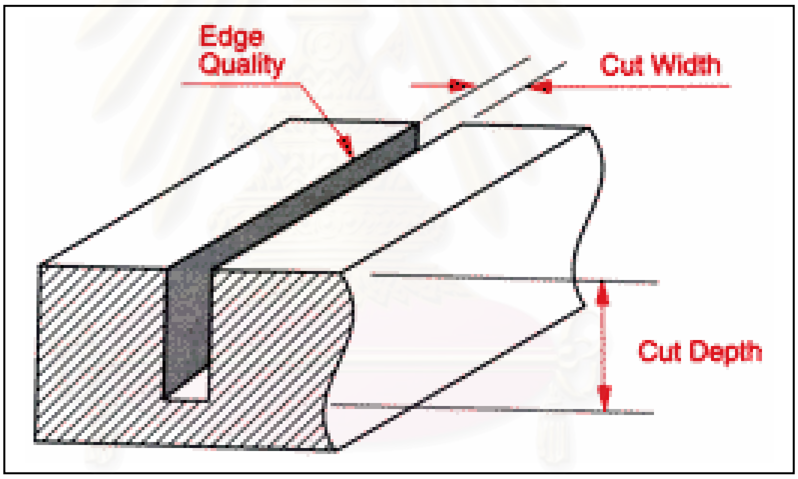
2.8 Principles of Dicing

According to Levinson (1991) dicing (or diamond-wheel sawing) is used in the microelectronics industry for die separation and also for fine, accurate, partial and cut-through of exotic, very hard and brittle materials. The wide range of materials processed makes it necessary to use different blades. These may be based on hard or soft binders, with various diamond particle sizes. Large-scale production and high productivity rely on low, consistent blade wear and superior cut quality as demanded by today's sophisticated industrial environment.

2.8.1 Diamond Wheel Dicing

Diamond Wheel Dicing is the most common technique in the industry. The cut quality is higher than other techniques. Also, it is possible to keep cut width, depth, and straightness as well as edge quality under tight control as illustrated in Figure 2.40

Figure 2.40: Dicing with Diamond Blade (Levinson, 1991)



2.8.2 Blade Basics

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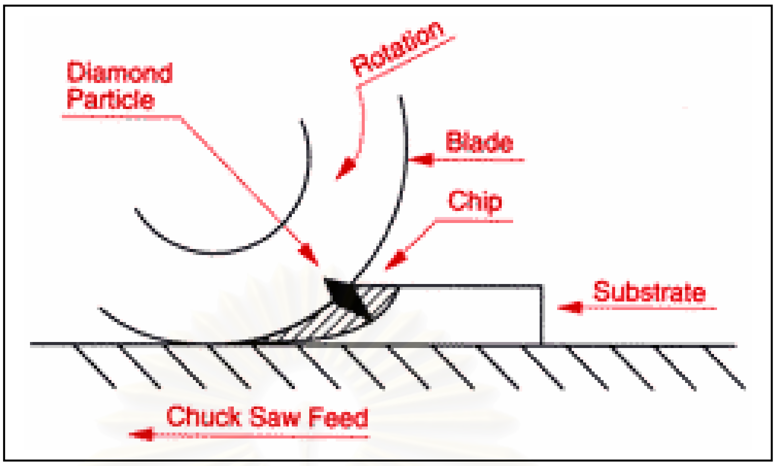
A diamond blade is actually a ring composed of abrasive grains (diamond particles) held together by a binder - either nickel or phenolic resin or metal-powder sintering. Each individual diamond particle acts as a single-cutting tool, pushing a chip of material ahead of it. As there are many diamond particles on a blade edge, there are therefore many single-cutting tools pushing out the substrate material and creating a kerf (Figure 2.41).

2.8.3 Blade Binders

Materials used nowadays in the microelectronics industry exhibit a wide range of hardness, from relatively soft to extremely hard and brittle. This large variety requires a range of soft and hard blade binders.

Figure 2.41: Single Diamond Machining Mechanism (Levinson, 1991)



A hard and brittle material requires a soft blade binder. A phenolic resin binder is used on those materials to achieve free cutting action, with very fine chip-free kerfs. Cutting performance is based on the binder's ability to release dulled diamonds and expose, new sharp ones at the same time.

On softer, less brittle substrates a harder matrix is necessary. Nickel and metal sintered binders are normally used for these applications. The nickel-type blade is a state-of-the-art electro formed product. It has a very hard nickel matrix, with diamonds distributed homogeneously through it. This bond is the key for very low wear. The Metal Sintered blade is in between the Resin and the Nickel binders, it is a very uniform matrix and has better wear characteristics than the nickel matrix and therefore is less loading.

Choosing the right binder is a matter of experience. See Figure 2.42 for a blade selection table; however, as each application is unique, it should be used only as a guideline. Final selection should be done only after the process has been optimized in production mode.

Figure 2.42: Blade Selection Guidelines (Levinson, 1991)

Material	Nickel	Resinoid	Metal Sintered
Alumina		53 mic.	
Ferrite	3-6 mic	9 mic.	2-4mic. 3-6mic.
Glass		45 mic.	
Garnet		35 mic.	
Barium titanate		45 mic.	17mic.
Kovar		53 mic.	
Quartz		30 mic.	

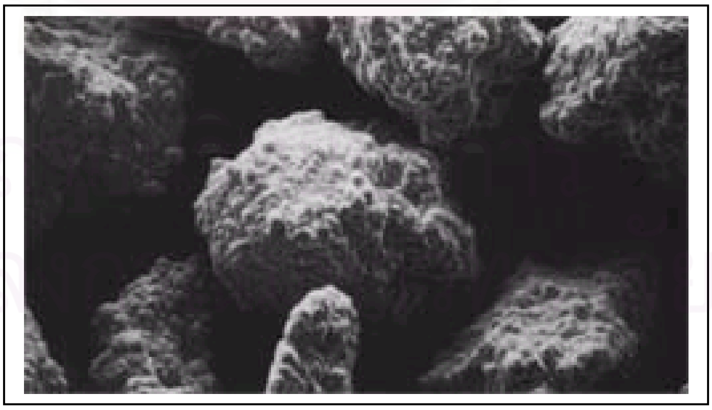
2.8.4 Diamond Selection

It is important to control the quality, purity, size and reliability of the diamond particles in order to ensure superior kerf quality and long blade life. With nickel electro formed and metal sintered blades the best results are obtained by using well-formed, strong, block, single-crystal diamonds. (see Figure 2.43).

Figure 2.43: Strong, Block, Single Crystal Diamonds (Levinson, 1991)

In resin-bonded blades friable diamond particles are used to achieve self-sharpening, free cutting action. The diamond particles are coated with a nickel alloy in order to improve the diamond-resin bond. The coating also sinks the heat generated during cutting (see Figure 2.44).

Figure 2.44: Friable Diamonds Coated with Nickel Alloy (Levinson, 1991)

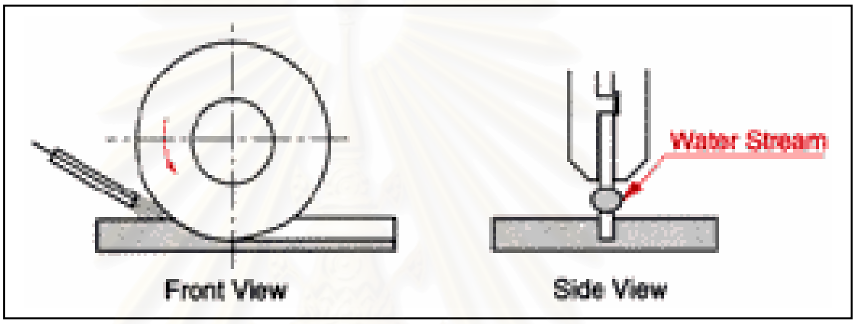


2.8.5 Blade and Substrate Cooling

Cooling of the blade and the substrate is basic and essential for any dicing application. Following are the main basic points to be aware of:

- Alignment of the cooling nozzles with the blade and substrate (See Figure 2.45).
- Cooling pressure - consult the recommendations of the manufacturer of the saw
- The ability of the blade to cool itself.

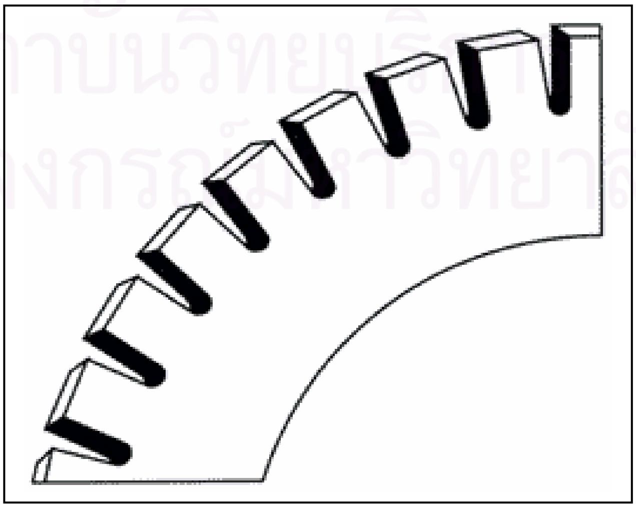
Figure 2.45: Blade Cooling Front View and Side View (Levinson, 1991)



Cutting heavy substrate .100 to .500 thick creates cooling and overloading problems. Nozzle alignment and coolant pressure are not the only solutions. A serrated blade is used for these applications (See Figure 2.46).

The serrated blades are designed for freer cutting with less load. The slots eliminate continuous contact between blade and material, and improve cooling of both blade and substrate.

Figure 2.46: Serrated Blade (Levinson, 1991)

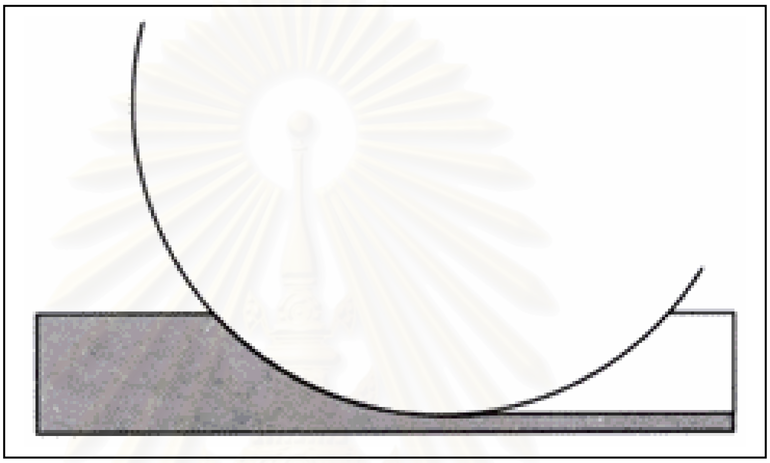


Advantages and Disadvantages of Serrated Blades (See Figure 2.47)

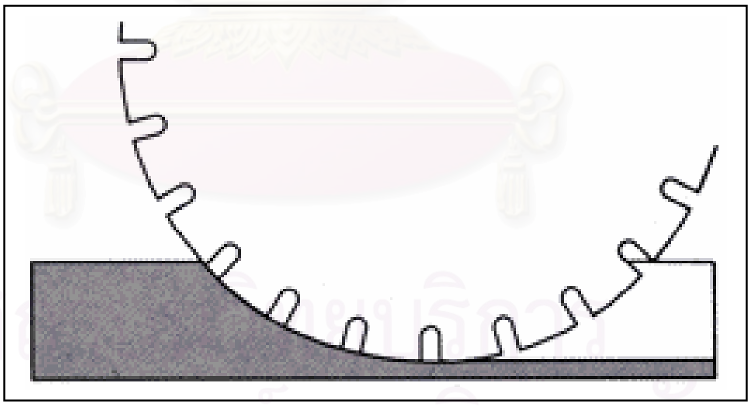
Advantages:

1. Less contact between edge and substrate, which translates into less load during cutting.
2. Better cooling, due to serrations.

Figure 2.47: Regular Blade versus Serrated Blade (Levinson, 1991)



Contact on Regular Blade

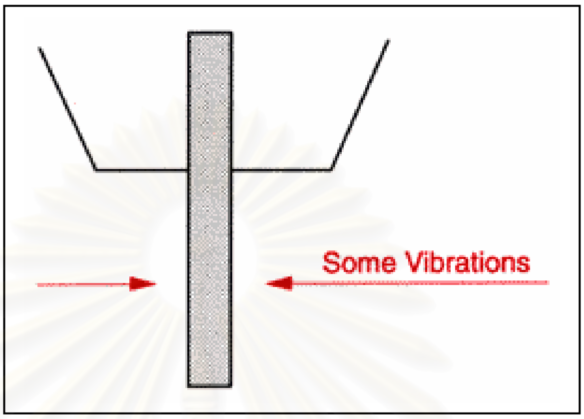


Less Contact on Serrated Blade

Disadvantages

1. Kerf width is not as accurate as with regular blades due to some vibrations (See Figure 2.48).

Figure 2.48: Vibration on Serrated Blade (Levinson, 1991)

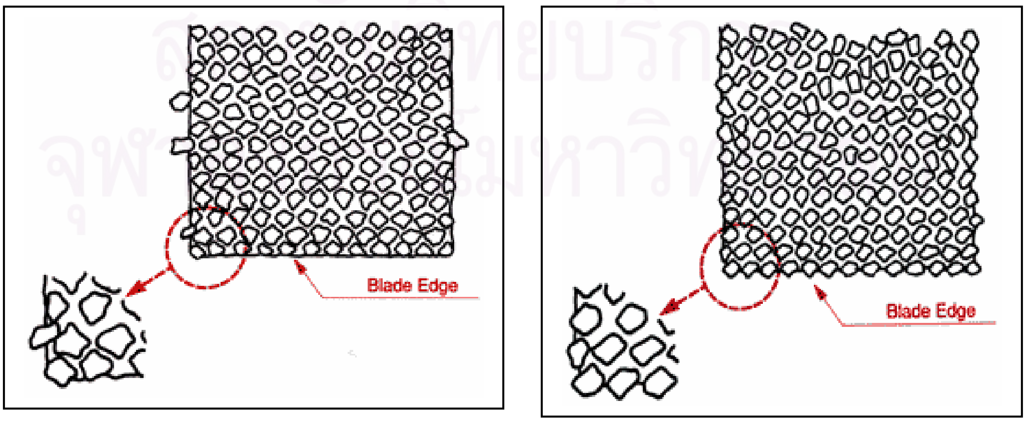


2.8.6 Dressing

One of the most important steps to assure accurate dicing is dressing the blade before cutting. Dressing is important for the following reasons:

- Excess binder material or loose diamond particles are machined off - See Figure 2.49.
- The binder holding the diamonds is machined off, exposing the diamonds
- It trues the outside diameter run out and the blade edge geometry.
- Minimizes the load, creates a cooler and freer cut.

Figure 2.49: Nickel Bond Dressing (Levinson, 1991)



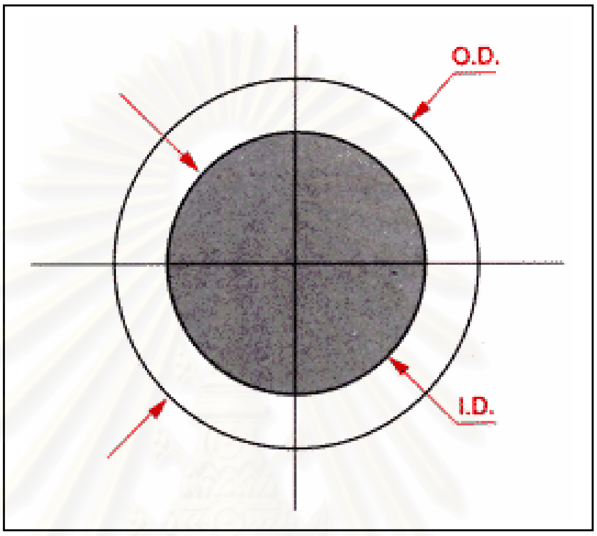
Blade Before Dressing   Blade After Dressing

2.8.7 Dicing Glossary

1. Blade Parameters – Refer to Figure 2.50

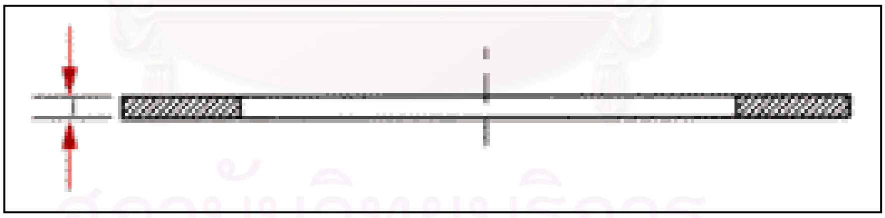
Blade O.D. - outer diameter
Blade I.D. - inside diameter

Figure 2.50: Blade O.D. and I.D. (Levinson, 1991)



Blade Thickness – Refer to Figure 2.51

Figure 2.51: Blade Thickness (Levinson, 1991)

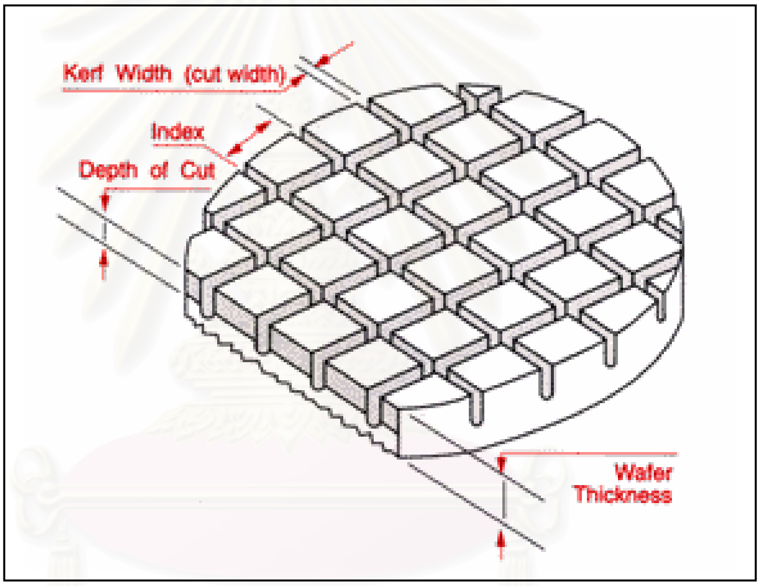


Diamond Grit - diamond size in microns or in mesh
Blade Binder - the matrix holding the diamonds: nickel, resin, metal powder sintering
Serrated Blades - have slots on their edge, for better cooling

2. Cutting Parameters

Spindle R.P.M. - spindle revolutions per minute
Feed rate - table speed
Index - the distance between the cuts (See Figure 2.52)
Cut depth: (See Figure 2.52)
Cut length - the substrate size to be diced
Mounting method - how the substrate is clamped (vacuum, magnet, glue, wax, tape)
Cut width: (See Figure 2.52)
Chipping - Chipping on edge of cut depth [top side & back side]
Kerf - cut
Substrate - Material type: ceramic, silicon, etc.
Thickness: (See Figure 2.52)

Figure 2.52: Wafer Parameters (Levinson, 1991)



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CHAPTER 3

METHODOLOGY

3.1 Dicing Blade Evaluation

The appropriate dicing blade for CSP application has to be evaluated prior to production ramp up. The dicing blade evaluation was carried out at two facilities. Initially the first evaluation was performed at Disco Corporation, which is one of the world-leading suppliers for dicing blades. The second evaluation was carried at the IC manufacturer site, AMD Thailand.

3.1.1 Dicing Blade Selection at Supplier

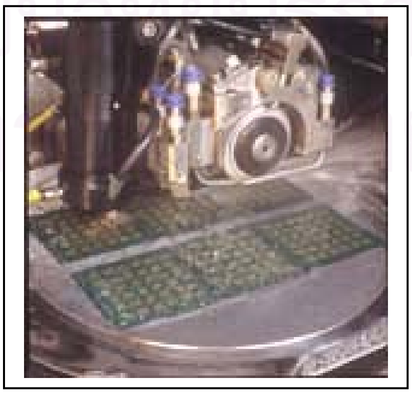
3.1.1.1 Objective and Scope

The objective of the evaluation was to establish a blade for cutting BT Resin material and mold compound by using Disco DFD641 fully automatic dicing saw machine. The target of the evaluation is to achieve both top and backside chipping within 50 microns, and a kerf width of 350 +/- 5 microns. The substrate material used is an AMD standard CSP substrate with outer dimension of 191 x 51 x 0.91 mm (length x width x thickness). The substrate drawing and dimension is referred from Hua [27] FBGA 8 mm x 9 mm substrate design.

3.1.1.2 Test Method

Substrate samples were affixed to a tape (D-510T) as dead bug position, meaning that the molded side of the substrate is attached onto the adhesive tape with the ball side facing upwards – Refer to Figure 3.1

Figure 3.1: Package Singulation on Adhesive Tape

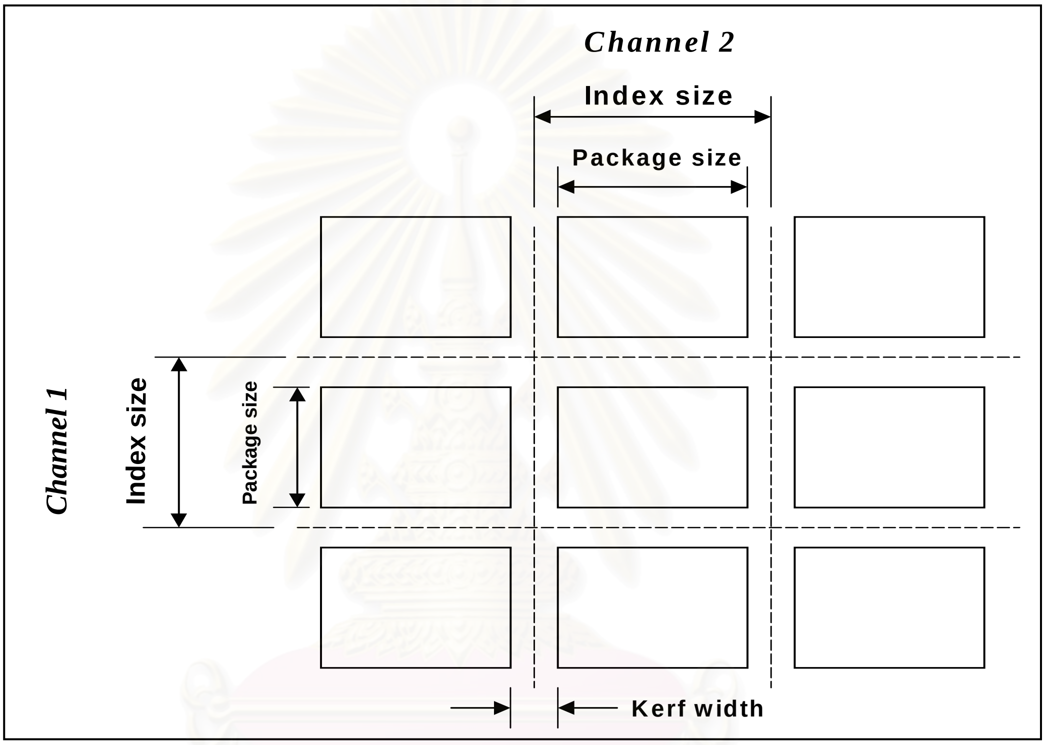


The evaluation result is based on a measurement of two FBGA packages from each substrate by using a factory microscope. The actual kerf width was computed by subtracting package size from index size – Refer to Figure 3.2

The evaluated FBGA package is a package with outer dimension of 8 mm x 9 mm. The index size that required to be programmed into the dicing machine is calculated based on Hua (1999) FBGA 8 mm x 9 mm substrate design. The sawing requires two-channel cutting with index size as the follows:

Channel 1 (CH1): 8.298 mm
Channel 2 (CH2): 9.298 x 4 times + 10.545 x 1 time

Figure 3.2: Kerf Width Calculation



3.1.1.3 Test Blades

The evaluated blades were all manufactured from Disco Corporation. In this evaluation 3 different types of blade were selected. The 3 blades vary in terms of binding materials and diamond mesh size. The dimensions for the 3 types of blades are the same with 58 mm x 0.34 mm x 40 mm (Outer diameter x blade thickness x inner diameter). Table 3.1 illustrates the properties of the various blades.

Table 3.1: Dicing Blade Properties

Blade	NBC-Z 111OLG3S3	B1A801S3	B1A803S3
Mesh	#400	#280	#400
Bond strength	Soft	Soft	Soft
Concentration	50	50	50
Bond material	M (Nickel)	M51(Metal)	M51(Metal)
Dimensions(mm)	58 x 0.34 x 40	58 x 0.34 x 40	58 x 0.34 x 40

3.1.1.4 Cutting Conditions

The cutting conditions during dicing needs to be controlled otherwise the results of cutting quality significantly vary – Refer to Table 3.2

Table 3.2: Cutting Conditions on Tape

Feed Speed (mm/second)	**76.2**
Cut depth (microns)	**100 into the tape**
Cut mode	**AS (down cut)**
Coolant type	**City water**
Flow rate (liter/minute)	**Blade: 1.5 Shower: 1.0**
Spindle rotation (RPM)	**30,000**
Flange size (mm)	**54**

The dress method for each of the blades needs to be controlled as well. The types of dresser board and the parameters during dressing are significant factors that contribute to the cut quality of the product. The dress conditions are listed in Table 3.3.

Table 3.3: Dress Conditions on Tape

Dresser board	**MODV 032040**
Cut mode	**B (up cut)**
Cut depth (micron)	**100**
Cut speed (mm/second)	**20,30,40,50,60,70**
No of lines cut	**4 lines for each speed (Total 24 lines)**

In this evaluation a precut was not performed. A precut is a process where the cutting starts at a low speed in order to self- dress or exposed the diamonds of a new dicing blade, and slowly the cutting speed ramps up until reaches the maximum cutting speed. The duration from the slowest cutting speed until the machine reaches the maximum cutting speed is known as the “precut”.

3.1.1.5 Measurement

The blade performance from the evaluation can be measured as follows:

1) Cutting Results: Measured in terms of top side chipping, backside chipping, package size both X and Y direction, and kerf width both X and Y direction

2) Spindle Current: The load that applies onto the spindle during cutting is a direction proportion to the current that is supplied to the spindle.

3) Blade Wear Rate: Wear rate determines the cut quality as well as the blade life.

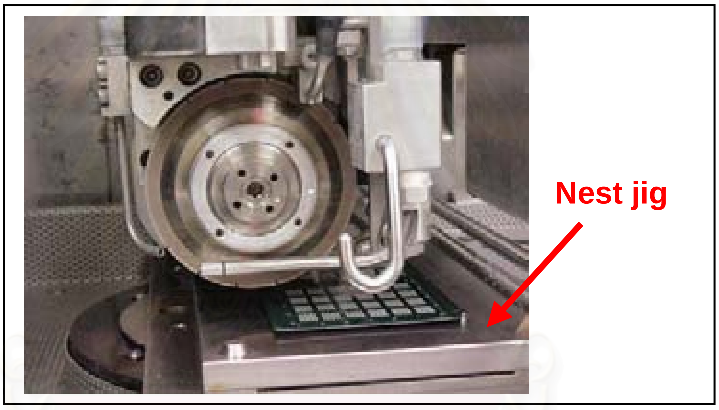
3.1.2 Dicing Blade Evaluation at IC Manufacturer

3.1.2.1 Objective and Scope

The objective of this evaluation is to evaluate the selected blade on the Intercon system with the nest jig concept, which is used in production – Refer to Figure 3.3. The evaluated FBGA package is a package with outer dimension of 8 mm x 9 mm. The tolerance ranges specified by Hua (1999) are 7.900-8.000mm and 8.900–9.000mm.

