Design of Experiment on Ultra Violet Curing Die Attach Film by Using Taguchi Method to Optimize Quality

By

ROSHIDA HASSAN JAMIL

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Technology (Hons)
(Mechanical Engineering)

JAN 2008

Supervisor:
MR.HJ KAMAL ARIFF ZAINAL ABIDIN

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuàn

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ROSHIDA HASSAN JAMIL

CERTIFICATION OF APPROVAL

Design of Experiment on Ultra Violet Curing Die Attach Film by Using Taguchi Method to Optimize Quality

by

Roshida Hassan Jamil

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

(Mr.Hj.Kamal Ariff Zainal Abidin)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2008

ABSTRACT

The highly growth on semiconductor manufacturing field makes the expertise on the semiconductor manufacturer industry keep on struggle to create higher speed, smaller, highly integrated and more reliable and powerful chips for various needs. The new technology in making chips process continuously developed to produce goods semiconductor. Product and process optimization was a crucial part in manufacturing production line to produce high volume throughput with reducing in lead times, engineering changes and development cost but with higher quality. Engineering particularly decisions be the most important side in making the process properly in reaching the zero defect target. Every single thing has to be concerned, whether it is from technical parts to managerial parts in order to ensure the process going smoothly and efficiently with excellent quality. For this project, I am going deeper inside