Package dimensions depend on the sawing pitch and the blade thickness. Sawing pitch is fixed and programmed in the saw machine according to substrate design. Blade thickness determines the saw kerf width. The saw kerf determines the package dimensions. A saw kerf width of 350 microns is required to obtain the package dimension nominal value of 7.95 mm x 8.95 mm.

Figure 3.3: Saw Singulation with Nest Jig Concept



3.1.2.2 Cutting Conditions

The cutting conditions that will be used for evaluation on the Intercon system are listed in Table 3.4

Table 3.4: Cutting Conditions on Nest Jig

Feed Speed (mm/second)	**100**
Cut depth (mm)	**0.15 above nest surface**
Cut mode	**AS (down cut)**
Coolant type	**City water**
Flow rate (liter/minute)	**Blade: 1.0** **Shower: 1.0**
Spindle rotation (RPM)	**40,000**
Flange size (mm)	**54**

The dress conditions on nest jig are listed in Table 3.5

Table 3.5: Dress Conditions on Nest Jig

Dresser board	**MODV 032040**
Cut mode	**AS (down cut)**
Cut depth (micron)	**250**
Cut speed (mm/second)	**20,30,40,50,60,70**
No of lines cut	**4 lines for each speed (Total 24 lines)**

3.1.2.3 Measurement

The blade performance from the evaluation can be measured as follows:

1) Cutting Results: Measured in terms of kerf width both X and Y direction package size both X and Y direction and package chip.

2) Blade Life: Measured in terms of maximum cut lines that each blade can last without giving any cutting quality problems.

3.1.2.4 Blade Dressing Evaluation

A blade dressing procedure is to perform cutting of a new blade on a carbide dresser board – Refer to Figure 3.4. This is to sharpen the blades before actual using in production. The reason for dressing is to expose the diamonds that are hidden by the bonding material of the blade. Exposed diamond allows more effective cutting and reduces the chance of having package chips or cracks on the product. The dressing procedure recommended by Disco can be referred from Blade Dressing (1997). The machine operation method to perform dressing has also been established and documented in AMD specification 707-771 by Vijchulata (2000). The blade is dressed to expose the diamonds as shown in Figure 3.5.

Figure 3.4: Carbide Dresser Board on Saw Chuck

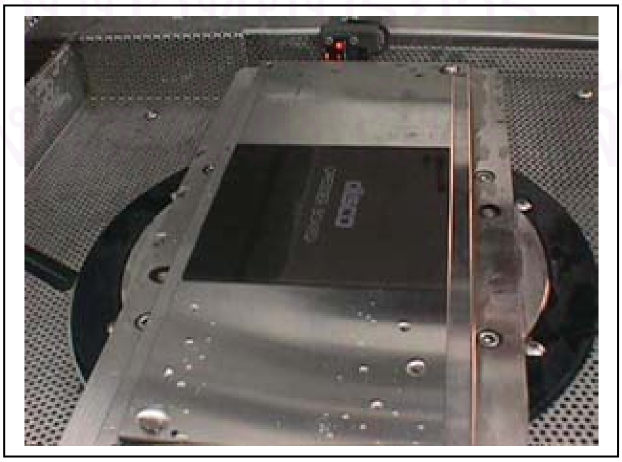
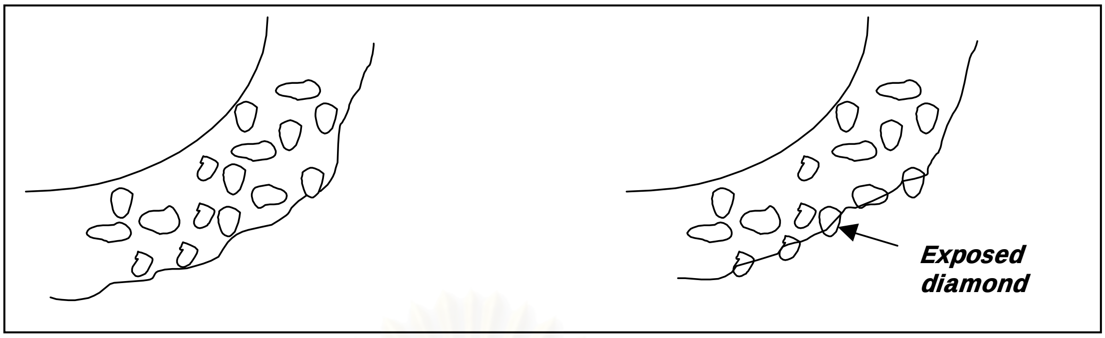


Figure 3.5: Blade Before/After Dressing



Before Dressing **After Dressing**

The evaluation of blade dressing is to compare the results of package chip between condition of blade dressing and blade without dressing. The blade used in the evaluation will be from a qualified blade that has been selected from previous evaluation.

3.2 Cutting Sequence Evaluation

3.2.1 Pattern Recognition System (PRS)

The Disco saw module is equipped with 2 microscopes, one with high magnification and the other with low magnification – Refer to Figure 3.6. The Pattern Recognition System (PRS) is capable of using features on the substrate in order to perform pre-saw pattern recognition checks. In CSP application, the features used are the fiducials on the ball side of the substrate to auto-correct the θ axis – Refer to Figure 6.13. This ensures good alignment prior to sawing.

The PRS system checks 3 or more fiducials on the ball side to locate the position of substrate and auto-corrects the θ axis to compensate for any shift in position – Refer to Figure 3.7. The drifts in fiducial position can occur within different substrate suppliers or variation from lot to lot or even substrate to substrate of the same lot.

The fiducials are used as reference in order to locate the first cut line in each channel of sawing. The sawing of subsequent cut lines are then indexed according to the index parameter that has been programmed previously by the user. The input index parameter depends on the substrate design that corresponds to the FBGA package type. The index parameters that are used for programming the saw can be referred from Appendix F and Appendix G, which provide critical FBGA 6x9 substrate dimensions.

Figure 3.6 : Pattern Recognition System (PRS)

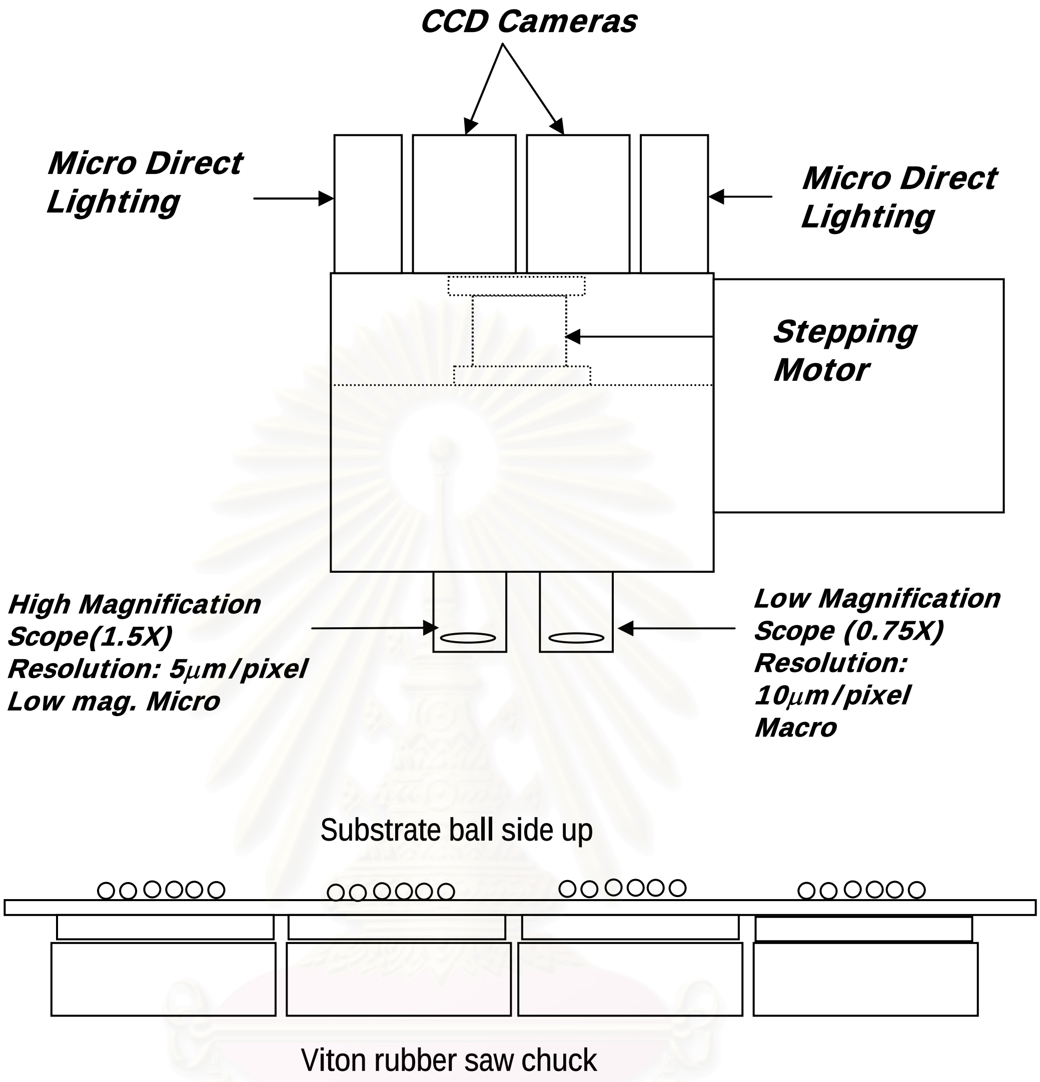
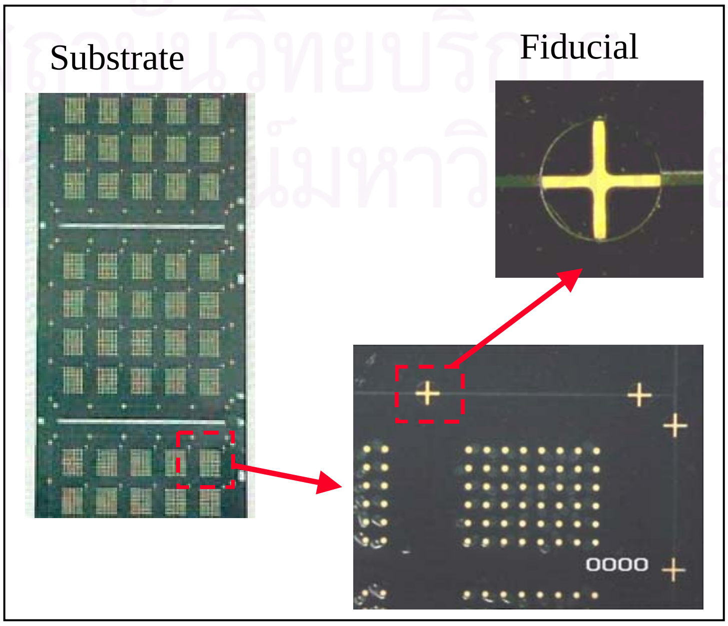


Figure 3.7: Fiducial Mark on Substrate Ball Side



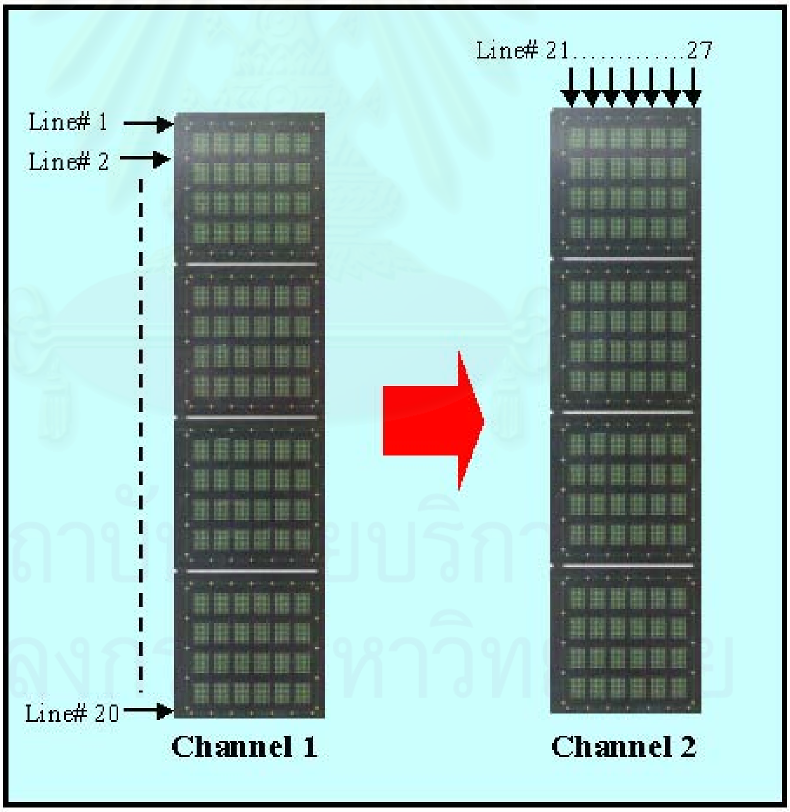
3.2.2 Cutting Sequence Test

The cutting or sawing sequence refers to the sequences used for sawing the FBGA substrate. The cutting sequence can be programmed according to the user on the saw machine. The cutting sequence needs to be evaluated prior to production to determine the cutting quality. The measurement is based on side burrs of the singulated units especially on units near the scrap line. Cutting sequences to be tested are separated into 2 trials as follows:

3.2.2.1 Two Channel Cutting Sequence

The saw sequence that was initially recommended by Intercon for sawing FBGA 6x9 substrate – Refer to Figure 3.8. The saw sequence starts with channel 1 (CH1) and cuts the substrate on the short side from line# 1 to line # 20. The saw chuck then rotates 90 degrees to cut the substrate in channel 2 (CH2). The substrate is cut on the long side from line # 21 to line # 27. The complete saw sequence requires only 2 channel cutting sequence with a total of 27 cut lines.

Figure 3.8 Two Channel Cutting Sequence for FBGA 6x9 Package

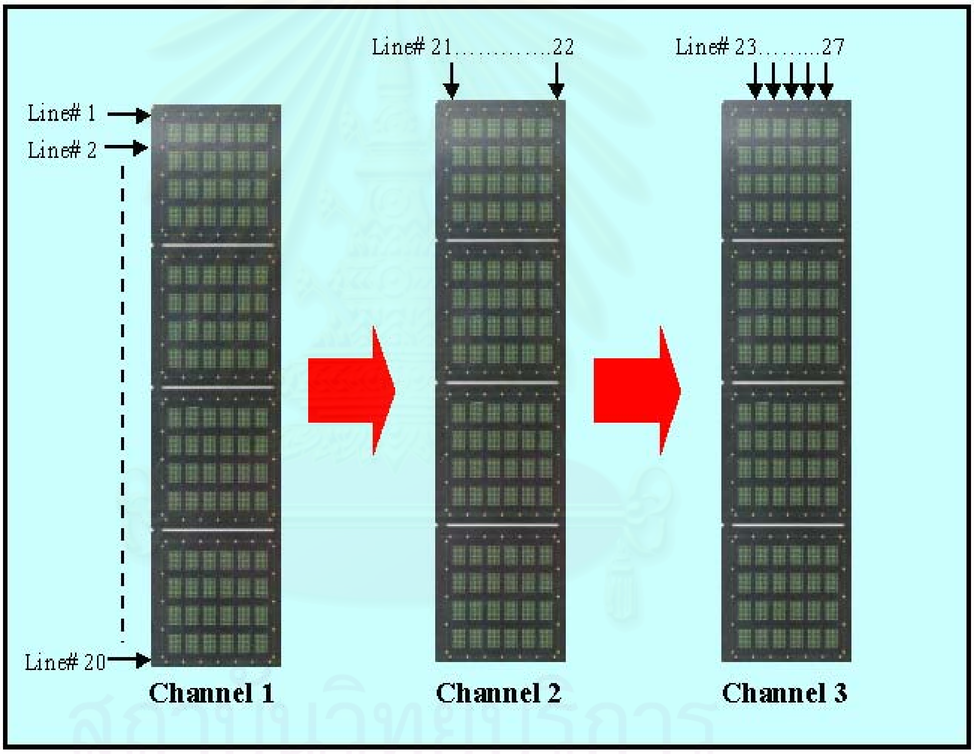


Sequence	Side	# of cuts/sequence
CH1	Short	20
CH2	Long	7

3.2.2.2 Three Channel Cutting Sequence

The 3 channel cutting sequence process – Refer to Figure 3.9, begins on channel 1, cutting from line #1 to line #20. Next, the saw chuck rotates 90 degrees to cut channel 2—i.e., the two long scrap lines (line #21 and line #22). The last sequence is channel 3, where the blade cuts the rest of the units from line #23 to line #27. The additional second channel saw sequence was to cut off and eliminate the two scrap lines first before cutting the remaining units on channel 3. The reason behind this change is that during cutting the two scrap lines, maximum vacuum suction area is required so that movement or twitching of substrate is minimized which may lead to side burrs problem.

Figure 3.9: Cutting Sequence for FBGA 6x9 Package with 3 Channel



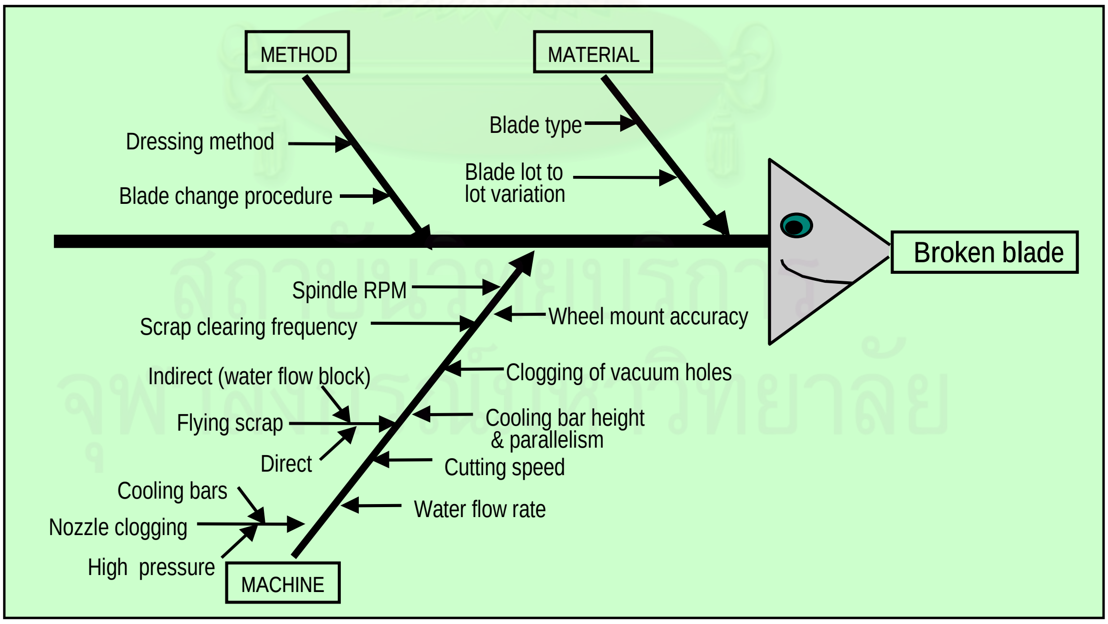
Sequence	Side	# of cuts/sequence
CH1	Short	20
CH2	Long	2
CH3	Long	5

3.3 Cause & Effect Analysis

The methodology of the research involved setting up a quality circle team consisting of members from process engineering, preventive maintenance, production operators and technicians, as well as vendors from Intercon Technology and Disco Corporation. The researcher as well as team leader is from process engineering and he has experience on wafer dicing process for 4 years. Members from preventive maintenance have extensive experience for over 10 years in semiconductor equipment. The service manager from Intercon is also a former Disco employee so he has sound knowledge on both the Disco saw and the Intercon handler. A brainstorming session was conducted among team members to identify possible causes of blade breakage by applying a cause and effect diagram – illustrated in Figure 3.10. The 4M (man, material, method, machine) were considered. The cause and effect diagram was partially derived from Appendix H: Blade Trouble Tree Diagram created by Disco Engineering Department.

The human factor was disregarded, since the singulation machine operates in fully automatic mode. Methods of dressing and blade changing procedures had already been established by Vijchulata (2000) Singulation Operating Procedure, and were not considered major causes of blade breakage. As for the material causes, a selection of different blades had been evaluated prior to production to obtain a suitable blade material with desired dimensions for CSP application. Therefore, machine conditions and cutting application were the main areas to pursue next in solving the blade breakage problem.

Figure 3.10: Cause & Effect Diagram



FMEA (Failure Mode Effects and Analysis) is also applied further to identify potential causes of failure and prioritize corrective actions to resolve the chronic blade breakage problem.

3.4 FMEA (Failure Mode Effect and Analysis)

3.4.1 Definition

FMEA according to Shah (2000) is a systematized group of activities intended to recognize and evaluate the potential failure of a product or process and its effects; to identify actions which could eliminate or reduce the chance of the potential failure from occurring and document the process. It is a living document and never ends. The FMEA used can be categorized into 3 types as follows:

1) Design FMEA (DFMEA) is an analytical technique utilized primarily by a design responsible engineer /team as a means to assure that, to the extent possible, potential failure modes and their associated causes/mechanisms had been considered and addressed.

2) Process FMEA (PFMEA) is an analytical technique utilized by a manufacturing engineer/team as means to assure that, to the extent possible, potential failure modes and their associated causes/mechanisms had been considered and addressed.

3) Containment FMEA is a FMEA that identifies critical failure mechanisms, which due to low detectability and / or high criticality require a containment screen.

3.4.2 FMEA Methodology

Prior to initiating the FMEA process, the responsible engineer will form a team of representatives from all affected functional areas. It should include, but not limited to internal personnel, but also to outside suppliers. The suppliers for AMD singulation system are Intercon Technology and Disco Corporation.

The initiation of the FMEA should be done at stages defined below:

- DFMEA, before or at design concept finalization.
- PFMEA, before or at the feasibility stage prior to tooling for production taking into account all assembly or manufacturing operations.
- Containment FMEA – after potential root cause(s) of a problem had been identified before generating corrective actions and for any improvement projects after the characteristics had been identified.

General FMEA flow used in this research – Refer to Figure 3.11

Refer to Appendix A, B and C for evaluation criteria and ranking for Severity, Occurrence and Detection.

Refer to Appendix D for definitions of terms used in FMEA Form.

Standard FMEA form as shown in Appendix E shall be used.

3.4.3 Applying FMEA

The general FMEA flow begins by addressing the potential problems in new IC packages, new process, corrective actions and continuous improvement projects. FBGA process at AMD Thailand is considered as a new package or new process that is differentiated from mature package – TSOP, SOIC, PDIP, PLCC. All process steps of FBGA starting from die attach, wire bonding, molding, laser marking, ball attach, re-flow and singulation requires proactive study on FMEA. This thesis discusses on FMEA relating to singulation process.

The researcher is a process engineer responsible of FBGA singulation process and he is accountable for forming a cross -functional team. He is expected to direct and actively involve this cross function team to stimulate the exchange of ideas between each function. The leader sets up a cross-functional team from related departments such as process, maintenance, production, and vendors to solve blade breakage problems at the singulation process.

The process FMEA is applied to determine all the possible causes and mechanisms that impact to the singulation process. A number is assigned in the header of FMEA form for tracking and identification purpose. Standard FMEA form – Refer to Appendix E provided by Quality Department shall be used for documentation.

The quality circle or cross-functional team conduct brainstorming sessions to identify all possible causes and scenarios that could potentially lead to blade breakage problems. Current process control and recommended corrective action for each scenario need to be filled in. Responsible person together with expected completion date is delegated to the appropriate member.

The quality circle team also needs to assign ranking for severity, occurrence and detection – Refer to Appendix A, B and C for evaluation criteria and ranking for Severity, Occurrence and Detection. A Risk Priority Number (RPN) is then obtained from the product of severity, occurrence and detection. This value should be used to rank order the concerns in the process (pareto fashion). For higher RPN's the team must undertake efforts to reduce this calculated risk through corrective action(s). However, in general practice, regardless of the resultant RPN, special attention should be given when severity is high.

The team leader implements corrective actions according to priority from the RPN. As mentioned earlier FMEA is a living document and new potential causes and corrective actions are updated on new FMEA revisions as the research goes on. After action is implemented and monitored then an evaluation for the effectiveness of implemented is required. The RPN on the action results column will then determine whether that further alternative action or improvement is required. Once the team has a consensus that the

FMEA does not require any changes then the FMEA file will be kept in a folder for documentation and history tracking purposes.

Kinetic [30] has described FMEA as a systematic group of activities intended to:

- Recognize and evaluate the potential failure of a product or process and its effects.
- Identify actions, which could eliminate or reduce the chance of the potential failure occurring.
- Document the process

Refer to Figure 3.12– Final process FMEA with a specific objective to reduce blade breakage problem in FBGA saw singulation process.

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Figure 3.11: FMEA Process Flow (Shah, 2000)

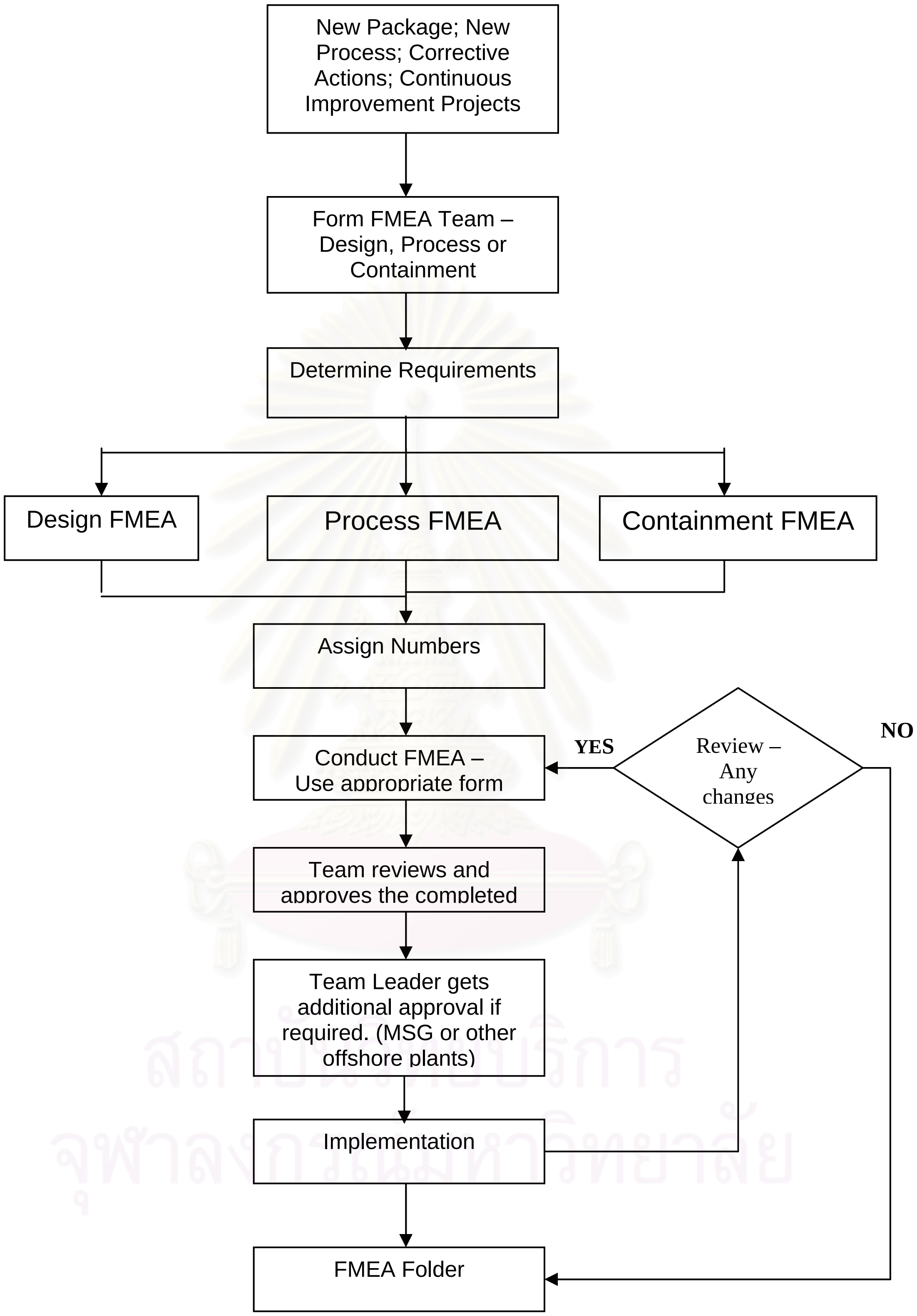

Figure 3.12: Final PFMEA at FBGA Singulation Process

AMD

Item	: FBGA package	FAILURE MODE AND EFFECT ANALYSIS	FMEA No. : BA00032E
Process Responsibility	: Assembly	☐ Design FMEA	FMEA Original Date : 07/03/00
Prepared By	: Prakorn V. (PE-Assembly)	■ Process FMEA	FMEA Revised Date : 02/25/01
Key Date	: Jul 3'00	☐ Containment FMEA	Page: 1 of 1
Spec Ref. 08-073 / Core team :	: Watana(New Package), Chuawalit (PM), Khanchit (PM)		

Process Functional Requirement	Potential Failure Mode	Potential Effects of Failure	SEV	CLASS	Potential Cause(s) of Failure	OCC	Current Process Control	DET	RPN	Recommended Corrective Action (s)	Person Responsible and Target Completion Date	Action Results: Action Taken	SEV	OCC	DET	RPN
Saw Singulation	Package chip, crack, wrong dimension	Package dimension failure, visual defect, test failure, reliability, SMT board failure	7	•	Improper blade selection	3	Visual mechanical inspection at low magnification scope	5	105	Blade evaluation at supplier and at AMD	Disco & Process, ww 25'00					
			7	•	Accumulated scrap in cutting chamber	7	Wet/dry vacuum cleaner every 2 magazines	7	343	Increase scrap clearing frequency to every magazine	Production, ww 31'00					
										Software modification to have self-alarm capability when number of strips reaches preset limit	Intercon, ww 48'00					
			7	•	Vacuum rubber pads & clogging of vacuum holes	3	Periodic maintenance schedule	6	126	Replace new rubber pads & clean any vacuum holes that are clogged	Production, ww 33'00					
			7	•	Clogging of high pressure nozzle	6	Periodic maintenance schedule	2	84	To install a new high pressure water nozzle which sprayed water in curtain form and improved scrap	Maintenance,ww 34'00					
			7	•	Improper setup conditions for cooling side bars	2	None	9	126	Check clogging of outlet slits, parallelism of 2 side bars and distance from blade tip should be	Maintenance,ww 36'00					
			7	•	Scrap hitting water flow control block	8	None	8	448	Removal of water flow control block	Production, ww 37'00					
			7	•	High cutting speed	3	AMD specification	3	63	Reduce cutting speed from 100 mm/sec to 50 mm/sec	Process, ww38'00					

Page 1

Figure 3.12: Final PFMEA at FBGA Singulation Process (Con't)

AMD

Item : FBGA package
Process Responsibility : Assembly
Prepared By : Prakorn V. (PE-Assembly)
Key Date : Jul 3'00
Spec Ref. 08-073
Core team : Watana(New Package), Chuawalit (PM), Khanchit (PM)

FAILURE MODE AND EFFECT ANALYSIS
☐ Design FMEA
■ Process FMEA
☐ Containment FMEA

FMEA No. : BA00032E
FMEA Original Date : 07/03/00
FMEA Revised Date : 02/25/01
Page: 1 of 1

Process Functional Requirement	Potential Failure Mode	Potential Effects of Failure	SEV	CLASS	Potential Cause(s) of Failure	OCC	Current Process Control	DET	RPN	Recommended Corrective Action (s)	Person Responsible and Target Completion Date	Action Results: Action Taken	SEV	OCC	DET	RPN
Saw Singulation	Package chip, crack, wrong dimension	Package dimension failure, visual defect, test failure, reliability, SMT board failure	7	•	Improper water flow-rate setup	5	AMD specification	3	105	Vary water flow-rate within specified specification	Process, ww 39'00					
			7	•	Improper spindle RPM	3	AMD specification	3	63	Reduce spindle speed from 40K RPM to 30K RPM	Process, ww 41'00					
			7	•	Wheel mount not perpendicular with saw chuck	1	Vendor setup with tolerance accuracy of 1 micron	9	63	A dial guage with a fixture to confirm the wheel perpendicularity with the saw chuck	Disco,ww 42'00					
			7	•	Ineffective scrap purging nozzle design	8	None	9	504	Change high pressure nozzle design to purge scraps from both front and rear of saw blade	Team,ww 39'00					
			7	•	Small flying scraps hit the blade during cutting	8	None	9	504	Modification of saw sequence from 3 channel to 4 channel	Process, ww43'00					
										Combination for 4 channel saw sequence & new high pressure nozzle design to reduce dented ball	Team,ww 46'00					
			7	•	Human handling	2	AMD specification	6	84	None						
			7	•	Blade changing method	2	AMD specification	6	84	None						
			7	•	Dressing method	5	AMD specification	4	140	None						

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3.5 Recommended Corrective Actions

During July 2000, the following recommended corrective actions derived from the FMEA were sequentially implemented:

3.5.1 Scrap Clearing Frequency

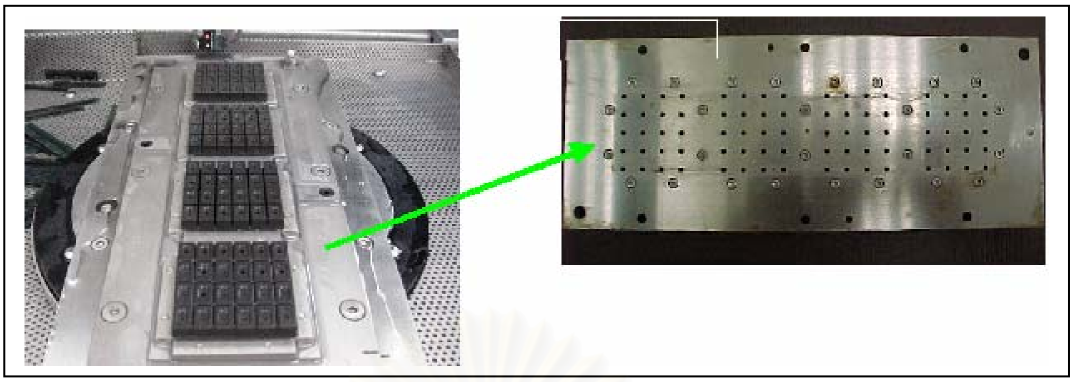
It was speculated that scraps from the cutting process accumulate inside the basket of the cutting chamber, could possibly swirl around in the chamber and hit the saw blade—Refer to Figure 3.13: Scrap Accumulated in Saw Chamber. The scrap inside the cutting chamber is normally cleared out by a vacuum cleaner every 2 magazines of FBGA strips. The change implemented involved increasing the frequency of scrap clearing to every single magazine, to prevent scraps from accumulating, and damaging the saw blade.

Figure 3.13: Scrap Accumulated in Saw Chamber & Vacuum Cleaner

3.5.2 Vacuum Rubber Pads & Clogging of Vacuum Holes

The vacuum rubber pads that support the molded substrate during cutting were replaced with new ones. The mount base jig, located beneath the rubber pads, and consisting of arrays of vacuum holes that are used for dispersing the vacuum generated by the saw chuck through vacuum holes towards the rubber pads above, was cleaned—Refer to Figure 3.14. Clogging of the vacuum holes on the mount base jig can result in low vacuum suction, and poor grip on the FBGA substrates during cutting, causing the substrate to move or twitch. Movement of substrates during cutting increases the load on the dicing blade and consequently may cause it to break.

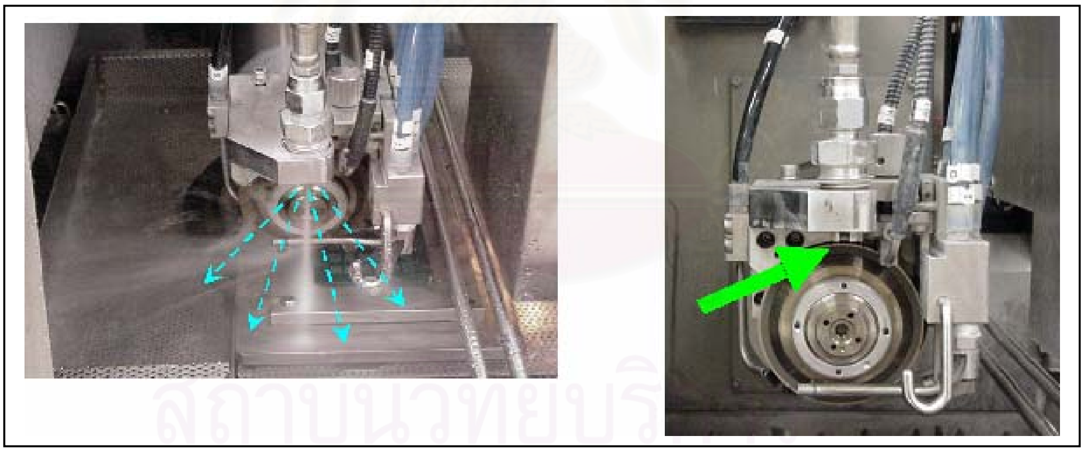
Figure 3.14: Clogging of Vacuum Holes on Mount Base Jig



3.5.3 High-Pressure Nozzle

A high-pressure nozzle is used for purging scrap from the cutting chamber—Refer to Figure 3.15: High-Pressure Water Spray in Curtain Form. The team observed that the original design of the high-pressure water system was not dispensing water in curtain form, and could cause ineffective scrap clearing inside the cutting chamber. A new high-pressure water nozzle was installed, which sprayed water in curtain form, and improved scrap purging.

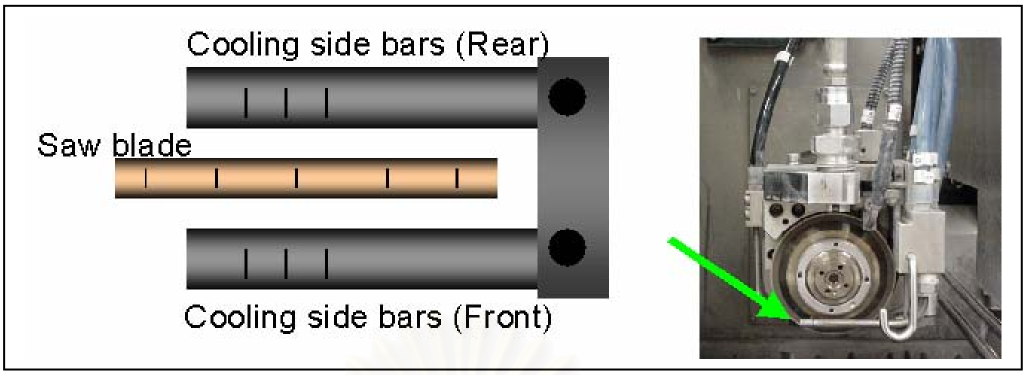
Figure 3.15: High-Pressure Water Spray in Curtain Form



3.5.4 Cooling Side Bars Conditions

The cooling side bars, used for cooling the saw blade during cutting, are basically two cylindrical rods located at the front and the rear of the blade—Refer to Figure 3.16: Cooling Side Bars. For these parts to function as desired, there should be no clogging of the outlet slits, the 2 bars must be perfectly parallel, and the distance from the blade tip should be 4mm. If these conditions are not met, they may cause vibration and imbalance of the load on to the blade, eventually causing it to break. These conditions were carefully investigated, and the appropriate corrective actions were taken.

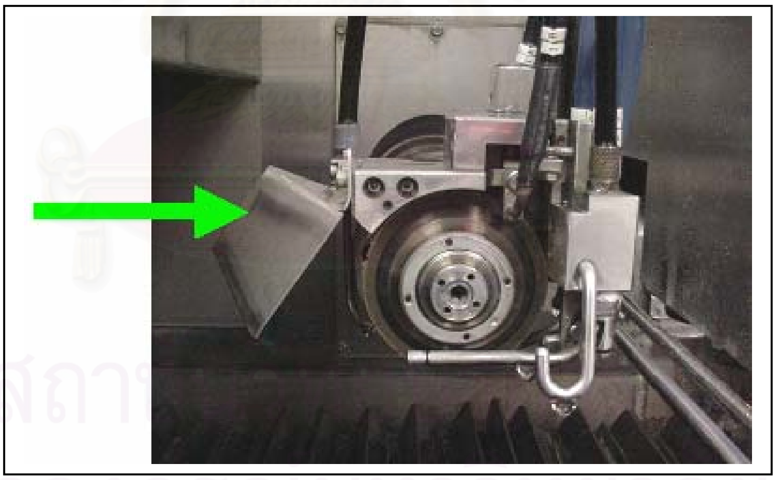
Figure 3.16: Cooling Side Bars



3.5.5 Water Flow Control Block Removal

The water flow block is used for controlling the water flow that cools the blade during cutting—Refer to Figure 3.17: Water Flow Control Block. Water flows through the block from the front on the right, and exits at the rear on the left, in an orderly manner, so that water is properly drained, and does not splash all over the cutting chamber. The corrective action involved removing the original metal water flow block, to eliminate the possibility of any scrap pieces hitting the block, and bouncing back to hit and damage the blade.

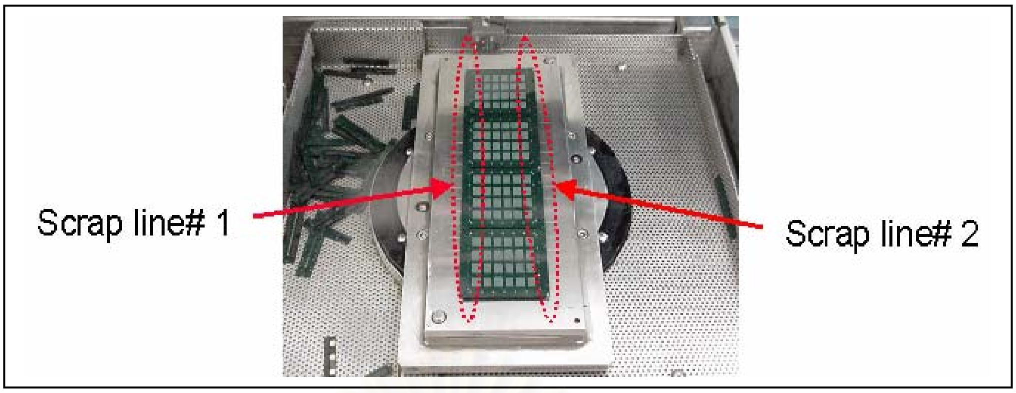
Figure 3.17: Water Flow Control Block



3.5.6 Cutting Speed Reduction

The observation from the blade breakage problem shows that it occurs repeatedly on the scrap saw line position —Refer to Figure 3.18: Scrap lines. The scrap line location is the most critical portion because there is no vacuum holding unlike the rest of the work-piece where there is vacuum to hold down the units. In order to prevent blade breakage at these critical locations, cutting speed was reduced by half—from 100 mm./sec to 50 mm./sec—for cutting on the two scrap lines. The method of changing cutting speed can be referred from Disco Operation Manual (1999).

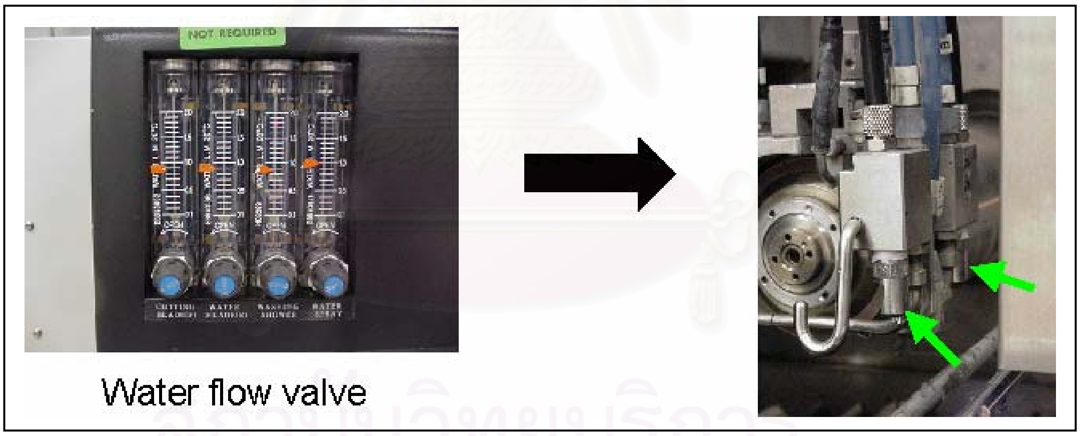
Figure 3.18: Scrap Lines



3.5.7 Flow Rate of Cooling Water

A set of water flow-rate meters and valves controls the cooling of saw blade and water spray that purges out the scrap—Refer to Figure 3.19: Water Flow Rate Control. The experiment involved increasing and decreasing the water flow rate between 1.0 to 2.0 liter/minute, which is within the range specified in 805-758.11 specification according to Anuar (2000). The corrective action is to study the impact of water flow rate on blade breakage.

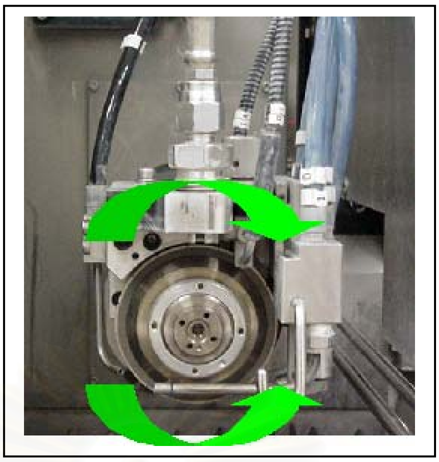
Figure 3.19: Water Flow Rate Control



3.5.8 Varying Spindle Speed

It was suspected that the current spindle speed of 40,000 RPM might not be suitable for our CSP application. It was decided to implement a slower speed of 30,000 RPM, to minimize the affect of blade vibration that could lead to blade breakage problem – Refer to Figure 3.20: Spindle RPM

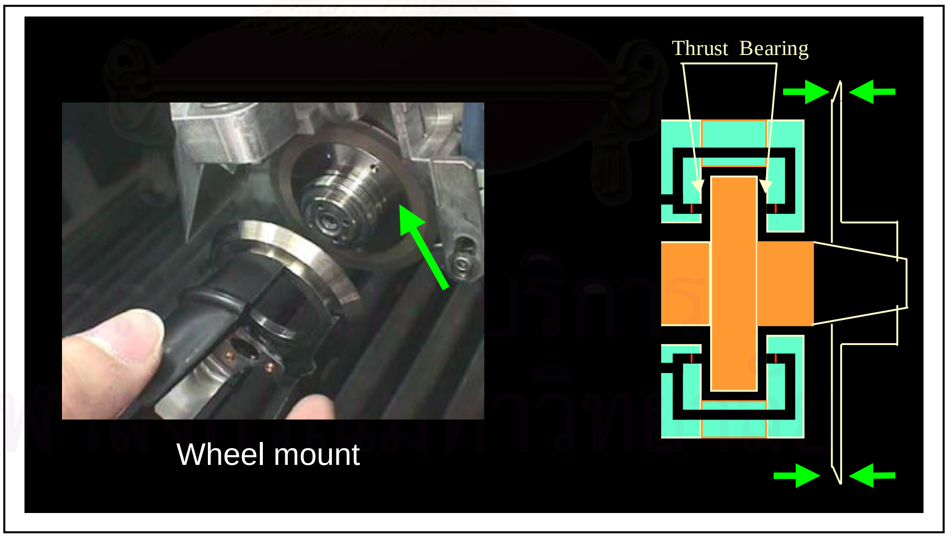
Figure 3.20: Spindle RPM



3.5.9 Wheel Mount Perpendicularity with Saw Chuck

Since the surface of the blade adheres to the wheel mount, the wheel mount needs to be perfectly perpendicular with the saw chuck—Refer to Figure 3.21: Perpendicularity of Wheel Mount. If it is not, cutting could be slanted and there would be high loading on the blade, as well as on the spindle itself. A dial gauge is used to confirm the setup accuracy of the wheel mount. The accuracy should be within 1 micron as per the specification from Disco Maintenance Manual (1999).

Figure 3.21: Perpendicularity of Wheel Mount



3.5.10 New High-Pressure Nozzle Design

A high-pressure nozzle is an additional feature on dicing machines used specifically for CSP applications. The original, single high-pressure nozzle was located at the top of the cooling block and releases high-pressure water in a vertical direction to clear scraps towards the scrap basket. However, the location of the nozzle at the top of the block is a poor design, since it results in ineffective clearing of scrap on the 2 critical saw scrap lines. Therefore, a new high-pressure nozzle design was proposed and implemented. The new design utilized the existing water spray nozzles located at the front and rear of the saw blade.

A set of new high-pressure tubings was connected to both the front and rear water spray nozzles. The diameter of the outlet of the nozzles was also reduced, to maximize the flow for effectively purging scrap—Refer to Figure 3.22: Comparison Old and New High Pressure Water Systems.

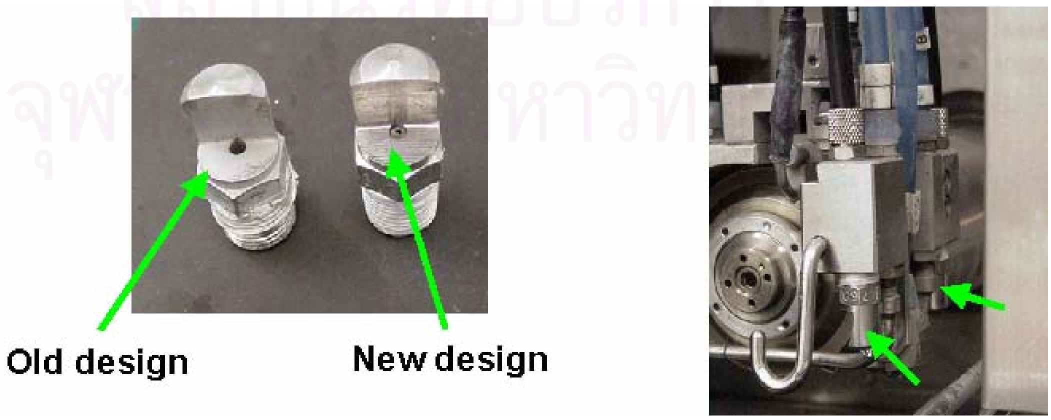
Figure 3.22: Comparison Old and New High Pressure Water Systems

<u>High Pressure Tubing</u>

Previous design (Single high pressure nozzle)

New design (Dual high pressure nozzle)

<u>High-Pressure Nozzles</u>



3.5.11 New Cutting Sequence

3.5.11.1 Modification of Cutting Sequence

Since the investigation into the root causes of blade breakage issues has led to suspect that flying scrap could be a main factor contributing to blade breakage, the current sawing sequence of molded substrates was further looked into—Refer to Figure 3.23: Existing 3 Channel Cutting Sequence. The original cutting sequence programmed in the dicing saw was a 3 channel cutting sequence. The process begins on channel 1, cutting from line #1 to line #20. Next, the saw chuck rotates 90 degrees to cut on channel 2—i.e., the two long scrap lines (line #21 and line #22). The last sequence is channel 3, where the blade cuts the rest of the units from line #23 to line #27. Blade breakage always occurred on the 2nd channel, where the two long scrap lines are being cut.

The theory of the root cause of blade breakage on the 2nd channel is that small scrap generated from the 2nd channel flies turbulently around the cutting area, hitting and damaging the rotating blade—Refer to Figure 3.25: Comparison 3 versus 4 Channel Cutting Sequence.

A new cutting sequence was therefore proposed, which required reprogramming of the dicing machine with a 4 channel cutting sequence—Refer to Figure 3.24: New 4 Channel Cutting Sequence. The 4 channel cutting sequence cuts all the scraps out first on channel 1 and channel 2 respectively. The rest of the units are then finally cut on channel 3 and channel 4.The major impact from this change is on the 2nd channel, where the size of generated scrap is larger than the one from the existing 3 channel cutting sequence.

Figure 3.23: Existing 3 Channel Cutting Sequence

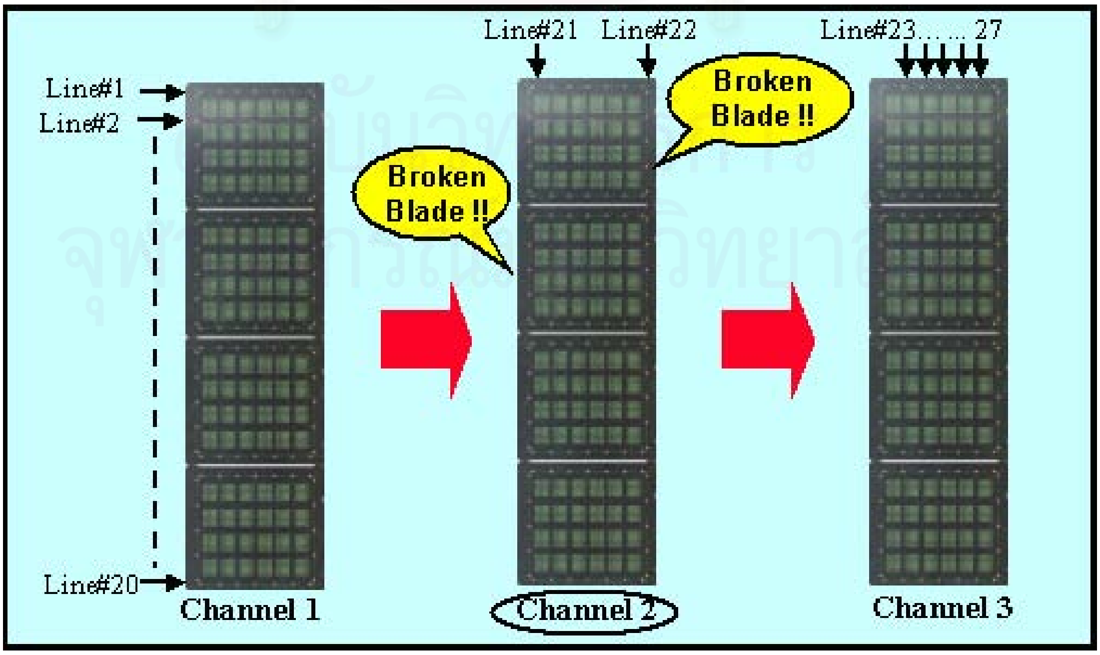


Figure 3.24: New 4 Channel Cutting Sequence

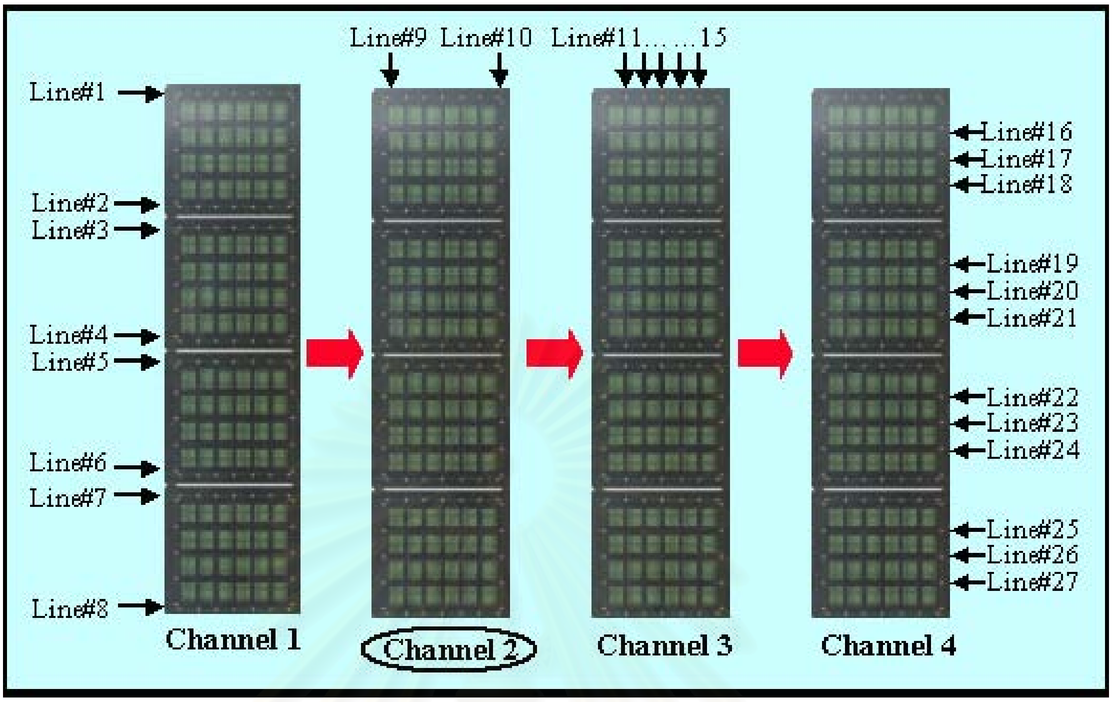
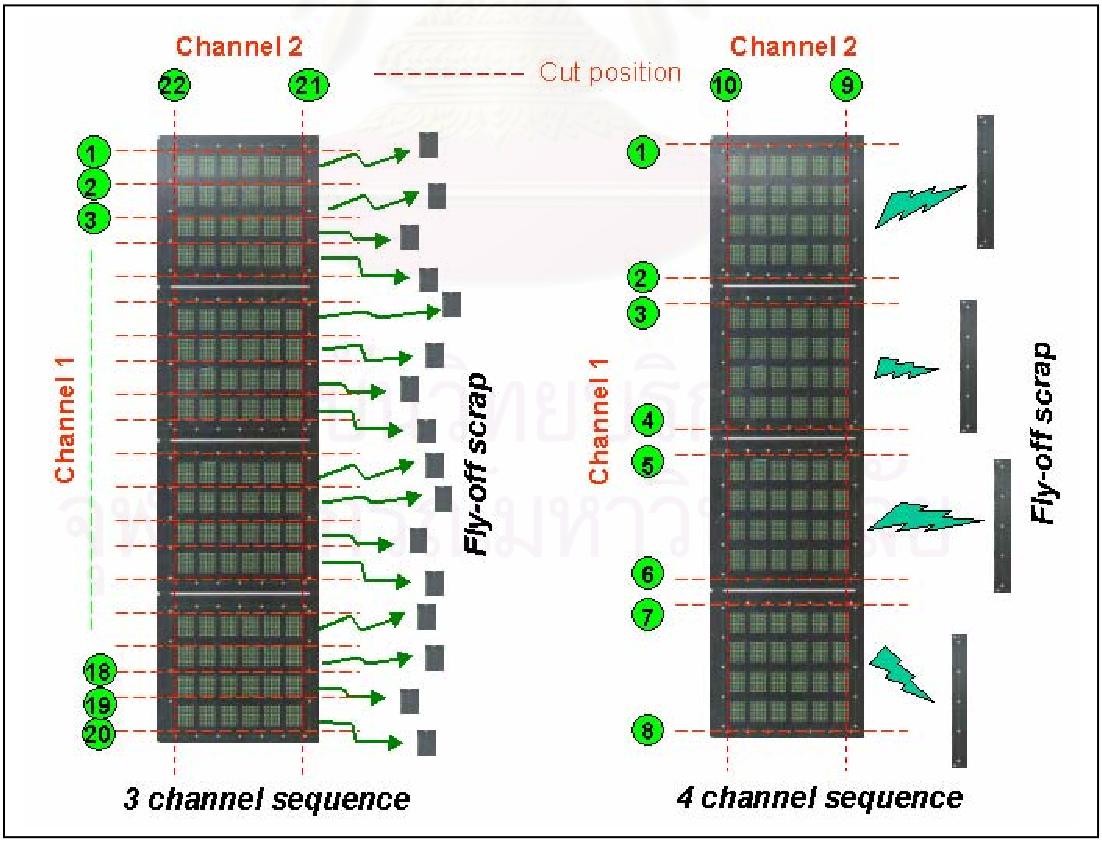


Figure 3.25: Comparison 3 versus 4 Channel Cutting Sequence



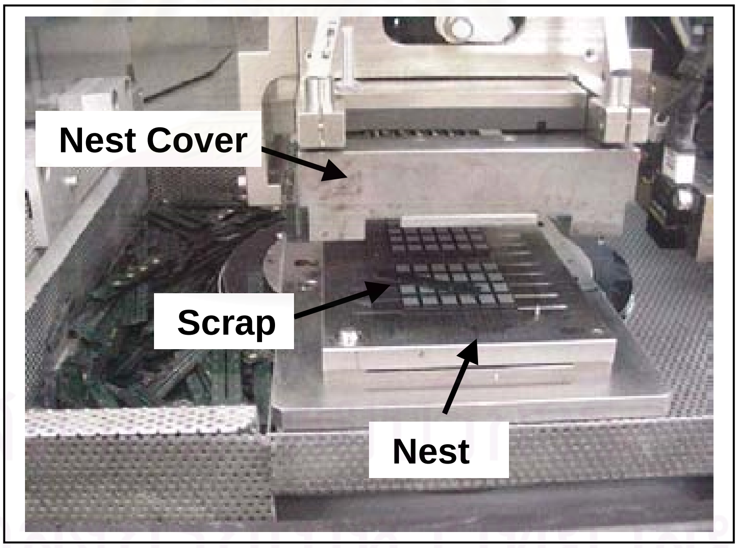
3.5.11.2 Design of Experiment

A design of experiment was conducted to collect information for a statistical analysis of the impact on 4 channel cutting sequence and dual high-pressure water nozzle design. The analysis involved application of a full factorial design, using JMP software, to investigate the impact of critical factors and their responses as shown in Figure 3.26: Design of Experiment Setup. The desirable responses were to have maximum blade life (no blade breakage), and the least amount of scrap remaining on the nest—remaining scrap causes dented balls during nest cover travels down to clamp on the units – Refer to Figure 3.27

Figure 3.26: Design of Experiment Setup

Factors:	**Levels**
1. High-pressure nozzle design:	—Single nozzle (existing design) —Dual nozzle (new design)
2. Cutting sequence:	—3 channel (existing saw sequence) —4 channel (new saw sequence)
Responses:	—Blade life (cut lines) —Remaining scrap on nest

Figure 3.27: Scrap Remaining on Nest Causes Dented Balls

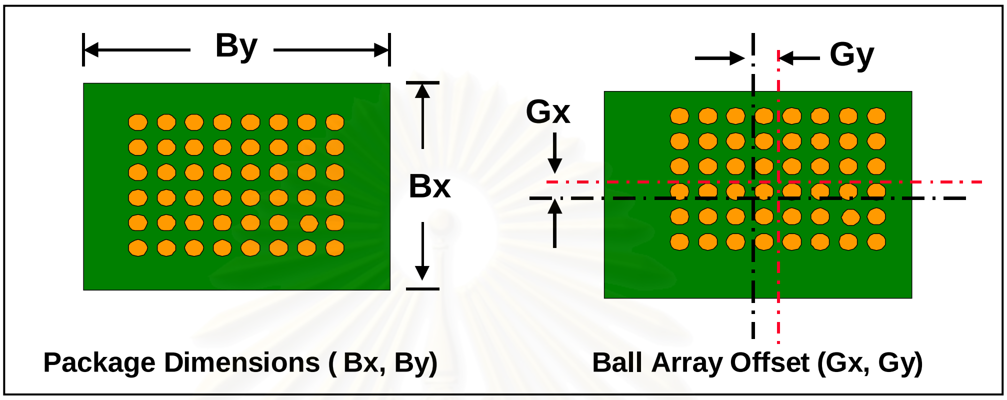


3.5.11.3 Cutting Quality Confirmation

The impact of the new cutting sequence and new dual nozzle design on cutting quality was next studied. The critical measurement parameters at FBGA singulation process are package dimension (Bx, By), and ball array offset (Gx, Gy)—Refer to Figure 3.28: Quality Control Parameters. Package dimension is the body length and width of the package. Ball array offset is the package offset as compared with the ball array matrix. Both package dimension and ball array offset are measured by ICOS, a fully automatic ball inspection machine.

The cutting quality has to be confirmed from the modification of cutting sequence. The critical measurement data obtained from ICOS are compared between 3 and 4 channel cutting sequence by using Analysis of Variance (ANOVA) statistical technique together with process capability index (Cpk). The burrs on the side view of singulated units have to be inspected as well.

Figure 3.28: Quality Control Parameters



CHAPTER 4

RESULTS

4.1 Dicing Blade Selection at Supplier

The results of the initial dicing blade evaluation carried out at the supplier site are measured in terms of cutting quality, spindle current and blade wear rate.

4.1.1 Cutting Results

The cutting results from the 3 types of blades are presented in Table 4.1. The cutting results are measured in terms of top side chipping, backside chipping, package size both X and Y direction, and kerf width both X and Y direction.

Table 4.1: Cutting Results

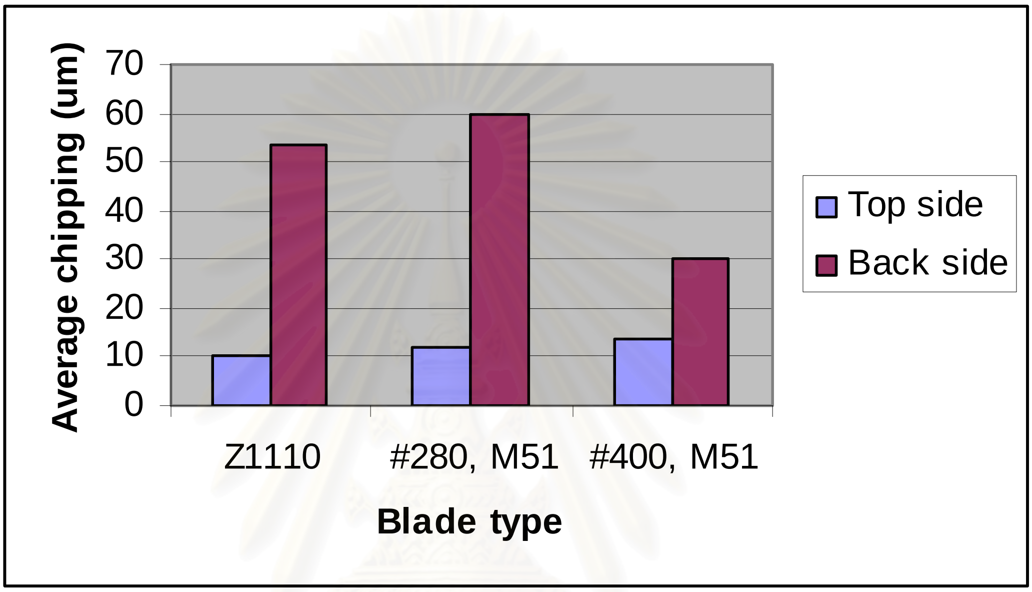
Blade type	Package no.	Top chipping (um)	Back chipping (um)	Package size (X,mm)	Packag e size (Y,mm)	Kerfwidth (X,um)	Kerfwidth (Y,um)
Z1110	1	11	70	8.959	7.958	339	340
	2	11	70	8.958	7.958	340	340
	3	8	29	8.958	7.960	340	338
	4	10	35	8.960	7.960	338	338
	5	9	85	8.960	7.960	338	338
	6	13	33	8.959	7.590	339	339
	Average	**10.3**	**53.7**	**8.959**	**7.959**	**339**	**338.8**
#280,M 51	1	9	66	8.955	7.957	343	341
	2	11	64	8.955	7.956	343	342
	3	12	52	8.955	7.956	343	342
	4	11	72	8.955	7.955	343	343
	5	13	80	8.956	7.955	342	343
	6	16	23	8.956	7.955	342	343
	Average	**12.0**	**59.5**	**8.955**	**7.956**	**342.7**	**342.3**
#400,M 51	1	14	26	8.956	7.956	342	342
	2	16	16	8.956	7.956	342	342
	3	11	46	8.956	7.956	342	342
	4	10	55	8.956	7.956	342	342
	5	17	26	8.958	7.958	340	340
	6	13	12	8.957	7.957	341	341
	Average	**13.5**	**30.2**	**8.957**	**7.957**	**341.5**	**341.5**

The average top and backside chipping from the evaluation can be illustrated in Figure 4.1. The results show that both blade Z111O and #280, M51 exceeded the back side chipping target value of 50 microns, while blade #400, M51 manage to keep both top and back side chipping within the expected target.

The nominal package dimension for FBGA 8x9 package according to Hua (1999) 16-039.8 specification is 8.95 mm x 7.95 mm with a tolerance of +/- 0.05 mm. The cutting results from all the 3 blades are well within specification.

The results of the kerfwidth in both x and y direction are nearly the same as the blade thickness of 340 microns. Therefore, this indicates that kerfwidth is equivalent to the blade thickness when cutting on CSP substrates.

Figure 4.1: Top and Back Side Chipping



4.1.2 Spindle Current Results

The different types of blades contribute to different amount of loading to the spindle, and results of the spindle current for the 3 types of blade are shown in Table 4.2.

The results of the spindle current among the 3 blades show that Z11O blade has higher value of blade loading during cutting when compared with the other 2 blades. The higher loading on the blade will also induce more top or backside chipping on the substrate.

Table 4.2: Spindle Current Values During Processing (Amps)

Substrate no.	Z111O	#280, M51	#400, M51
1	4.05	3.91	3.72
	4.05	3.71	3.70
	4.04	3.78	3.68
	4.04	3.65	3.70
	4.01	3.59	3.71
	4.00	3.45	3.70
2	4.02	3.50	3.68
	4.00	3.49	3.68

	3.99 4.01 4.00 4.02	3.45 3.45 3.48 3.42	3.69 3.69 3.69 3.69
3	4.06 4.05 4.05 4.07 4.08 4.09	3.43 3.45 3.44 3.42 3.45 3.41	3.67 3.68 3.68 3.69 3.68 3.68
Average	**4.04**	**3.53**	**3.69**

4.1.3 Blade Wear Results

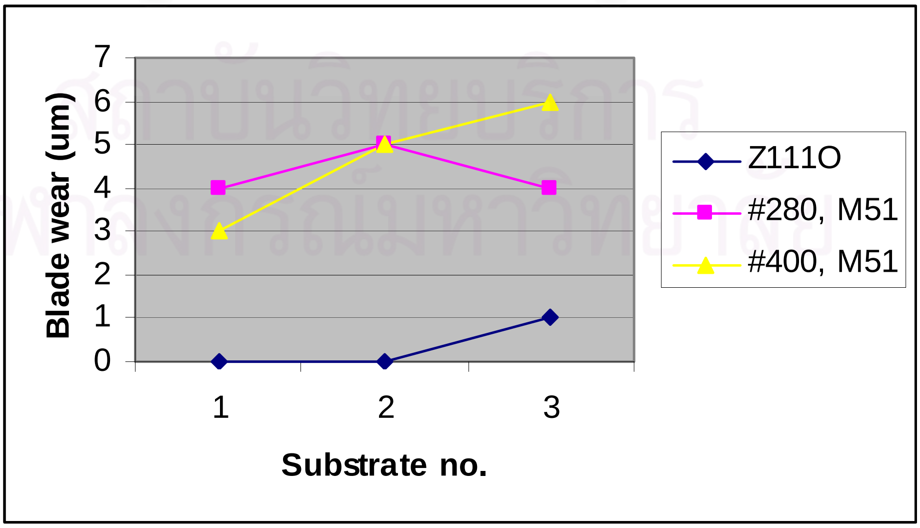
The blade life is measured in terms of wear rate. The result of blade wear is shown in Table 4.3 and graphical presentation of blade wear rate is illustrated in Figure 4.2.

Table 4.3: Blade Wear Data (Microns)

Substrate no.	Z111O	#280, M51	#400, M51
1	0	4	3
2	0	5	5
3	1	4	6

The blade wear rate for both #280, M51 and #400, M51 is significantly higher than of Z1110. This indicates that blade life will be more for Z1110 when compared with the other 2 blades, but cutting quality can be sacrificed as shown from the top and backside chipping results.

Figure 4.2: Blade Wear Rate



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4.1.4 Blade Selection Summary

The recommendation from Disco is that blade #400, M51 is the most appropriate blade for AMD CSP application. This blade has achieved the expected target for both top and backside chipping size, acceptable spindle loading, and sufficient blade wear for self-sharpening of the diamonds. The nickel bond blade (Z111O) and metal bond blade with large diamond grit size (#280, M51) gives poorer cut quality when compared to the metal bond with fine diamond grit (#400, M51).

The test result from kerf width implies that the kerf width is almost equivalent to the blade thickness. This means that the target of getting a kerf width of 350 micron by using a blade thickness of 340 microns was not achievable. Therefore it is recommended to use a blade thickness of 350 micron in order to meet the package dimension nominal target.

The evaluation performed was by sawing on a substrate attached to tape. The actual singulation system that AMD uses is the nest jig type. The nest jig carries the substrate and uses vacuum rubber pads to hold down the units during cutting. Therefore the evaluation must be repeated by using this recommended blade on the nest jig singulation system at AMD site.

4.2 Dicing Blade Evaluation at IC Manufacturer

4.2.1 Cutting Results

The evaluation is conducted on the Intercon system with the nest jig concept. The evaluated FBGA package is a package with outer dimension of 8 mm x 9 mm. The tolerance range specified by Hua (1999): 7.900-8.000mm and 8.900–9.000mm

4.2.1.1 Kerf Width Results

The kerf width can be calculated by subtracting package dimension from the saw index size – Refer to Figure 4.3. The control parameters at the dicing saw are listed and blade used is the metal bond blade (#400,M51) with 340 microns blade thickness that was recommended by Disco previously.

The result shows that the blade thickness is identical to the kerf width created. For this application, the data obtained seems to correlate this assumption – Refer to Figure 4.4. It can therefore be assumed that the blade thickness directly effects the package dimensions.

Figure 4.3: Kerf Width Definition

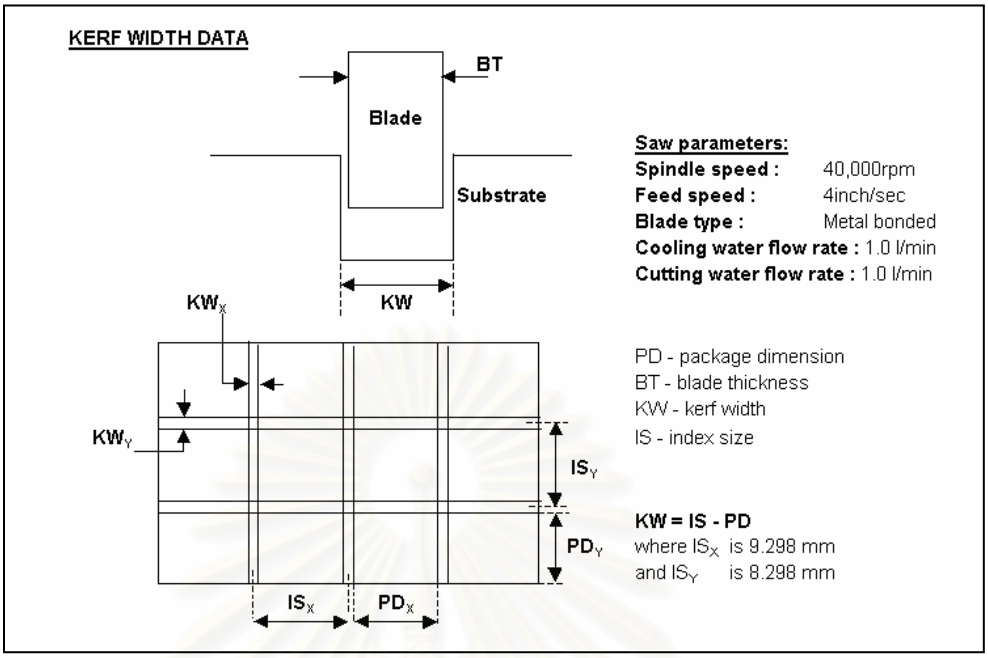

Figure 4.4: Kerf Width Measurement Data

All dimensions in mm

	BT	KW_X	DELTA	KW_Y	DELTA
	0.340	0.341	-0.001	0.340	0.000
	0.340	0.340	0.000	0.341	-0.001
	0.340	0.340	0.000	0.342	-0.002
	0.340	0.341	-0.001	0.341	-0.001
	0.340	0.340	0.000	0.341	-0.001
	0.340	0.342	-0.002	0.342	-0.002
	0.340	0.341	-0.001	0.342	-0.002
	0.340	0.342	-0.002	0.342	-0.002
	0.340	0.341	-0.001	0.341	-0.001
	0.340	0.340	0.000	0.340	0.000
	0.340	0.342	-0.002	0.341	-0.001
	0.340	0.342	-0.002	0.342	-0.002
	0.340	0.341	-0.001	0.341	-0.001
	0.340	0.341	-0.001	0.340	0.000
	0.340	0.341	-0.001	0.342	-0.002
	0.340	0.341	-0.001	0.343	-0.003
	0.340	0.341	-0.001	0.342	-0.002
	0.340	0.342	-0.002	0.341	-0.001
	0.340	0.341	-0.001	0.341	-0.001
	0.340	0.342	-0.002	0.340	0.000
	0.340	0.341	-0.001	0.341	-0.001
	0.340	0.341	-0.001	0.340	0.000
	0.340	0.340	0.000	0.342	-0.002
	0.340	0.342	-0.002	0.341	-0.001
	0.340	0.340	0.000	0.342	-0.002
Average	**0.340**	**0.341**	**-0.001**	**0.341**	**-0.001**

Based on this evaluation, it can be proposed that the 0.340 mm blade may be replaced by the 0.350 mm blade in order to allow a larger process window and hence meet the target nominal value for package dimensions.

4.2.1.2 Package Dimension

The evaluated FBGA package is a package with nominal dimension of 7.95 mm x 8.95 mm. The tolerance range specified by Hua (1999) is 7.900-8.000mm and 8.900–9.000mm. The results of the measured package dimension in X direction (Bx) and package dimension in Y direction (By) are shown in Figure 4.5. The results are within the specification tolerances.

Figure 4.5: Package Dimension Results

Package No	B_X(um)	B_Y(um)
1	8959	7959
2	8960	7962
3	8962	7965
4	8965	7968
5	8969	7970
6	8971	7969
7	8975	7977
8	8978	7981
9	8982	7985
10	8980	7992
11	8958	7995
12	8966	7963
13	8952	7956
14	8958	7958
15	8963	7961
16	8973	7962
17	8971	7968
18	8973	7977
19	8977	7973
20	8983	7975
21	8991	7983
22	8995	7991
23	8990	7982
24	8984	7995
25	8987	7992
Average	8973	7974

4.2.1.2 Package Chip

Both front-side and backside chipping occurs but the backside chipping is bigger since the sawing process is done ‘dead-bug’ or ball side up. The criteria for maximum allowable chip equals 20 mils in both X and Y direction and less than 9 mils in Z direction. The chip criteria for AMD is based on specification 16-049 by Nguyen (1999) – Refer to Figure 4.6. Based on this requirement, the recommended blade type was the Metal Bonded, which produced very little chip.

The serrated metal bonded blade has a diamond grit size of 30-40 microns and is soft bond. The blade thickness is 340 microns. The package chip result measured in X, Y and Z direction is shown in Figure 4.7

Figure 4.6: Package Chip Definition

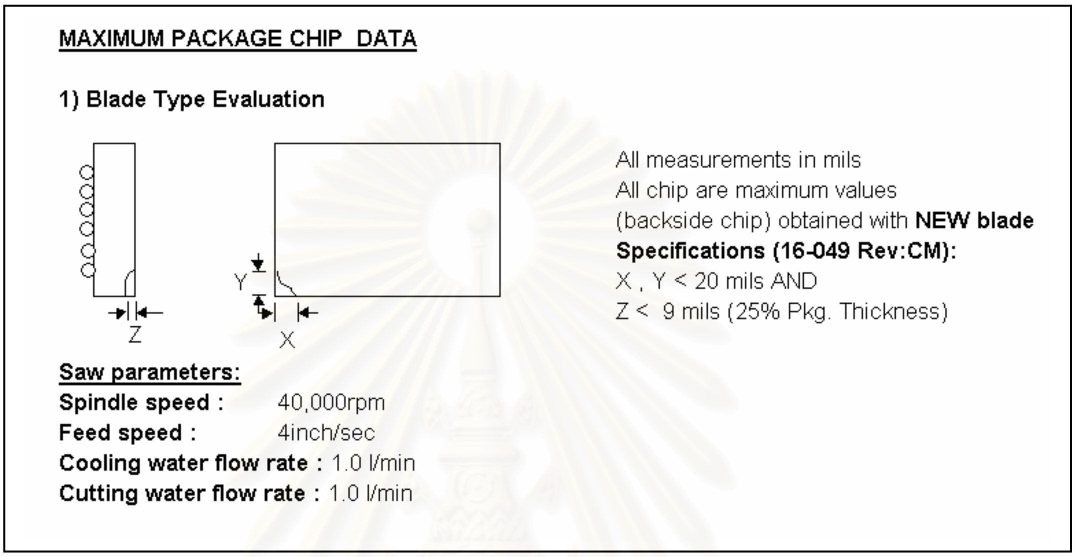

Figure 4.7: Package Chip Measurement Data (mils)

	Metal Bonded		
Units	X	Y	Z
1	1.28	0.45	0.4
2	1.33	0.26	0.31
3	0.95	0.33	0.44
4	1.56	0.35	0.37
5	1.48	0.4	0.39
6	1.87	0.22	0.45
7	0.8	0.38	0.23
8	1.2	0.45	0.32
9	2.01	0.34	0.46
10	1.4	0.2	0.29
11	0.78	0.11	0.31
12	1.44	0.32	0.29
13	1.9	0.21	0.27
14	1.9	0.18	0.38
15	1.16	0.44	0.37
16	1.73	0.25	0.39
17	1.34	0.19	0.27
18	1.94	0.35	0.3
19	1.38	0.22	0.22
20	1.58	0.3	0.24
21	2.3	0.19	0.48
22	0.88	0.39	0.21
23	1.29	0.28	0.28
24	1.77	0.29	0.31
25	1.83	0.19	0.27
Maximum	**2.3**	**0.45**	**0.48**
Average	**1.48**	**0.29**	**0.33**
Std. Dev.	**0.401**	**0.095**	**0.078**

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The evaluation showed that the metal bonded blade produced chip that were within the limits specified in the 16-049 specification. The limit is that X and Y must be less than 20 mils and Z must be less than 9 mils, which is 25% of package thickness.

4.2.2 Blade Life

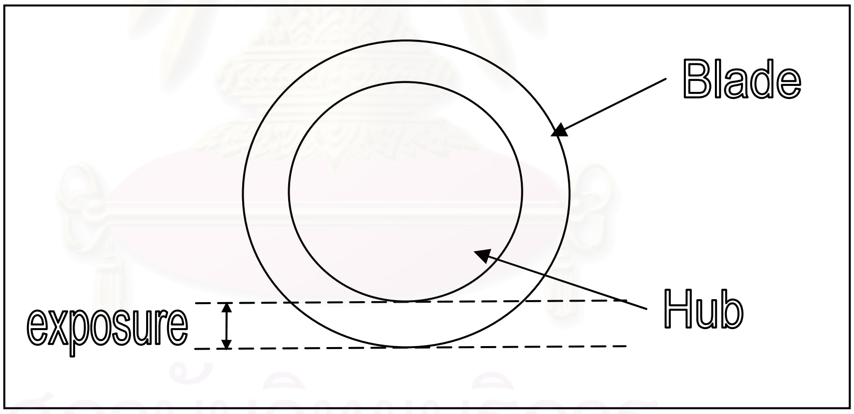
Blade life is measured in terms of blade wear. How much a blade can wear depends on the exposure of the blade. Refer to Figure 4.8 for definition of blade exposure. The blade exposure reduces as the blade wears. The blade wear normally correlates with the amount of cut lines that the blade had been used. The more cut lines naturally the more wear.

The maximum allowable wear is defined by the following factors:

1) Usable blade height: limited by serration height rather than blade exposure. The serration height for the evaluated blade is 1 mm – Refer to Figure 4.9

2) Cutting quality: limited by package chip, package side burrs and oversize package dimensions

Figure 4.8: Blade Exposure



The evaluation in Figure 4.10 shows that the blade exposure is not the limiting factor for wear in this application. Package dimension limits are reached well before the exposure is reduced beyond the usable height of 1 mm. The amount of cut lines at 2600 is already producing oversize package dimensions whereas the blade wear is only approximately at 0.3 mm. Therefore serration height is not the limiting factor in determining blade life.

Figure 4.9: Disco Blade with Serration Height of 1 mm

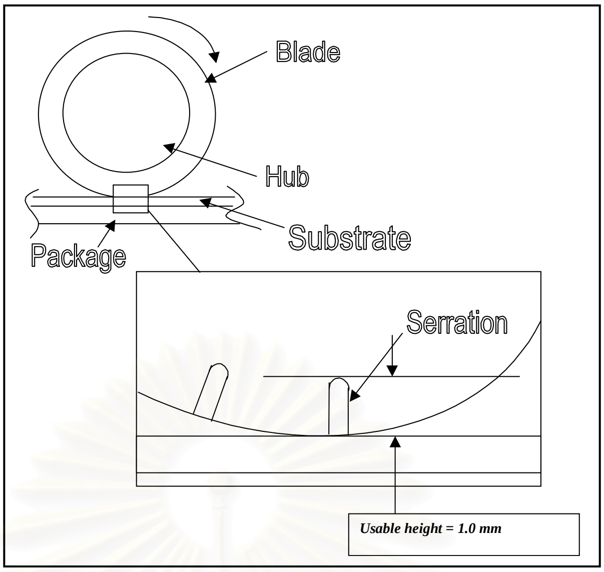
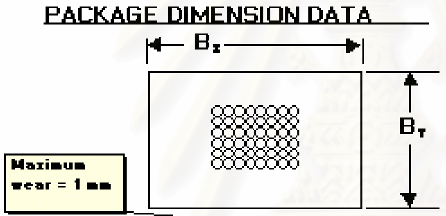


Figure 4.10: Blade Life Limited by Package Dimension



All data obtained with ICOS CI-8250

Specifications 16-039

BX : 8900 - 9000 um

BY : 7900 - 8000 um

Saw parameters:

Spindle speed : 40,000rpm
Feed speed : 4inch/sec
Blade type : Metal bonded
Cooling water flow rate : 1.0 l/min
Cutting water flow rate : 1.0 l/min
Serration height: 1 mm

Lines cut	Blade Wear (mm)	B_X(um)	B_Y(um)
New Blade	0.042	8957	7958
260		8960	7962
520	0.105	8962	7965
780		8965	7968
1040	0.168	8969	7970
1300		8971	7974
1560	0.209	8975	7977
1820		8978	7981
2080	0.279	8982	7985
2340		8987	7992
2600	0.317	9002	7995
2860	0.319	9007	8003
New Blade	0.041	8952	7956
260		8958	7958
520	0.085	8963	7961
780		8964	7962
1040	0.147	8971	7968
1300		8973	7970
1560	0.187	8977	7973
1820		8983	7975
2080	0.255	8991	7983
2340		8996	7991
2600	0.293	9004	7995
2680	0.298	9010	8007

Fails package dimension, Spec Bx max=9.000 mm

Fails package dimension, Spec By max=8.000 mm

Fails package dimension, spec Bx max=9.000 mm

Fails package dimension, spec By max=8.000 mm

4.2.3 Blade Dressing Results

The result of package chip comparing between dressing and without dressing is shown in Figure 4.11. Even though package chip results of without blade dressing is within specification, but observation shows that without dressing had the larger chips by far and this factor must be considered. Also, the chip pattern show a tendency to be much longer, indicating that there may be cracks propagating simultaneously. The blade dressing process should be applied when used in FBGA production.

Figure 4.11: Blade Dressing Results

	Blade Dressing			Without Blade Dressing		
Units	X	Y	Z	X	Y	Z
1	1.28	0.45	0.4	11.14	3.78	4.29
2	1.33	0.26	0.31	7.05	3.7	4.72
3	0.95	0.33	0.44	20.24	3.86	4.12
4	1.56	0.35	0.37	13.74	3.78	3.98
5	1.48	0.4	0.39	19.02	4.17	4.31
6	1.87	0.22	0.45	9.8	2.87	4.13
7	0.8	0.38	0.23	23.31	4.06	4.55
8	1.2	0.45	0.32	5.84	3.91	4.39
9	2.01	0.34	0.46	5.16	3.87	4.1
10	1.4	0.2	0.29	7.91	3.28	3.29
11	0.78	0.11	0.31	5.71	3.09	4.19
12	1.44	0.32	0.29	5.16	3.19	4.29
13	1.9	0.21	0.27	6.1	4.11	3.67
14	1.9	0.18	0.38	4.96	3.1	3.88
15	1.16	0.44	0.37	5.28	3.18	3.01
16	1.73	0.25	0.39	5.2	3.29	4.3
17	1.34	0.19	0.27	5.98	3.79	4.1
18	1.94	0.35	0.3	5.51	3.38	3.2
19	1.38	0.22	0.22	5.39	3.2	3.9
20	1.58	0.3	0.24	5.71	3.1	3.92
21	2.3	0.19	0.48	6.3	3.98	3.59
22	0.88	0.39	0.21	7.13	3.18	4.21
23	1.29	0.28	0.28	9.84	4.41	4.18
24	1.77	0.29	0.31	9.87	4.23	3.99
25	1.83	0.19	0.27	7.13	3.89	4.09
Maximum	**2.3**	**0.45**	**0.48**	**23.31**	**4.41**	**4.72**
Average	**1.48**	**0.29**	**0.33**	**8.74**	**3.62**	**4.02**
Std. Dev.	**0.401**	**0.095**	**0.078**	**5.110**	**0.440**	**0.404**

4.3 Blade Evaluation Summary

The appropriate blade to be used for FBGA singulation process is a Disco metal bond blade with serration. The serration allows more cooling water to get into contact with the cutting surface, and provides more efficient cooling method. The blade provided satisfactory results on package chip and package dimension.

The blade life was limited by the package dimension specification limits not the serration height. The kerf width was equivalent to the blade thickness so by design to achieve the nominal package dimension, a 350 microns blade thickness is recommended for production. Blade dressing for new blades was also required to exposed diamonds and achieved better cutting quality.

4.4 Cutting Sequence Evaluation

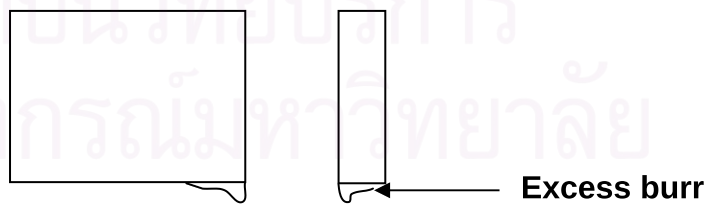
The cutting sequence evaluation results compare between two and three channel cutting sequence is shown in Figure 4.12. The result shows that two channel cutting sequence produces side burr rejects average at 3.65% per each FBGA substrate.

Figure 4.12: Cutting Sequence Evaluation Results

	2 Channel			3 channel		
Substrate	Total Units	Side Burrs	% Side Burr	Total Units	Side Burrs	% Side Burr
1	96	5	5.2	96	0	0
2	96	3	3.13	96	0	0
3	96	2	2.08	96	0	0
4	96	7	7.29	96	0	0
5	96	1	1.04	96	0	0
6	96	2	2.08	96	0	0
7	96	2	2.08	96	0	0
8	96	4	4.17	96	0	0
9	96	5	5.21	96	0	0
10	96	4	4.17	96	0	0
Total	**960**	**35.000**	**3.65**	**960**	**0**	**0**

The results from two channel cutting sequence indicated that this sequence produced problem in the peripheral cut, or the scrap line. The sequence caused units on that side to be incompletely sheared resulting in a burr-like residue, due to no vacuum support on the two long scrap lines – Refer to Figure 4.13. During cutting all the singulated units are hold down by the vacuum chuck but the scrap lines, parts not belonging to the FBGA package, do not have vacuum suction and they are normally purge out to the scrap basket by high-pressure water. Most of the affected units are located adjacent to the scrap lines. The excess burr extends outside the package dimension outline and they are considered as rejected.

Figure 4.13: FBGA Units with Burrs on Package Edge



The three channel cutting sequence is able to eliminate side burrs on the FBGA units. The main reason behind this change is that during cutting the two scrap lines, maximum vacuum suction area is required so that movement or twitching of substrate is minimized which in previous case leads to side burrs problem. The idea from three channel cutting sequence is that channel 1 (partially cut parts) provides more vacuum suction area during sawing of channel 2 (scrap parts) when compared to the two channel cutting sequence method.

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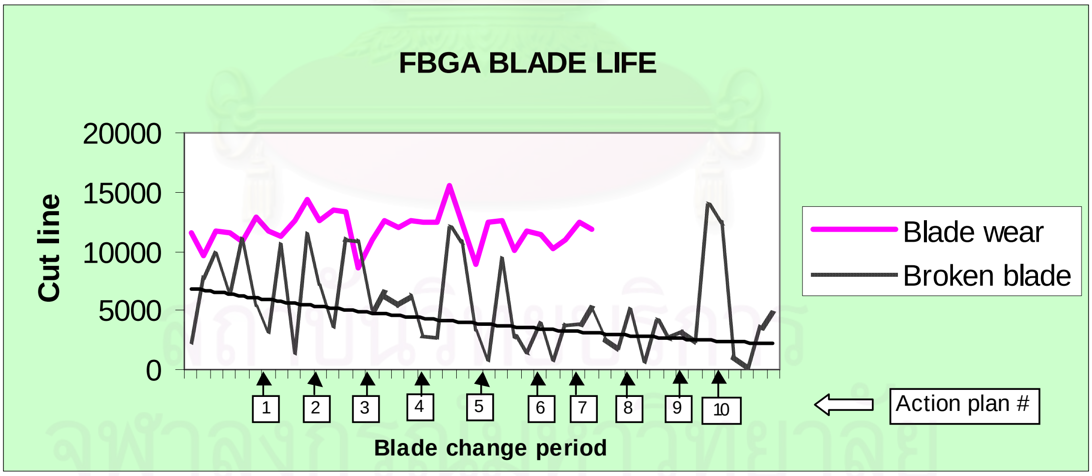
4.4.1 Summary on Cutting Sequence Evaluation

The recommended cutting sequence for FBGA application is a three channel cutting sequence. The sequence is able to eliminate side burrs on the package edges and therefore qualified to be used in FBGA production since second quarter of 2000.

4.5 FMEA Corrective Actions

The recommended corrective actions derived from the FMEA are evaluated sequentially after each implemented corrective actions. The rate of blade breakage rate is monitored as the corrective actions to solve blade breakage issues are being implemented—Refer to
Figure 4.14: FBGA Blade Life after Implementation of Corrective Actions. The saw blade was changed each time the blade reached its life limit (blade wear), or when it broke during cutting (broken blade). FBGA blade life was measured in terms of amount of lines cut—i.e., An average of lines cut of approximately 12,000 is the expected blade life. If blades are changed due to breakage then the amount of lines cut varies a lot more, and is significantly lower than blade wear. From the data collected indicated that blade breakage issues continued to occur as each corrective action was implemented, while blade life persisted in showing a decreasing trend. It can therefore be concluded that the corrective actions had not yet been successful in solving blade breakage problem, and decided to look further into the impact of the cutting sequence.

Figure 4.14: FBGA Blade Life after Implementation of Corrective Actions



4.6 New Cutting Sequence

A design of experiment is conducted to collect information for a statistical analysis of the impact on 4 channel cutting sequence and dual high-pressure water nozzle design. A full factorial design is used for the experiment.

4.6.1 Statistical Analysis

The studied factors includes cutting sequence (3 channel and 4 channel) and high-pressure nozzle design (Old design and New design). The measured responses are blade life and remaining scrap on nest that causes dented ball rejects. The result from the design of experiment is shown in Figure 4.15

Figure 4.15: Results from Design of Experiment

JMP - [DOE for nozzle & ch]

File Edit Tables Rows Cols Analyze Graph Tools Window Help

7 Cols / 12 Rows	Pattern	Channel	Nozzle	Broken Blade(time)	Scrap(time)	Blade Life(lines)	Scrap/Blade life
1	--	3CH	Old	1	0	3929	0
2	-+	3CH	New	1	0	2698	0
3	+-	4CH	Old	0	8	12590	0.06354
4	++	4CH	New	0	0	11912	0
5	--	3CH	Old	1	1	2401	0.04165
6	-+	3CH	New	1	0	3562	0
7	+-	4CH	Old	0	5	12850	0.03891
8	++	4CH	New	0	0	14727	0
9	--	3CH	Old	1	0	1429	0
10	-+	3CH	New	1	0	3832	0
11	+-	4CH	Old	0	14	12553	0.11153
12	++	4CH	New	0	1	12369	0.00808

The data collected are analyzed by using the JMP statistical software. The results from effect test in Figure 4.16 shows that cutting sequence has significant impact to blade life (Prob Value < 0.05), while high-pressure nozzle design has no significant impact to blade life (Prob Value > 0.05). There is no interaction effect between cutting sequence and nozzle design that impact to blade life (Prob Value > 0.05).

Figure 4.16: Effect Test on Blade Life

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Channel	1	1	291560208	274.5675	<.0001
Nozzle	1	1	934092	0.8797	0.3757
Channel*Nozzle	1	1	144760	0.1363	0.7215

The result from effect test in Figure 4.17 shows that both cutting sequence and high-pressure nozzle design have significant impact to remaining scrap on nest (Prob Value < 0.05). Also there is no interaction effect between cutting sequence and nozzle design that impact to remaining scrap (Prob Value > 0.05).

Figure 4.17: Effect Test on Scrap Remains

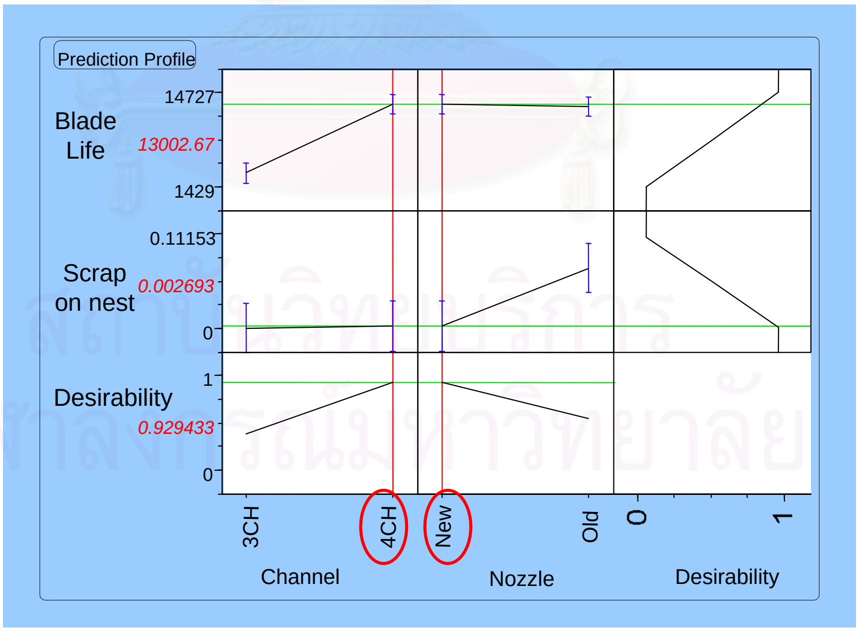
Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Channel	1	1	0.00271231	5.5244	0.0467
Nozzle	1	1	0.00510675	10.4013	0.0121
Channel*Nozzle	1	1	0.00224817	4.5790	0.0648

Prediction profile is analyzed – Refer to Figure 4.18. The JMP software allows user to input the desirable response. In this experiment, the maximum blade life is desired, while least amount of scrap remaining on nest causing dented balls is preferred. The software with just a single click automatically provides optimum level for each of the factors so that it gives out the most desirable response. The guideline for using JMP software is provided in JMP Statistics and Graphic Guide Version 3.1 (1995).

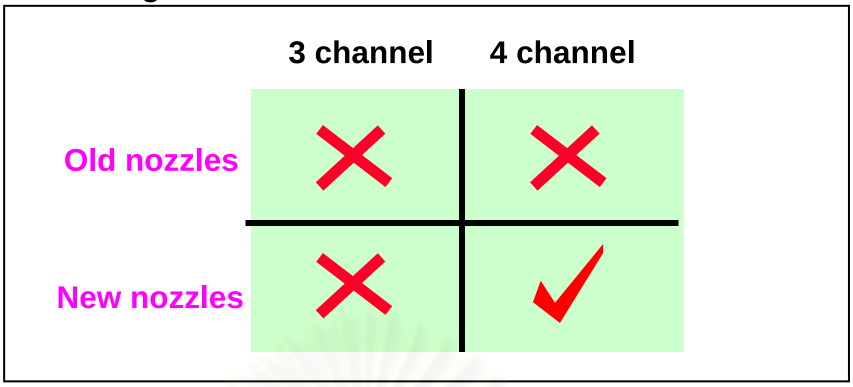
From the prediction profile analyzed by JMP statistical software, it can be concluded that the 4 channel cutting sequence improves blade life or in other words eliminated blade breakage, but since it produced a larger scrap size there is significantly more scrap remaining on the nest causing dented ball rejects. The old design nozzle can not handle to purge the longer scraps effectively and results with more scraps remaining on nest when 4 channel cutting sequence is used. New high-pressure nozzle design significantly improves this and minimizes chances of having scrap remaining on nest.

Figure 4.18: Prediction Profile by JMP Software



Therefore, a combination of the 4 channel sequence with usage of the dual nozzle design reduced blade breakage satisfactorily as well as effectively purged out the larger scrap size from the nest generated by the 4 channel cutting sequence—Refer to Figure 4.19.

Figure 4.19: Combination of 4 Channel Saw Sequence and New Nozzle Design



4.6.2 Cutting Quality Confirmation

The cutting quality has to be confirmed from the modification of cutting sequence. The critical measurement data obtained from ICOS are compared between 3 and 4 channel cutting sequence by using Analysis of Variance (ANOVA) statistical technique together with process capability index (Cpk)—Refer to Figure 4.20: ANOVA & Cpk Results for Package Dimensions, and Figure 4.21: ANOVA & Cpk Results for Ball Array Offset. The statistic formulas were obtained from Fasser and Bretter (1992).

From the ANOVA it is concluded that there are no significant difference for package dimension (Bx and By) and ball array offset (Gx and Gy) parameters between 3 channel and 4 channel cutting technique, at 95% confidence level. The Cpk for all the critical parameters are above the expected target of 1.5.

Figure 4.20: ANOVA & Cpk Results for Package Dimensions

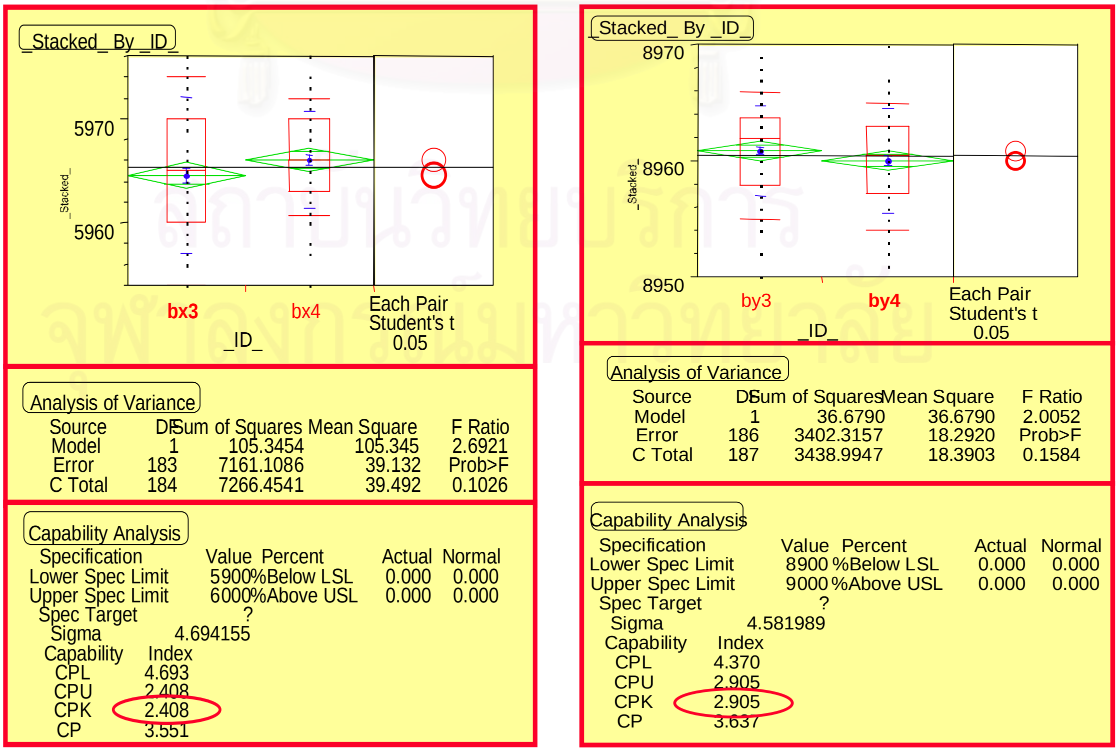
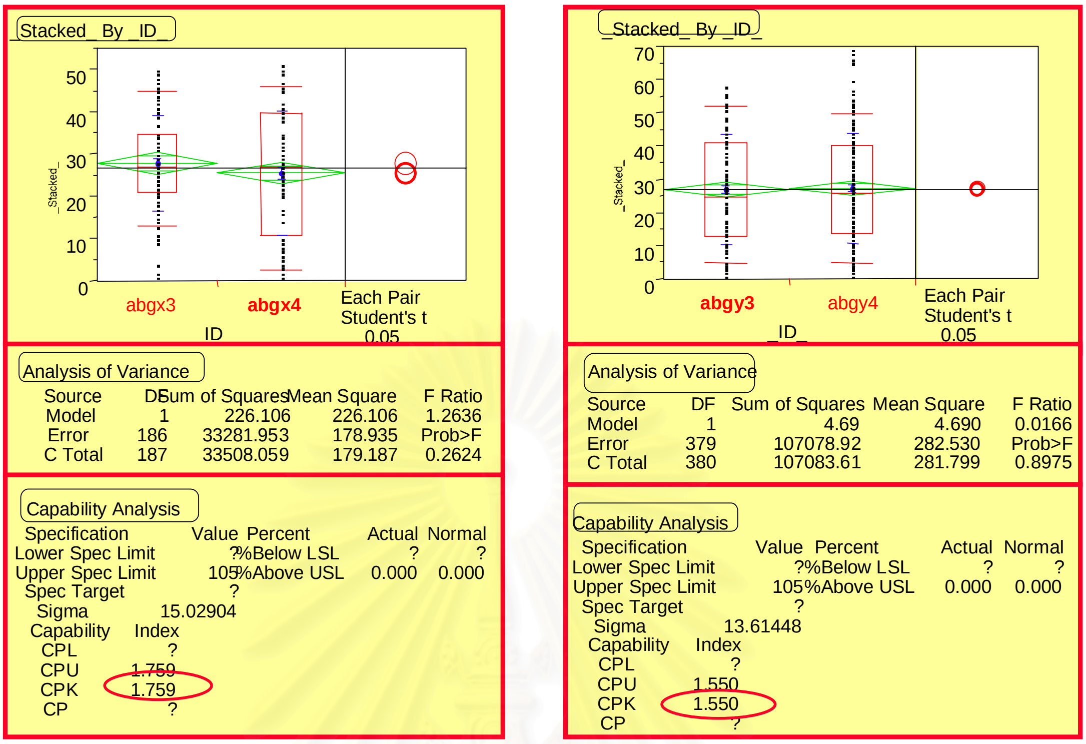
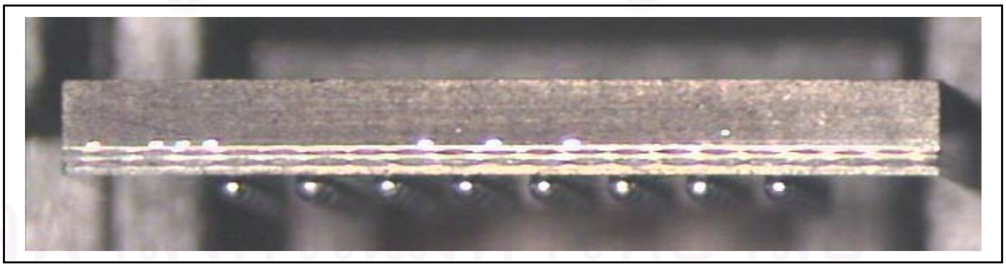


Figure 4.21: ANOVA & Cpk Results for Ball Array Offset



The singulated units from the 4 channel cutting sequence were inspected on the side view for any slanted cut or burr on the side of the units. The observation result is that there were no slanted cuttings nor burr, especially the units near the scrap line, which is the most critical area because of the lack of vacuum suction on the scrap lines—Refer to Figure 4.22: Side View of FBGA Units Using 4 Channel Cutting Sequence.

Figure 4.22: Side View of FBGA Units Using 4 Channel Cutting Sequence



4.7 Conclusions of Results

From inspections and analyses of the impact of implemented corrective actions it can be concluded that:

1. A combination of 4 channel cutting sequence with dual high-pressure nozzle design solves blade breakage problem and remaining scrap on nest.

2. Changing from a 3 to 4 channel cutting sequence has no impact on cutting quality, no burr or slanted cut were observed on the sides of singulated FBGA products, and delivers an acceptable Cpk (>1.5) for both package dimension and ball array offset.

3. The 4 channel cutting sequence with dual high-pressure nozzle design has been implemented in full production mode since WW48'00.

4. The complete PFMEA is documented as shown in Figure 4.23. The RPN on the action results is filled in to determine the effectiveness of the implemented actions. It is decided that RPN for blade breakage resulting from small flying scraps has to be reduced significantly after the proposed solutions.

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Figure 4.23: Complete PFMEA with RPN Action Results

Item	: FBGA package	FAILURE MODE AND EFFECT ANALYSIS	FMEA No. : BA00032E
Process Responsibility	: Assembly	☐ Design FMEA	FMEA Original Date : 07/03/00
Prepared By	: Prakorn V. (PE-Assembly)	■ Process FMEA	FMEA Revised Date : 02/25/01
Key Date	: Jul 3'00	☐ Containment FMEA	Page: 1 of 1
Spec Ref. 08-073	Core team : Watana(New Package), Chuawalit (PM), Khanchit (PM)		

Process Functional Requirement	Potential Failure Mode	Potential Effects of Failure	SEV	CLASS	Potential Cause(s) of Failure	OCC	Current Process Control	DET	RPN	Recommended Corrective Action(s)	Person Responsible and Target Completion Date	Action Results: Action Taken	SEV	OCC	DET	RPN
Saw Singulation	Package chip, crack, wrong dimension	Package dimension failure, visual defect, test failure, reliability, SMT board failure	7	•	Improper blade selection	3	Visual mechanical inspection at low magnification scope	5	105	Blade evaluation at supplier and at AMD	Disco & Process, ww 25'00	Done, ww 19'00	7	2	5	70
			7	•	Accumulated scrap in cutting chamber	7	Wet/dry vacuum cleaner every 2 magazines	7	343	Increase scrap clearing frequency to every magazine	Production, ww 31'00	Done, ww 31'00	7	5	7	245
										Software modification to have self-alarm capability when number of strips reaches preset limit	Intercon, ww 48'00	Done, ww 48'00	7	5	1	35
			7	•	Vacuum rubber pads & clogging of vacuum holes	3	Periodic maintenance schedule	6	126	Replace new rubber pads & clean any vacuum holes that are clogged	Production, ww 33'00	Done, ww 33'00	7	3	6	126
			7	•	Clogging of high pressure nozzle	6	Periodic maintenance schedule	2	84	To install a new high pressure water nozzle which sprayed water in curtain form and improved scrap	Maintenance,ww 34'00	Done, ww 34'00	7	6	2	84
			7	•	Improper setup conditions for cooling side bars	2	None	9	126	Check clogging of outlet slits, parallelism of 2 side bars and distance from blade tip should be	Maintenance,ww 36'00	Done, ww 36'00	7	2	9	126
			7	•	Scrap hitting water flow control block	8	None	8	448	Removal of water flow control block	Production, ww 37'00	Done, ww 37'00	7	8	8	448
			7	•	High cutting speed	3	AMD specification	3	63	Reduce cutting speed from 100 mm/sec to 50 mm/sec	Process, ww38'00	Done,ww 38'00	7	3	3	63

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Figure 4.23: Complete PFMEA with RPN Action Results (Con't)

AMD	Item : FBGA package	FAILURE MODE AND EFFECT ANALYSIS		FMEA No. : BA00032E
	Process Responsibility : Assembly	☐ Design FMEA		FMEA Original Date : 07/03/00
	Prepared By : Prakorn V. (PE-Assembly)	■ Process FMEA		FMEA Revised Date : 02/25/01
	Key Date : Jul 3'00	☐ Containment FMEA		Page: 1 of 1
Spec Ref. 08-073	Core team : Watana(New Package), Chuawalit (PM), Khanchit (PM)			

Process Functional Requirement	Potential Failure Mode	Potential Effects of Failure	SEV	CLASS	Potential Cause(s) of Failure	OCC	Current Process Control	DET	RPN	Recommended Corrective Action (s)	Person Responsible and Target Completion Date	Action Results: Action Taken	SEV	OCC	DET	RPN
Saw Singulation	Package chip, crack, wrong dimension	Package dimension failure, visual defect, test failure, reliability, SMT board failure	7	•	Improper water flow-rate setup	5	AMD specification	3	105	Vary water flow-rate within specified specification	Process, ww 39'00	Done, ww39'00	7	5	3	105
			7	•	Improper spindle RPM	3	AMD specification	3	63	Reduce spindle speed from 40K RPM to 30K RPM	Process, ww 41'00	Done, ww41'00	7	3	3	63
			7	•	Wheel mount not perpendicular with saw chuck	1	Vendor setup with tolerance accuracy of 1 micron	9	63	A dial guage with a fixture to confirm the wheel perpendicularity with the saw chuck	Disco,ww 42'00	Done ww42'00	7	1	9	63
			7	•	Ineffective scrap purging nozzle design	8	None	9	504	Change high pressure nozzle design to purge scraps from both front and rear of saw blade	Team,ww 39'00	Done, ww42'00	7	8	9	504
			7	•	Small flying scraps hit the blade during cutting	8	None	9	504	Modification of saw sequence from 3 channel to 4 channel	Process, ww43'00	Done, ww 43'00	7	1	9	63
										Combination for 4 channel saw sequence & new high pressure nozzle design to reduce dented ball	Team,ww 46'00	Done, ww46'00	7	1	9	63
			7	•	Human handling	2	AMD specification	6	84	None		None				0
			7	•	Blade changing method	2	AMD specification	6	84	None		None				0
			7	•	Dressing method	5	None	4	140	Established training guidelines	Process, ww 30'00	Done ,	7	5	4	140

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CHAPTER 5

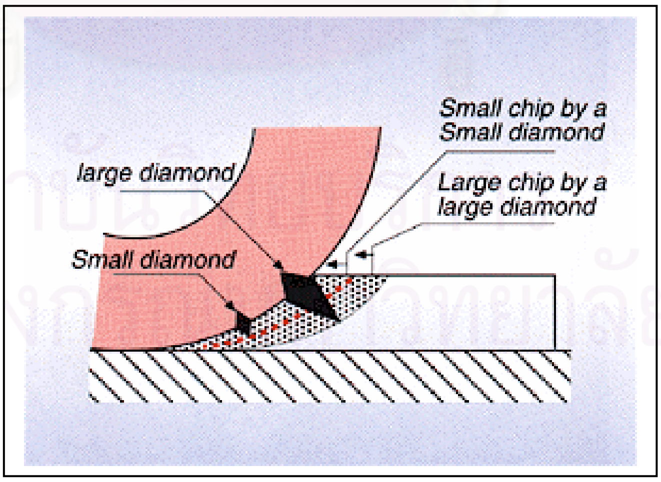
DISCUSSION OF RESULTS

5.1 Dicing Blade Evaluation

Dicing is used in the semiconductor industry for die separations, package singulation and also for very hard and brittle materials. The wide range of materials processed makes it necessary to use different type of blades. These may be based on hard or soft binders, with various diamond particle sizes. The variations of diamond sizes and binders or bonding material usually impact the chipping size on the product.

The diamond size is a major player in the results of any dicing process. Larger diamonds usually cause larger chipping while smaller diamonds will have less impact to chipping. The result from the evaluation holds true when comparing blade #280,M51 that has a larger diamond grit size than blade #400,M51. Blade #280, M51 on the average produces larger backside chipping when compared to blade #400, M51. According to Levinson (1996) the diamond size determines the load and the edge quality of the kerf during the dicing process. A large diamond particle will dig out a large portion of the substrate material and a small diamond particle will proportionally dig out a small portion. This digging action is the reason for higher loads when using smaller diamond particles at a given feed rate – Refer to Figure 5.1.

Figure 5.1: Small and Large Diamond Dicing Mechanism (Levinson, 1996)



The required size of the diamond particle is determined by the hardness and the brittleness of the material being diced. For free cutting of hard materials, large diamond particles are used in the blade matrix. However, good edge quality requires smaller diamond particles to minimize chipping. When used on hard materials, the smaller diamond particles tend to overload the blades, creating high temperatures, material damage, and in some cases, even blade failure or saw overload. The solution for overloading the blade is optimizing a few blade parameters, including the diamond particle size.

According to Levinson (1996) A hard and brittle material requires a soft blade binder. Cutting performance is based on the binder's ability to release dulled diamonds and expose, new sharp ones at the same time. On softer, less brittle substrates a harder matrix is necessary. Nickel and metal sintered binders (metal bonded) are normally used for these applications. The nickel-type blade has a very hard nickel matrix, with diamonds distributed homogeneously through it. This bond is the key for very low wear. The Metal Sintered blade has a very uniform matrix and has better wear characteristics than the nickel matrix and therefore is less loading. Loading is also discussed in 5.1.2 Spindle Current. The harder bond on the nickel blade (Blade #Z1110) causes more backside chipping as compared to the metal bond with same diamond grit size (Blade #400,M51) which corresponds to the dicing theory.

The blade life is measured in terms of wear rate. The wear rate and the cut quality are always a trade-off. The higher the wear rate, meaning more diamonds are released during cutting and new diamonds are exposed so cutting is more effective and result in better cut quality but affect to shorter blade life. On the contrary, lower wear rate releases less diamonds so more loading is applied to the substrate during cutting, and result in poorer cut quality but impact is longer blade life. The advantage of nickel blade is that it has a lower wear characteristic and blade life can be extended. In some applications that quality can be sacrificed to certain extent then nickel-bonded blade may be worth using. In this research, the metal bonded blade with 40 micron diamond grit size (#400, M51) had met the expected cutting quality requirement which is treated as first priority and also the blade was giving satisfactory blade life.

5.1.1 Kerf Width

The evaluation results of kerf width indicated that the kerf width is almost equivalent to the blade thickness. Based on dicing mechanism on silicon wafers, the blade pushes the material and generates chipping along the kerf width. The kerf width naturally is wider than the blade thickness. The initial blade evaluation started off with a blade thickness of 340 micron and expecting an additional of 10 micron to obtain a kerf width of 350 micron. The result was not to be, instead the kerf width could be assumed equivalent to the blade thickness. The target of getting a kerf width of 350 micron by using a blade thickness of 340 microns was not achievable. Therefore it is recommended to use a blade thickness of 350 micron in order to meet the package dimension nominal target

The difference can be explained is that silicon material is more brittle and less resistance to fracture when compared with molded epoxy and BT substrate so kerf width tends to be larger than the blade thickness. Another difference is blade characteristic between wafer dicing and CSP package singulation. Different binding materials, diamond sizes, concentrations, hardness of bonding materials contribute to different dicing characteristics.

5.1.2 Spindle Current

The load that applies onto the spindle during cutting is a direction proportion to the current that is supplied to the spindle. The dicing machine is equipped with a real time load monitoring that measures the current intake of the spindle during the process cutting. The current draw of the motor that powers the spindle to which the dicing blade is attached is proportional to the interaction force between blade and substrate as explained by Weisshaus (2000). The current is expected to increase once loading is increase and vice versa.

The conclusions drawn by Weisshaus (2000) from the on-line monitor studies:

- The blade interaction force is a reliable indication to the process robustness.
- The blade force can be on-line monitored and used to warn of potential problems.
- The monitor can be used for optimization of dressing procedure and dicing process.
- On-line monitor is an important tool for statistical process control.

The research make used of this spindle current on-line monitoring feature by using it to determine the appropriate blade for CSP applications. The nickel bonded blade end up with spindle current exceeding 4 amperes whereas the other two metal bonded blades are in the range of 3 amperes. The blade interaction force of the nickel blade is significantly higher than that of metal bonded blades and usually leads to higher problem on backside chipping. The evaluation results on backside chipping also correspond to this theory. However, spindle current monitoring is not a universal tool to use as sole measurement for determining cut quality. There are several other factors to be considered in the dicing process that contributes to the end result of cut quality.

5.1.3 Serrated Blades

Dicing thick substrates creates high loads during the dicing process. In order to minimize these loads and create a freer dicing process, a blade with serrations on the edge can be used – Refer to Figure 5.2

The slots on a serrated blade actually cause less contact between the blade and the substrate material. This reduces the loads, improving the cooling of the blade and substrate. The slots on the blade edge also help to clean the kerf from the powder residue created during dicing. (See Figure 5.3)

Figure 5.2: Standard and Serrated Blades (Levinson, 2000)

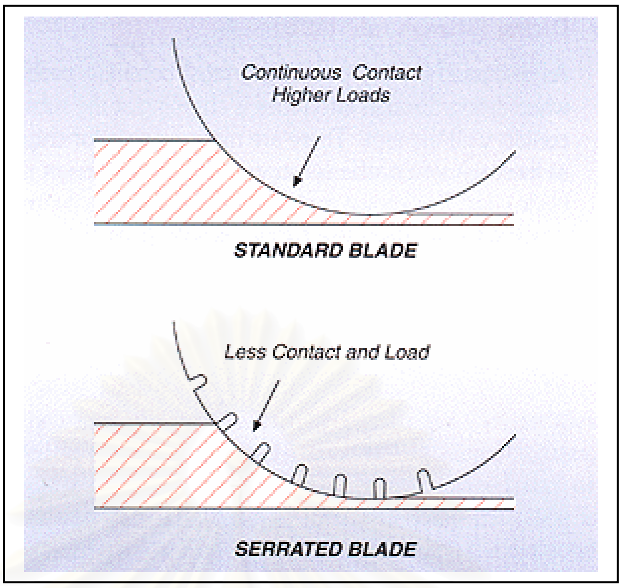
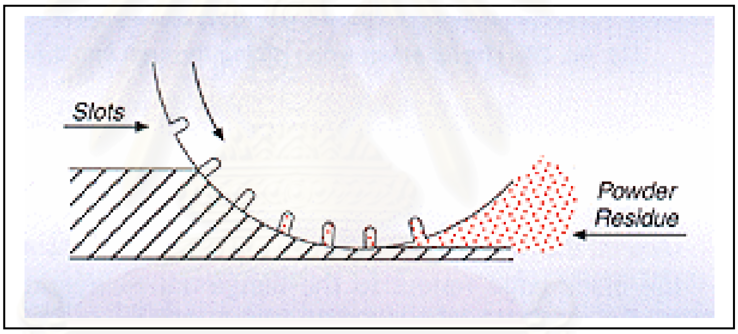


Figure 5.3: Powder residue Washed Out of the Kerf (Levinson, 2000)



The decision to use serrated or slotted blades by Tsutsumi [17] Disco Corporation was made based on the following factors:

1) Less contact between edge and substrate, which translates into less load during cutting.

2) Better cooling, due to serrations.
Levinson (1996) mentioned that serrated blades minimize the loads during the dicing, but they have the limitation of dicing wider kerfs and the disadvantage of wearing faster. To optimize and reduce the above disadvantages, a blade optimization can be performed in order to minimize the number of slots and change the slot geometry.

Evaluation results also shows the serration height of 1 mm is the limiting factor on the blade life. Package dimension limits are reached well before the exposure is reduced beyond the usable height of 1 mm. Blade life is therefore limited by the package dimension specification limits. Further recommendation is to study on the maximum possible cut lines that the blade can achieve by using metal bonded blade with blade thickness of 350 micron. Also serration height and width can be further optimized.

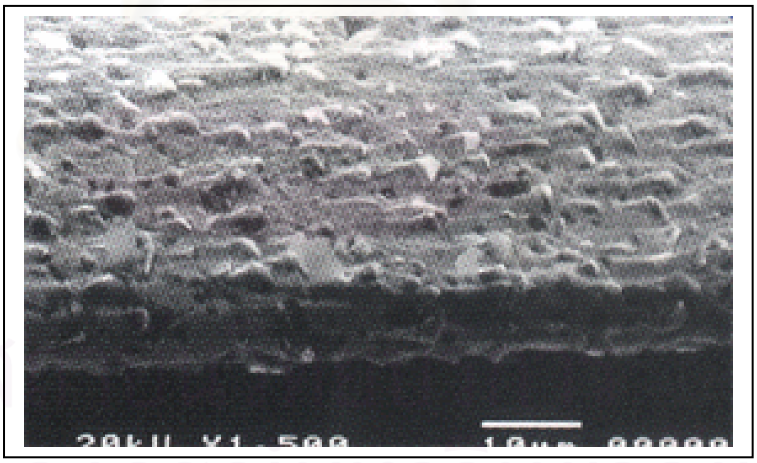
The other important criteria to be considered is logistics of blade supplier. Blade availability for Disco is not a problem. Disco has a representative in Thailand as well as capable of supplying CSP blades from Disco Singapore. Availability of the blade is refer as the range of blades available for a particular application and the thickness and finish required for any given blade type. The information is available from Disco Dicing Application Seminar for CSP/BGA (1999).

5.1.4 Blade Dressing

"Dressing a blade" is the process of treating the surface of the blade in contact with the substrate material in order to enable it to freely penetrate into the material, minimize loads, and perform with good cut quality. According to Levinson (1996) dressing blades can be done by the following methods:

- Chemical etching (nickel binders)
- Chemical electrical etching (nickel binders)
- Grinding (all blade types)
- Surface lapping (all blade types)
- On-line dressing on the dicing saw (all blade types). See Figure 5.4

Figure 5.4: On-Line Dressing (Levinson, 1996)



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The idea of dressing a blade is to machine off any loose diamonds from the blade edge and the blade sides (See Figure 5.5) to expose the diamonds mainly on the edge but also on the sides (See Figure 5.6) to get a perfect run out of the O.D. to the spindle and to achieve a good side run out.

Figure 5.5: Dressing Out Loose Diamonds (Levinson, 1996)

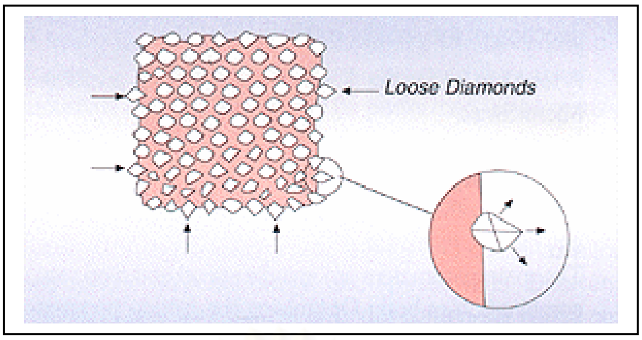
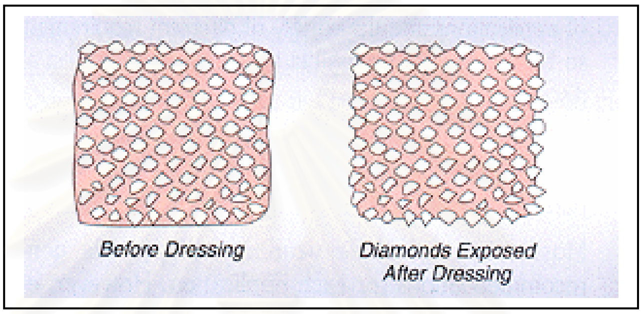


Figure 5.6: Dressing to Expose Diamonds (Levinson, 1996)



It is important to note that blades without well exposed diamonds do not penetrate easily into the material. It will tend to push the material, creating high loads, high temperatures and poor cut quality. In some cases, it can cause blade breakage.

There is a major difference between different blade binders. Resinoid blades by nature have a soft binder and in most cases will require minimum dressing, if at all. Resinoid blades will easily be dressed in the material being diced. Resinoid blades are called "self resharpening blades" by the industry. Nickel electroformed blades and metal sintered blades have a much harder binder and a much more aggressive dressing is needed in order to achieve the above mentioned goals. The result from the evaluation confirms this statement. By comparing dressing process and without dressing process reveals that blade with dressing process generates far less package chipping and has been used a standard procedure when setting up new blades on the singulation system.

According to Levinson (1996) concluded that dressing is performed for the following reasons:

1) Excess binder material or loose diamond particles are machined off.

2) The binder holding the diamonds is machined off, exposing the diamonds

3) It trues the outside diameter run out and provides accurate blade edge geometry.

4) Minimizes the load, creates a cooler and freer cut

5.1.4.1.On-Line Dressing

This dressing process is performed on the saw by the user, either on a new blade or during the dicing process to improve the cut quality and to minimize the load. This process will not change the edge shape. But it will open the blade by grinding off the blade binder and cleaning any residue from the dicing to expose the diamonds. The dicing media is usually a silicon carbide dressing board or stick or an aluminum oxide stick. The dressing media is mounted to the saw chuck. The blade penetrates into the board or stick at low feed rates.

The table speed, spindle speed, cut depth and number of passes should be developed and optimized for each application. The dressing board or stick grit and hardness should also be optimized. On today's newly developed saws, a dressing program of how many cuts at what speed and depth can be programmed in order to achieve optimal quality.

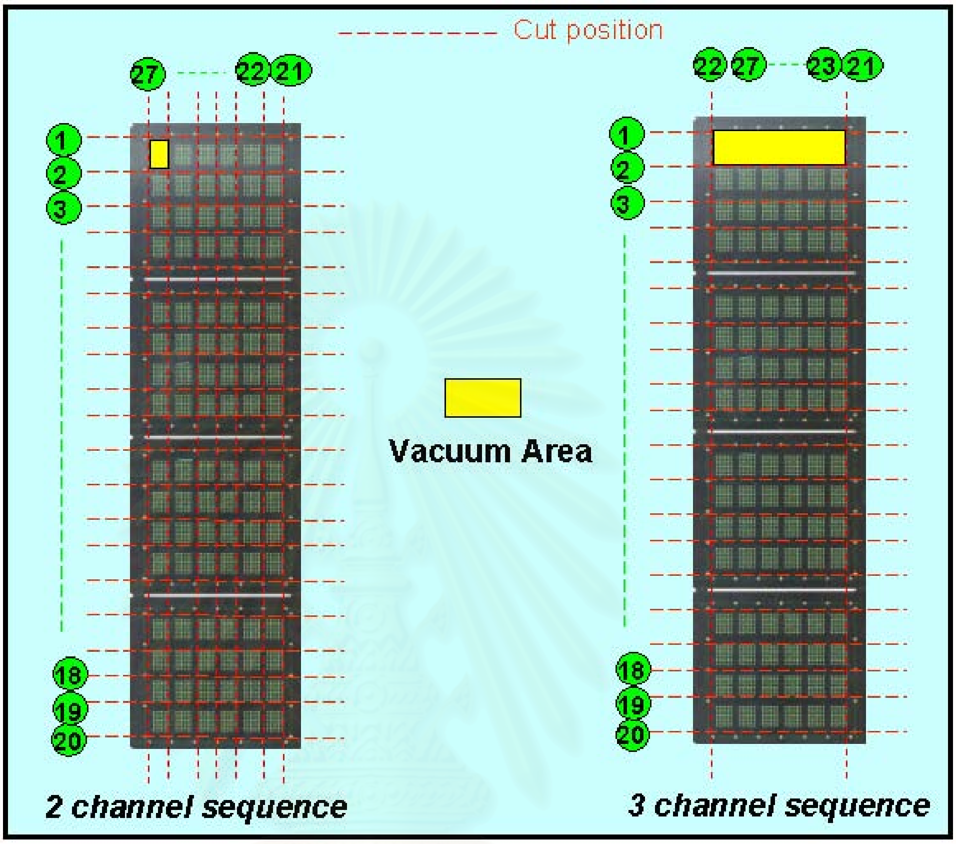
5.2 Cutting Sequence Evaluation

A normal standard cutting sequence would be a 2 channel sequence where the blade cuts on the first channel of substrate panel and then saw chuck rotates 90 degrees to cut on the 2nd channel. The sequence had problems with cutting quality that included side burrs on singulated parts. During cutting all the singulated units are hold down by the vacuum chuck but the scrap lines, parts not belonging to the FBGA package, do not have vacuum suction and they are normally purge out to the scrap basket by high-pressure water. The effected units are usually locate near the scrap line which is the last cut line (Line #27) for 2 channel cutting sequence – Refer to Figure?.

The reason behind this phenomenon is that during the last cut line of the scrap there is very minimal vacuum area suction on the units. The vacuum area holding the units during blade attempts to cut the scrap line is represented as the rectangular block area shown in Figure 5.7. The 3 channel cutting sequence is programmed to cut the outer two long scrap lines first so vacuum area holding the remaining units is much larger compared with 2 channel cutting sequence. The additional vacuum area gives more robustness and stability when cutting the scrap lines and does not generate the side burrs problem according to the evaluation results.

The CSP singulation process used a 3 channel cutting sequence when started full production mode. There were no problems with cutting quality but after using the cutting sequence for 2 months it generated another major problem, which was blade breakage.

Figure 5.7: Vacuum Suction on 3 Channel and 4 Channel Cutting Sequence



The root cause of blade breakage is that the second channel (two scrap lines # 21 and 22) from 3 channel cutting sequence generates small scraps that flies turbulently around the cutting area (See Figure 5.8) and therefore hitting and damaging the rotating blade. The quality circle team then implemented a 4 channel cutting sequence to solve blade breakage problem. The major impact from this change is on the second channel of 4 channel cutting sequence where the size of generated scrap is larger than the one from previous 3 channel cutting sequence (See Figure 5.8).

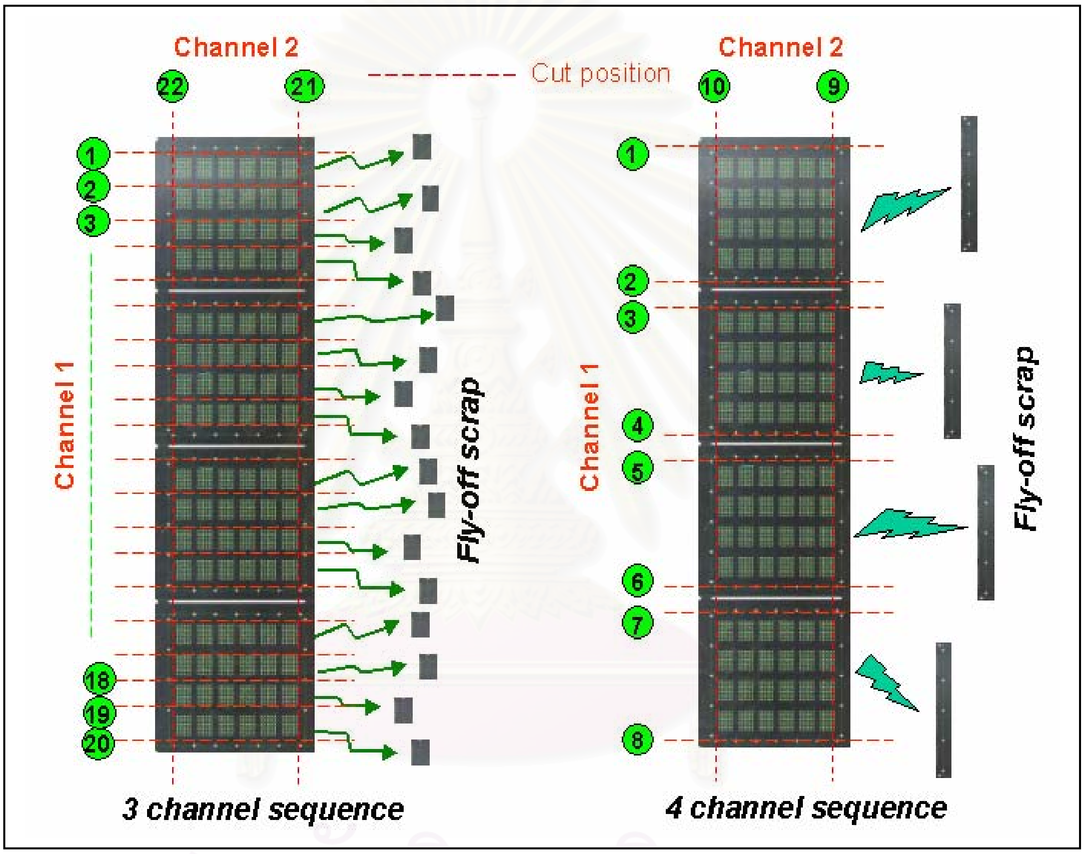
The larger or longer scrap generated from the 4 channel cutting sequence generated another problem, which is remaining scrap on nest. Once the cutting process is completed a nest cover clamps down onto the nest to transport the units at washing station. In this incident the weight of the nest cover together with remaining scrap crushes on the solder balls and causes them to be dented or rejected. This is where a dual high-pressure nozzle comes into picture.

The advantages of the new dual high-pressure nozzle design as compared to the previous single high-pressure nozzle design are discussed below.

Advantages of the new high-pressure nozzle concept include:

1. Lower level of nozzle position together with horizontal water flow direction to clear scrap more effectively towards the scrap basket.
2. Purging scrap from both sides of the saw blade (front and rear).
3. Higher water pressure with the new nozzle design enable to clear scraps away from the cutting area more quickly.

Figure 5.8: Comparison 3 versus 4 Channel Cutting Sequence



The factorial design of experiment leads to the conclusion that a combination of 4 channel cutting sequence with dual high-pressure nozzle design solves blade breakage problem and remaining scrap on nest.

The advantages and disadvantages of the new 4 channel cutting sequence when compared to the previous 3 channel cutting sequence are listed as follows.

Advantages of 4 channel cutting sequence:

1. Larger scraps exit the cutting area easier on the 2nd channel.
2. Minimized potential of small scrap flying up, hitting the blade tail, and consequently causing blade breakage.

Disadvantages of 4 channel cutting sequence:

1. Remaining scrap on nest due to longer length of scrap, causing dented solder balls.
2. Loss of machine UPH (Unit Per Hour) due to additional time from saw chuck rotation used during 4 channel cutting sequence.

The dual high-pressure nozzles design minimizes the chance of having remaining scraps on nest and the additional time of the 4 channel cutting sequence was not considered to have a significant impact on the overall machine capacity. The benefits in terms of less time for assisting the machine and reduce maintenance time are well covered for the additional time of 4 channel cutting sequence.

The changed from 3 to 4 channel cutting sequence also confirmed to have no impact on cutting quality, no burr or slanted cut were observed on the sides of singulated FBGA products, and also delivers an acceptable Cpk (>1.5) for both package dimension and ball array offset parameters.

5.3 Implementation Impact

The long-term impact on blade breakage rate, blade life increment, and Cpk of critical parameters are continuously tracked after two consecutive months of implemented corrective actions.

The confirmation result shows that there is zero blade breakage after implementation— Refer to Figure 5.9: Comparison of Blade Breakage Before & After Implementation. The comparison is based upon a period of two months before implementation and two months after implementation. The blade life has also significantly increased when using a 4 channel sequence as compared to the previous 3 channel sequence—Refer to Figure 5.10: ANOVA Results Comparing 3 versus 4 Channel Cutting Sequence. Detail data collection results comparing blade life between 3 and 4 channel cutting sequence is provided in Appendix I.

The process capability index (Cpk) for all critical parameters after implementation shows that package dimension (Bx, By) and ball array offset (Gx, Gy) are above target value of 1.5 as shown in Figure 5.11.

Figure 5.9: Comparison of Blade Breakage Before & After Implementation

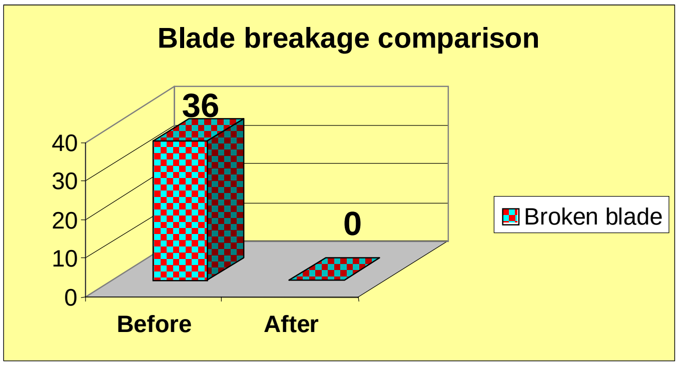


Figure 5.10: ANOVA Results Comparing 3 versus 4 Channel Cutting Sequence.

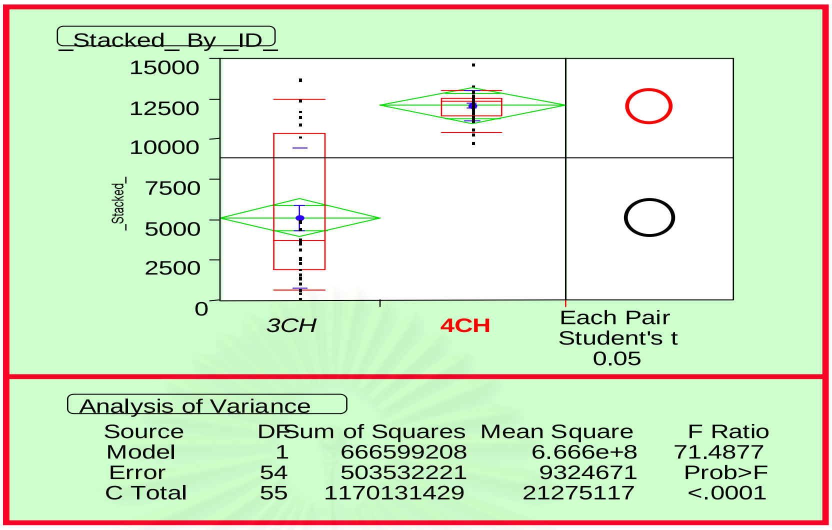
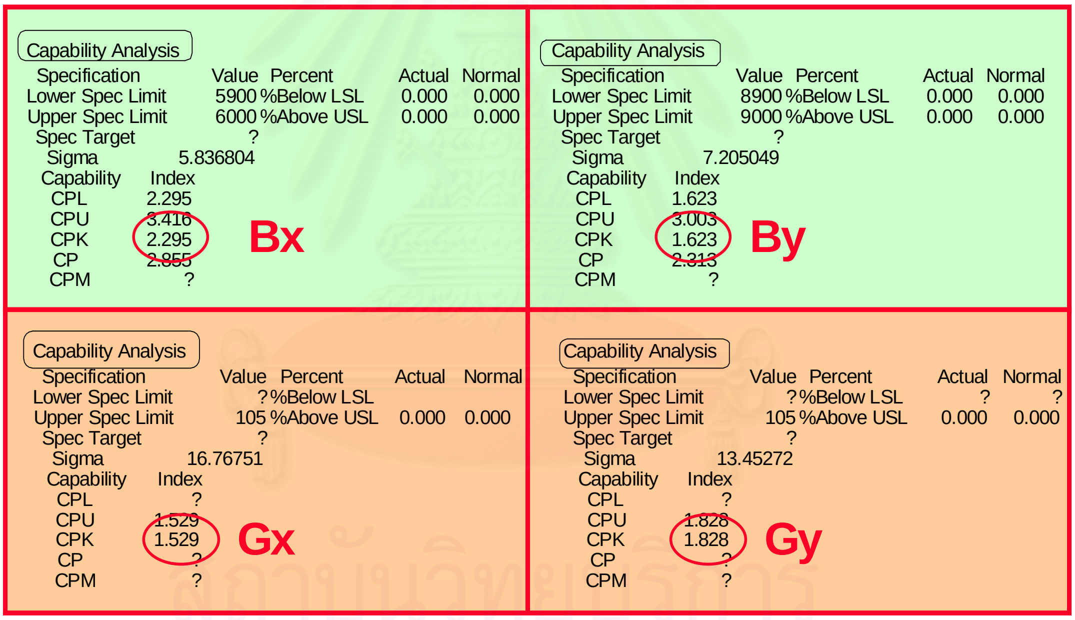


Figure 5.11: Cpk after Implementation



5.4 Benefits

The benefits of research can be subdivided into tangible and intangible benefits.

5.4.1 Tangible Benefits

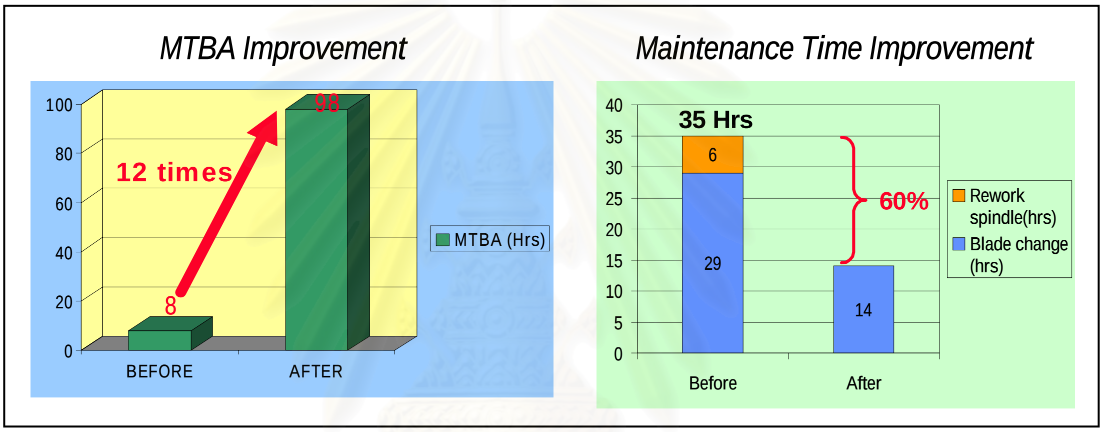
5.4.1.1 MTBA

MTBA (Mean Time Between Assist) is defined as the productive time divided by the number of assists. The number of assist in this case depends on the frequency that blade breakage occurs. From data collected before and after implementation of this research, it is concluded that MTBA regarding blade change has improved 12 times—Refer to Figure 5.12: MTBA & Maintenance Time Improvement.

5.4.1.2 Maintenance Time

Maintenance time in this case includes the time during blade change, machine setup, rework of incomplete cut substrates, and machine down time for spindle rework, or in serious cases, spindle replacement when reworking is impossible. Total maintenance time was reduced by 60% after the research was implemented—Refer to Figure 5.12: MTBA & Maintenance Time Improvement.

Figure 5.12: MTBA & Maintenance Time Improvement



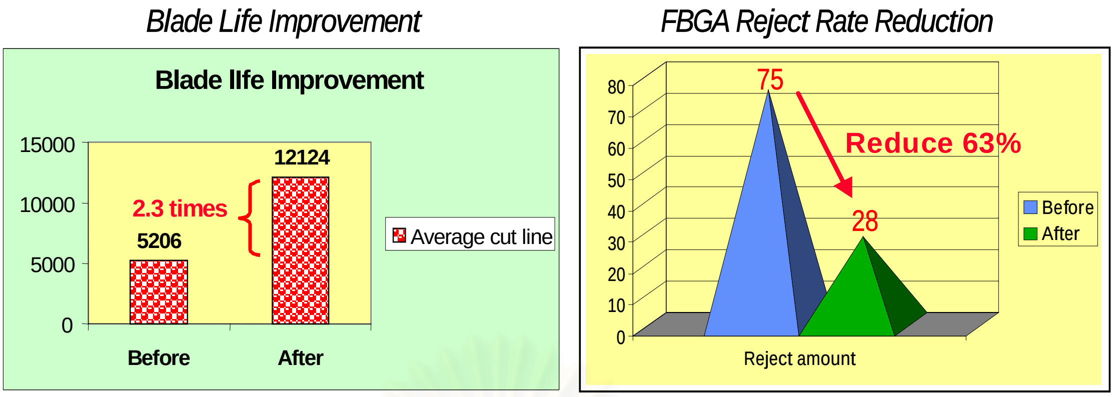
5.4.1.3 Blade Cost Reduction

Blade life measured in terms of average lines cut, has improved from 5,206 lines to 12,124 lines, or an improvement of 2.3 times the original life—Refer to Figure 5.13: Cost Reductions (Blade Life & FBGA Reject Rate). Thus, based on a volume of 595.8K units/week reference from MSD 2001 Business Plan (2000), a blade cost of US$ 89/piece, and FBB48 packages with 96 units per strip (27 cut lines per strip), annual blade cost savings will amount to US$ 87,932.

5.4.1.4 FBGA Unit Cost Savings

The major defects resulting from blade breakage concerned package dimension rejects. From data collected before and after implementation of this research, it can conclude that package dimension rejects was reduced from an average of 75 units per week to 28 units per week, which is a reduction of 63%—Refer to Figure 5.13: Cost Reductions (Blade Life & FBGA Reject Rate). Based on a volume of 595.8K/week, AMD will save 183 units/week. The FBGA assembly unit cost including die cost is US$ 6.2284. Total cost saving will thus amount to US$ 59,269 per year.

Figure 5.13: Cost Reductions (Blade Life & FBGA Reject Rate)



5.4.1.5 Total Cost Savings

There is no impact to the singulation machine capacity because of the increased machine performance with less maintenance time has sufficiently cover for the loss of UPH when using a 4 channel cutting sequence. Total cost saving can be calculated by adding the blade cost reduction and the FBGA unit cost saving to arrive at US$ 147,201 per year.

5.4.2 Intangible Benefits

5.4.2.1 Support Zero Catastrophic Prevention Plans

The impact of blade breakage has the potential of generating micro cracks on FBGA packages, or the internal die. These fine hairline cracks have high potential of escaping final visual inspection at the assembly process, and be released as good products to subsequent processes, or even to AMD customers. The stress applied onto the packages at later processes, or during transportation may cause the cracks to propagate even further, and at some point the device may not be functional, or fail in the field. This is a situation that posts serious product reliability concerns, and can be a catastrophic issue for the IC manufacturer if it occurs at customer sites.

5.4.2.2 Elimination of Spindle Seizure

Elimination of blade breakage also eliminates spindle seizure due to unbalanced loading on the spindle shaft due to partial breakage of blades. In worst scenario, spindle seizes to rotate and a replacement of new spindle is required. The result from this phenomenon will potentially shutdown the whole FBGA production line as the IC manufacturer has only one singulation machine and operates as a modular manufacturing line. On top of this the IC manufacturer has to absorb the high cost for a new spindle assembly.

5.4.2.3 Reduction of Rework

Technicians and operators do no longer have to spend much effort and time on reworking uncut/partially cut strips due to blade breakage, and utilize that time for other more productive tasks.

5.4.2.4 Support Ball Inspection Sampling Project

The impact of the project has improved package yield, and thus is a key factor in justification of CSP ball inspection sampling proposals.

5.4.2.5 Improved Technical Skills on Dicing Dynamics

The brainstorming sessions and work related to this project, has improved the technical skills, and team efforts, of all related functional departments and vendors for solving problems related to the singulation process.

5.4.2.6 Cycle Time Reduction

The improved machine performance, with improved MTBA, and less maintenance time, has greatly contributed to production achieving the cycle time targets.

5.4.2.7 Standardization

The new methodology is shared with AMD sister plant in Penang, Malaysia and has been used as a standard process throughout AMD.

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CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The flash memory market has been growing rapidly in year 2000. The optimistic outlook for Flash memory is based on several key factors that include technological superiority over many existing products, increasing popularity of consumer electronic items, and much higher demand than can be presently met.

One of the recent IC packages that have emerged is the FBGA (fine pitch ball grid array) as the new CSP (Chip Scale Package) of choice for flash memory devices. A "CSP" is an integrated circuit package with dimensions equal to or slightly larger than those of silicon chip size. The FBGA smaller form/fit factor saves considerable board space and provides a lower profile – all of which is needed when trying to cram more memory capacity onto ever smaller mother boards, or in product striving to fit into the palm of human's hand. Developing CSP technology is nowadays the preferred solution to meeting semiconductor-packaging needs.

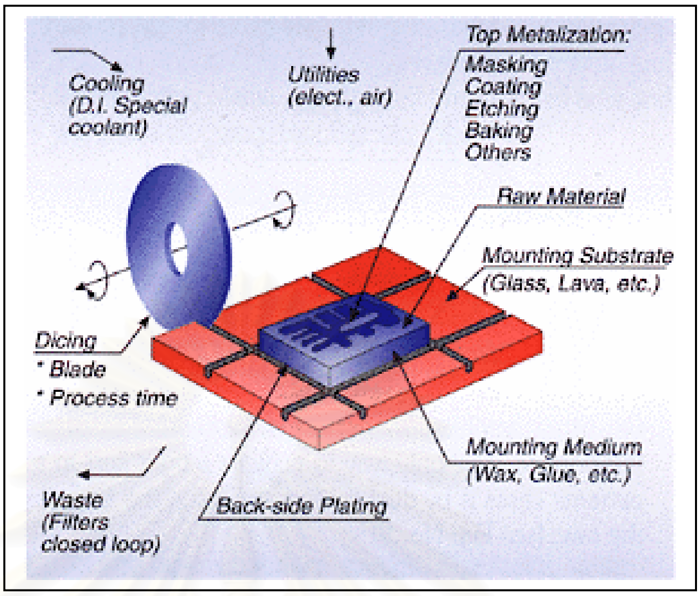
The FBGA assembly process consists of several processes with singulation as the last process step. The singulation process cuts the substrate into several individual units as final product. This research used the Intercon SBS-8800 saw singulation system as the main equipment for evaluation. The system consists of a dicing machine and a handler integrated together as one fully automatic BGA saw singulation system.

The total cost of ownership for CSP singulation process is a factor of all the production processes and raw materials involved in the dicing process as illustrated in Figure 6.1

Since the dicing process has a major impact on the die cost it must be optimized in order to reduce the costs. Failing to reduce the dicing cost may cause the product to become obsolete. The following are parameters affecting the dicing process costs:

- Direct Materials (Molded FBGA Substrate)
- Blade Cost (Blade Breakage/Wear)
- Speed of the dicing process (Machine Capacity)
- Mounting material (Nest fixtures)
- Utilities (Electricity, Air, Water, Nitrogen, Vacuum)
- Waste Handling (Scrap removal, Cutting Debris)
- Initial investment (Capital cost or Equipment)
- Labor cost
- Process yield

Figure 6.1: Cost of Process (Levinson, 1996)



Dicing blade is one of the highest indirect materials costs in CSP singulation process and for this reason it is necessary to have an optimized process to achieve the expected cutting quality and blade life.

The first phase of the research focuses on selection of dicing blades and cutting application of CSP. The evaluation was carried out prior to production start up of CSP Singulation process. Disco's metal bonded serrated blade #400, M51 with fine diamond grit size (40 micron) was found to be the most appropriate blade for this CSP application. This blade had achieved the expected target for both top and backside chipping size, acceptable spindle loading, and sufficient blade wear for self-sharpening of the diamonds. Blade thickness of 350 micron is used in order to meet the package dimension nominal target. The serration allows more cooling water to get into contact with the cutting surface, and provides more efficient cooling method. This reduces the loads, improving the cooling of the blade and substrate. The blade life is limited by the package dimension specification limits not the serration height. Blade dressing for new blades is also required to remove excess binder materials and exposed new diamonds to achieve better cutting quality.

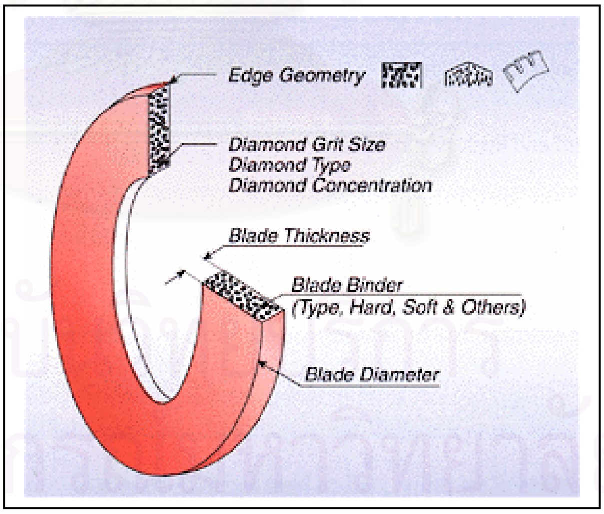
The second phase of the research involves a team work effort with participants from related department and vendors to find solutions to solve yield problems at the singulation process after CSP has gone through continuous assembly production. Resolving blade breakage problem is the major objective that the research focuses on. The methodology involved conducting brainstorming sessions to identify possible causes of blade breakage and recommend potential solutions. The potential solutions and various alternatives were developed by applying a cause and effect analysis together with FMEA (Failure Mode Effects Analysis). The factorial design of experiment led to the conclusion that a combination of 4 channel cutting sequence and dual high-pressure nozzle design has successfully eliminated blade breakage and minimized dented ball rejects caused from remaining scrap on nest. There is zero blade breakage after implementation in production mode and from ANOVA analysis indicates no impact on cutting quality from the changes. The Cpk of critical parameters such as package dimensions and ball array offsets also meet the expected goal of 1.5

The benefits from the research is able to reduce the rejects caused by blade breakage, improved on the blade life, reduced machine maintenance time and potential of spindle seizure, meeting production target schedules, and most critical of all benefits is to minimize the chance of having any crack or micro crack FBGA package escapes to IC manufacturer customers. The cost impact from this research is able to save the IC manufacturer US$ 147,201 per year.

6.2 Recommendation

Further improvement of blade life is currently under investigation through the possibility of using a thicker saw blade of 370 microns – Refer to Figure 6.2. The current FBGA blade life is usually determined by the package dimension specification. The package dimension usually is at the rear end of specification towards the end of the blade's life. Therefore, by implementing a thicker blade will enable to make full use of the 100 microns specification tolerance and should result with extended blade life. A thicker blade is also more robust and has less potential of blade breakage.

Figure 6.2: Blade Characteristics (Levinson, 1996)



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APPENDICES

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APPENDIX A.

Guidelines to Severity
Evaluation Criteria and Ranking
(Shah, 2000)

Effect	Criteria: Severity of Effect	Ranking
Hazardous-Without warning	May endanger machine or operator. Failure will occur without warning.	10
Hazardous-With warning	May endanger machine or operator. Failure will occur with warning.	9
Very High	Major disruption to production line. 100% of product may have to be scrapped. Loss of primary function. Customer very dissatisfied.	8
High	Minor disruption to production line. Product may have to be sorted and a portion (less than 100%) may have to be scrapped. Customer dissatisfied.	7
Moderate	Minor disruption to product line. A portion (less than 100%) of the product may have to be scrapped (no sorting). Customers experience discomfort.	6
Low	Minor disruption to production line. 100% of product may have to be reworked. Customer experiences some dissatisfaction.	5
Very low	Minor disruption to production line. Product may have to be sorted and a portion (less than 100%) reworked. Defect noticed by most customers.	4
Minor	Minor disruption to production line. A portion (less than 100%) of the product may have to be reworked. Defect noticed by average customers.	3
Very Minor	Minor disruption to production line. A portion (less than 100%) of the product may have to be reworked. Defect noticed by discriminating customers.	2
None	No effect.	1

Note: Team should agree on an evaluation criteria and ranking system, which is consistent, even if modified for individual process analysis.

APPENDIX B.

Guidelines to Occurrence
Evaluation Criteria and Ranking
(Shah, 2000)

Probability of Failure	Possible Failure Rates	Cpk	Ranking
Very High: Failure is almost inevitable	$\geq$1 in 2 1 in 3	<0.33 $\geq$0.33	10 9
High: Generally associated with processes similar to previous processes that have often failed.	1 in 8 1 in 20	$\geq$0.51 $\geq$0.67	8 7
Moderate: Generally associated with processes similar to previous processes which have experienced occasional failures, but not in major proportions.	1 in 80 1 in 400 1 in 2000	$\geq$0.83 $\geq$1.00 $\geq$1.17	6 5 4
Low: Isolated failures associated with similar processes	1 in 15,000	$\geq$1.33	3
Very Low: Only isolated failures associated with almost identical processes	1 in 150,000	$\geq$1.50	2
Remote: Failure is unlikely. No failures ever associated with almost identical processes.	$\leq$ 1 in 1,500,000	$\geq$1.67	1

Note: Team should agree on an evaluation criteria and ranking system, which is consistent, even if modified for individual process analysis.

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APPENDIX C.

Guidelines to Detection Evaluation Criteria and Ranking (Shah, 2000)

Detection	Criteria: Likelihood the existence of a defect will be detected by process controls before next or subsequent process, or before part or component leaves the Manufacturing or Assembly location	Ranking
Almost Impossible	No known control(s) available to detect failure mode	10
Very Remote	Very remote likelihood current control(s) will detect failure mode	9
Remote	Remote likelihood current control(s) will detect failure mode.	8
Very Low	Very low likelihood current control(s) will detect failure mode.	7
Low	Low likelihood current control(s) will detect failure mode.	6
Moderate	Moderate likelihood current control(s) will detect failure mode.	5
Moderately High	Moderately high likelihood current control(s) will detect failure mode.	4
High	High likelihood current control(s) will detect failure mode.	3
Very High	Very high likelihood current control(s) will detect failure mode.	2
Almost Certain	Current control(s) almost certain to detect the failure mode. Reliable detection controls are known with similar processes.	1

Note: Team should agree on an evaluation criteria and ranking system, which is consistent, even if modified for individual process analysis.

APPENDIX D.

Definitions of Terms Used in FMEA Form
(Shah, 2000)

(1) FMEA No.	Enter the FMEA Number. **Example : BA00001A (for PMEA by Bangkok Assembly plant, revision A)**
(2) Item	Enter the name and number of the system, subsystem or component, for which the process is being analyzed. **Example : PLCC**
(3) Process Responsibility	Enter the department and group. **Example : Test**
(4) Key Date	Enter the initial FMEA due date, which should not exceed the scheduled start of production date. **Note : Enter "NA" for existing processes**
(5) Core Team	List the names of the responsible individuals and departments, which have the authority to identify and/or perform tasks.
(6) Process Function/ Requirements	Enter a simple description of the process or operation being analyzed **Examples : Test, Bake, Final VM**
(7) Potential Failure Mode	Define the manner in which the process could potentially fail to meet the requirement. It is a description of the non-conformance at that specific process or operation being analyzed. It can be a cause associated with a potential failure mode in a subsequent (downstream) operation. **Examples : Crack package, mixed device, bent lead, wrong mark**
(8) Potential Effect(s) of Failure	Define the effects of the failure mode on the customer (could be the next subsequent operation). The effects of the failure should be described in terms of what the customer(s) might notice or experience. **Examples : Yield lost, board mount problem, intermittence operation**

(9) Severity	Assess the seriousness of the effect listed in the potential effect of failure column. Severity should be estimated on a "1" to "10" scale. The team should agree on evaluation criteria and ranking system, which is consistent, even if modified for individual process analysis.
(10) Classification	This column may be used to classify any special process characteristics (e.g., critical, key, major, significant) for product or systems that may require additional process controls. If a classification is identified in the process FMEA, notify the design responsible engineer since this may affect the engineering documents concerning control item identification.
(11) Potential Cause(s)/ Mechanism(s) of Failure	Define how the failure could occur, should describe in term of something that can be corrected or can be controlled. **Example : Jamming at input loader**
(12) Occurrence	Estimate how frequently the specific failure cause/mechanism is projected to occur. Estimate the likelihood of the occurrence on a "1" to "10" scale. The team should agree on evaluation criteria and ranking system, which is consistent, even if modified for individual process analysis. Recommended to ranks with the number of failures during the process execution **Example :PPM, Cpk**
(13) Current Process Controls	Description of the controls that either prevent to the extent possible the failure mode from occurring, or reduce their rate of occurrence, or detect the failure mode should it occur and lead to corrective action. These control can be process control **Example : Periodic preventive maintenance, Real time oven monitoring**
(14) Detection	An assessment of the probability that the proposed current process controls will detect a potential cause/mechanism, or will detect the subsequent failure mode, to prevent shipment of the part having this failure mode or defect. A "1" to "10" scale is used. The team should agree on evaluation criteria and ranking system, which is consistent, even if modified for individual process analysis.

(15) Risk Priority Number (RPN)	The product of severity, occurrence, and detection rankings. RPN = Severity x Occurrence x Detection This value should be used to rank order the concerns in the process (pareto fashion). For higher RPN's the team must undertake efforts to reduce this calculated risk through correct action(s). However, in general practice, regardless of the resultant RPN, special attention should be given when severity is high.
(16) Recommended Action (s)	The intent of any recommended action is to reduce the severity, occurrence, and/or detection rankings. If no actions are recommended for a specific cause, then indicate with a "None" in this column. **Example : Integrate vision system, implement bar code system**
(17) Responsibility/ completion date	Enter the organization and individual responsible for recommended action and the target completion date. **Example : WW9932 or Feb 17, 2000** **Note : Target completion date by month or quarter, (example "March" or "Q100") is not acceptable. Target completion date should include impleentation and data collection period**
(18) Action Taken Results	After an action has been implemented, enter a brief description of the action and effective date.

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APPENDIX E.

FMEA Form (Shah, 2000)

AMD Spec Ref : 08-073	Item : Process Responsibility : Prepared By : Key Date : Core Team :	**FAILURE MODE AND EFFECT ANALYSIS** ❑ Design FMEA ❑ Process FMEA ❑ Containment FMEA

FMEA No. :
FMEA Original Date :
FMEA Revised Date :
Page : of

Process Function Requirements	Potential Failure Mode	Potential Effect(s) of Failure	SEV	CLASS	Potential Cause(s) of Failure	OCC	Current Process Control	DET	RPN	Recommended Corrective Action(s)	Responsibility and Target Completion Date	Action Results				
												Action Taken	SEV	OCC	DET	RPN

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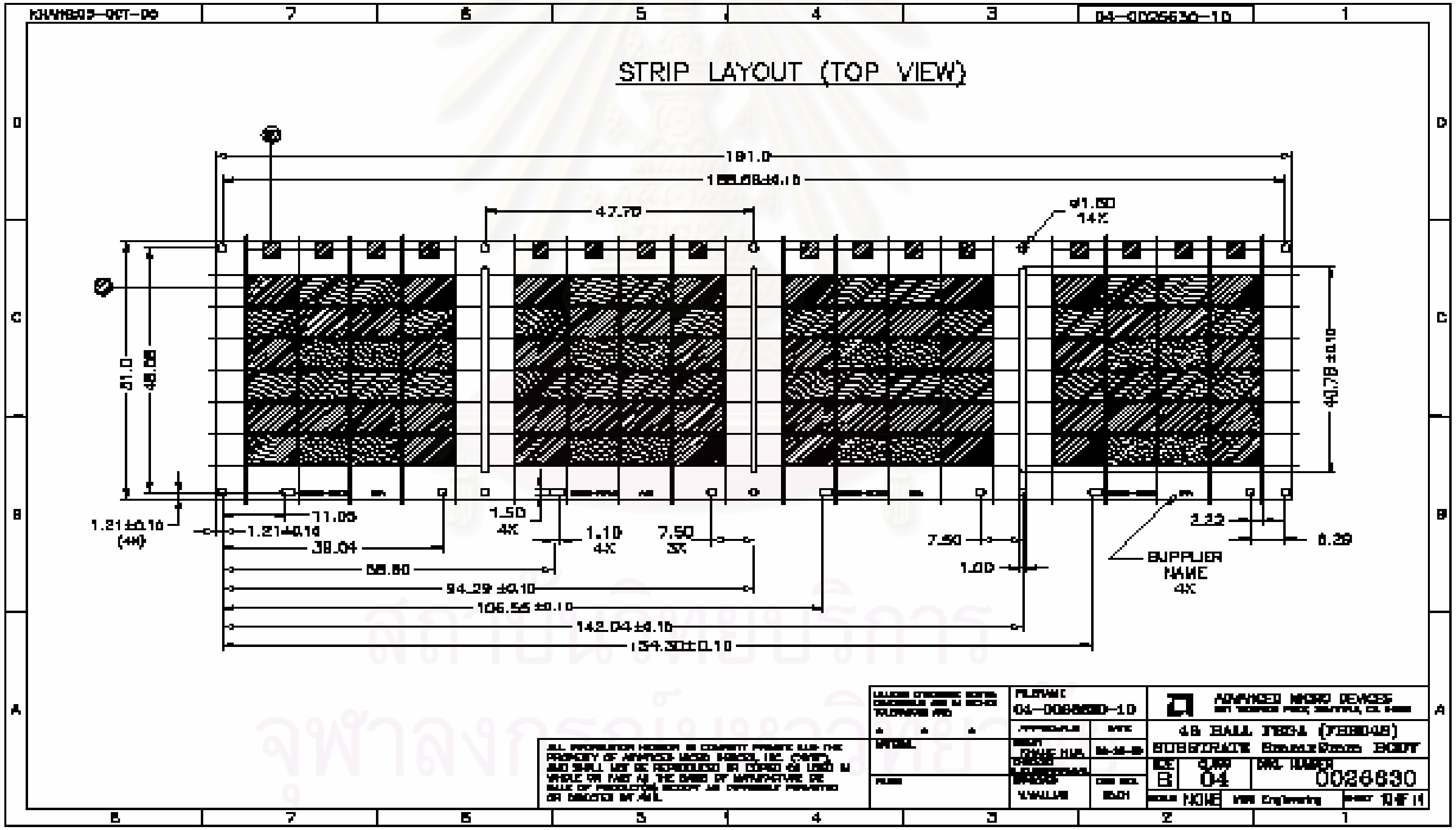
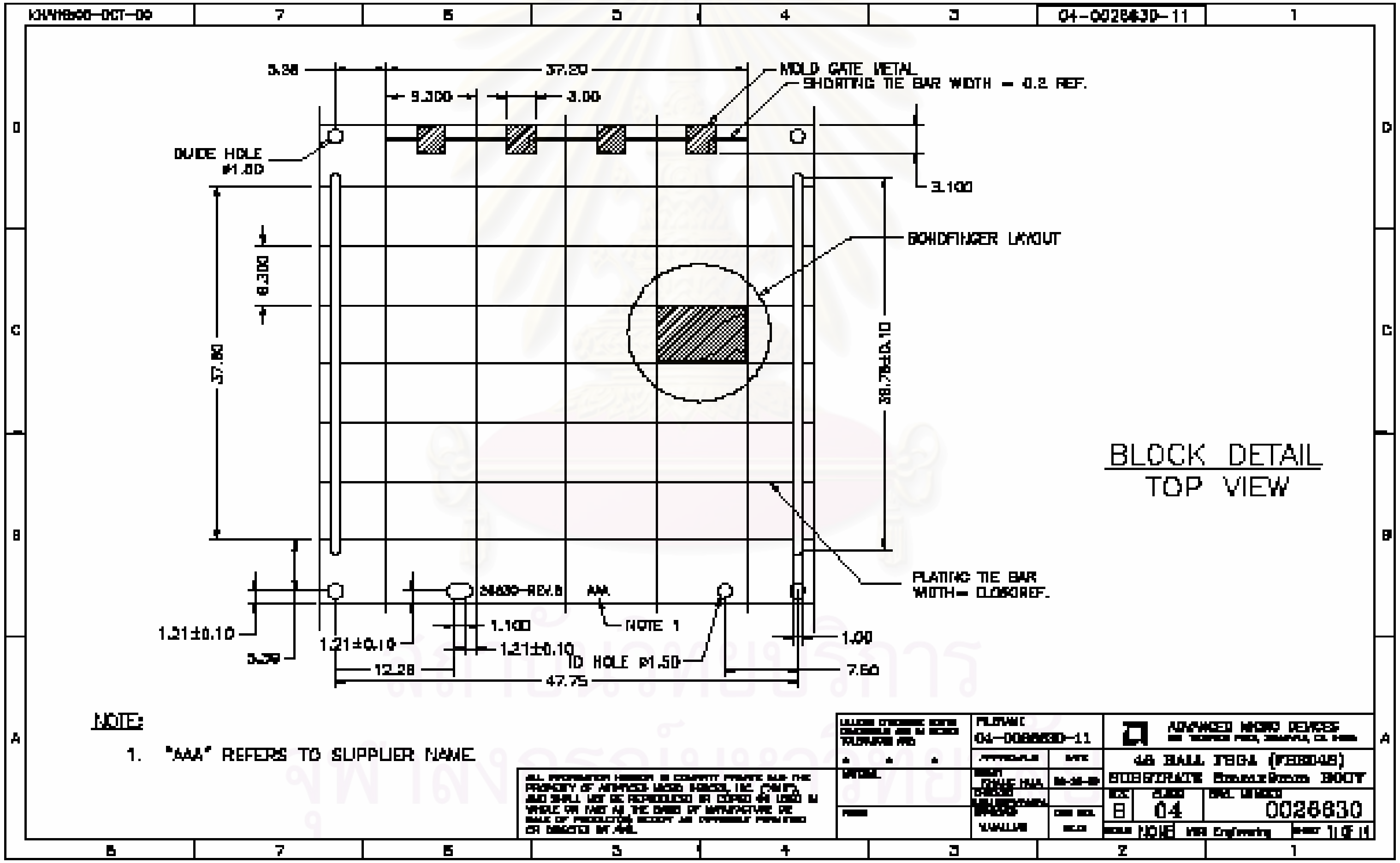
APPENDIX F.

FBGA 6X9 Substrate Layout (Hua, 1999)



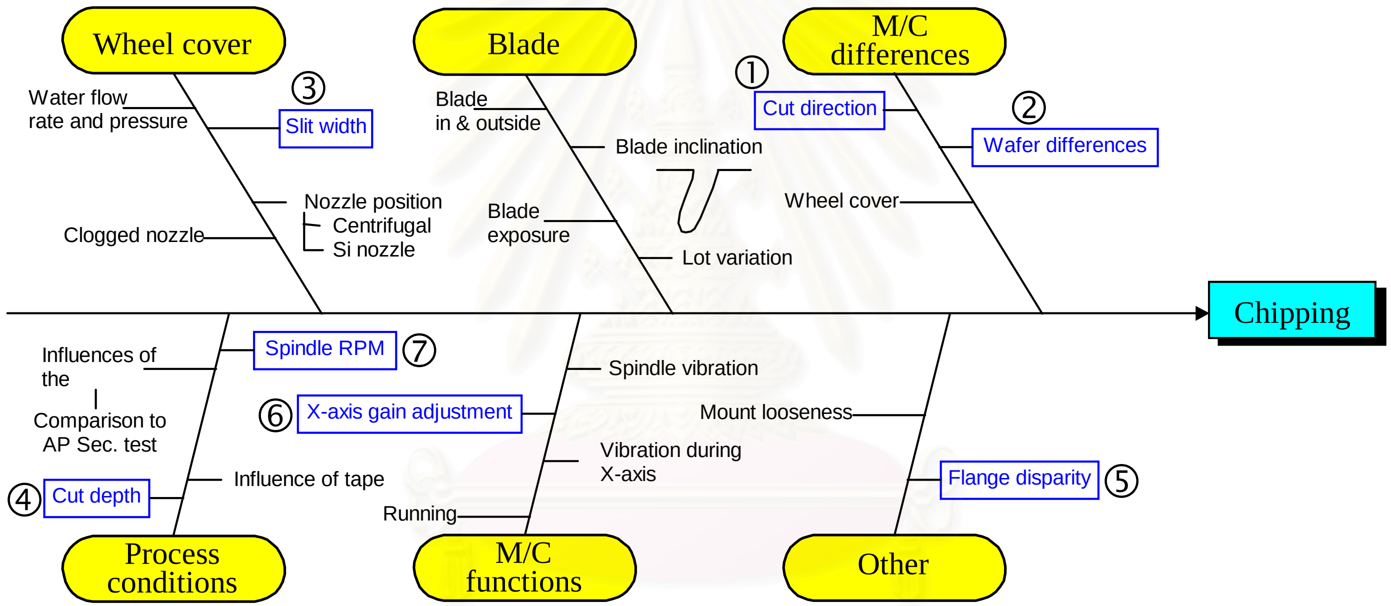
APPENDIX G.

FBGA 6x9 Block Detail (Hua, 1999)



APPENDIX H.

Blade Trouble Tree Diagram (Disco Overseas Sales Div. OTS/AP/ Engineering Dept., 1995)



Past Experience **Customers**

1. Resolved by standardizing direction of cutting
2. Confirmed differences in the identical devices --- Influence of dummy or product wafer
3. Influence of nozzle installation --- Slit width, Centrifugal type
4. Confirmed of cut depth into the tape --- Confirmed by visual observation without reliance on data
5. Type of flance used --- Differences of M and F types
6. X-axis gain adjustment
7. Increased spindle RPM

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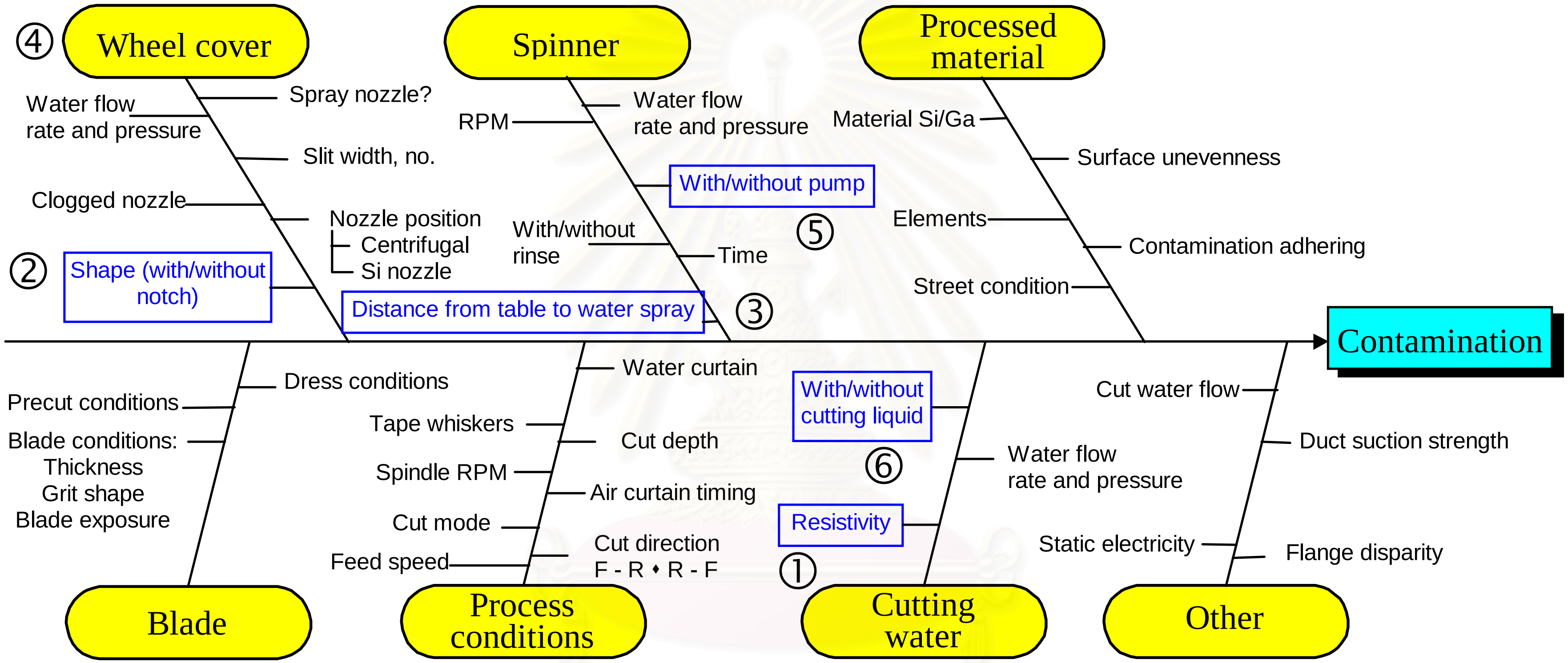
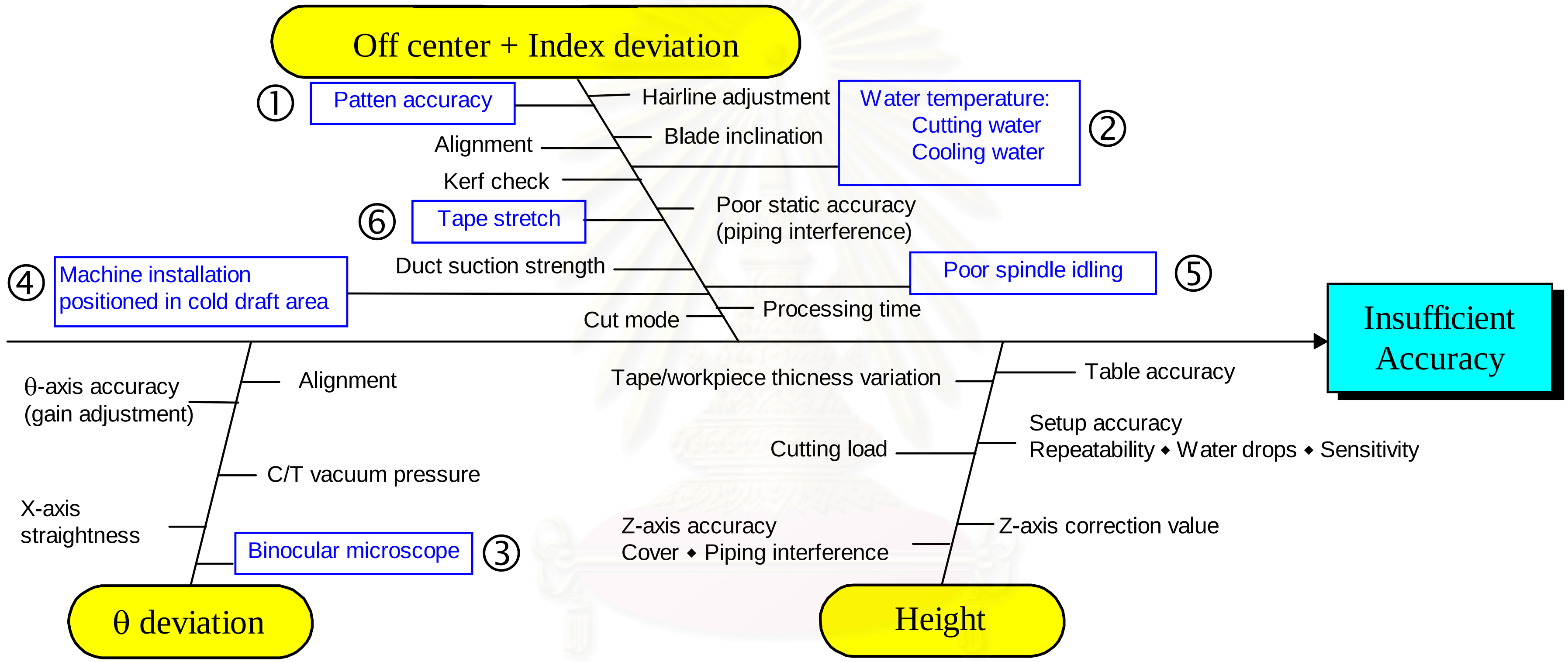


Past Experience

1. Influence from static electricity (Using super D. I. water as cutting water) --- Utilize CO_2 bubbler
2. Improved by changing the wheel cover --- Changed to notch wheel cover
3. Changed spinner nozzle position --- Changed from 25 mm to 12 mm distance from the table surface
4. Changed to high pressure nozzle (Changed wheel cover)
5. Cleaning water not emitted --- Due to having used high pressure nozzle with normal pressure
6. Resolved by using cutting liquid

Customers



Past Experience

1. The accuracy of workpirce pattern was poor --- Accumulated pitch was bad
2. Cutting water temperature control was not carried out
3. Poor installation of binocular microscope
4. Machine was installed directly below an air conditioning machine
5. Insufficient spindle idling
6. Influence of tape stretch --- Take care when full cutting with small index

Customers

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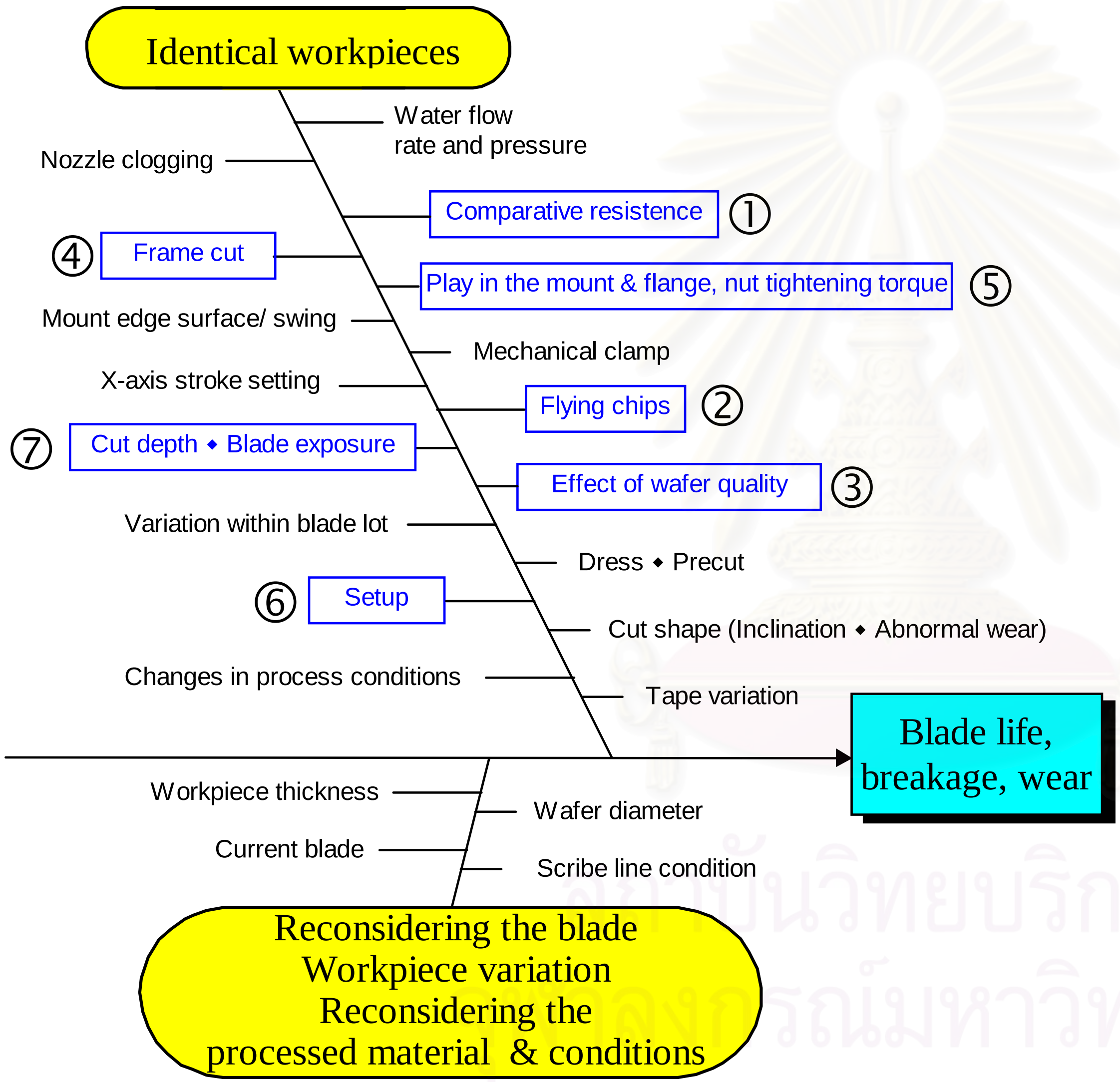

1. Blade dissolving
- Rise in the ph due to cutting water circulation
- Take care that comparative resistance is 0.5 M or less

2. Breakage from flying chips
- Reexamine the tape

3. Wafer external surface condition(Oxidized membrane ◆ Nitride membrane)
   - Change the blade
   - Change the blade exposure
4. Cutting of the frame clamp
   - Confirm rotation position
   - Check for changed shape of parts
5. Poor hub wheel mount accuracy
   - Axial diameter enlarged due to abrasion
6. Blade breakage after setup (C/T setup)
   - Initiate precut
   - Reexamine cutting conditions
7. Handling due to blade thickness
   - When blade thickness is 15 um or less, decrease water amount:

   Silicon nozzle: 1.0 l/min or less
   Centrifugal nozzle: 0.8 l/min or less

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APPENDIX I.

Blade Life Comparison between
3 Channel and 4 Channel Saw Sequence

JMP - [blade life 3CH vs 4CH]

File Edit Tables Rows Cols Analyze Graph Tools Window H

2 Cols / 30 Rows	Bade life 3CH (lines)	Blade llfe 4CH (lines)
1	1429	12590
2	3832	11912
3	2000	9845
4	11776	12850
5	11451	14727
6	755	11488
7	3682	12553
8	3828	12099
9	5000	10375
10	2676	11937
11	10206	12504
12	1725	11447
13	4972	11481
14	537	13395
15	3929	10398
16	2698	11234
17	3260	12504
18	2401	12501
19	13747	12772
20	12507	12423
21	11011	12369
22	1132	12342
23	12507	12504
24	192	12504
25	3562	13102
26	4539	10668
27	?	12524
28	?	11732
29	?	12238
30	?	12699

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BIOGRAPHY

Prakorn Vijchulata was born on July 10th, 1973 in Bangkok, Thailand. He graduated from Kasetsart University in 1995 with a Bachelor degree in Electrical Engineering. In 1995, he was employed by AMD (Thailand) Ltd., a leading Integrated Circuit (IC) manufacturing company, to work as a process engineer. In 1998, he studied for Master of Science in Engineering Management at the Regional Centre for Manufacturing Systems Engineering, Faculty of Engineering, Chulalongkorn University and University of Warwick, U.K. He is currently working for AMD Thailand and is actively involved in new package development projects.

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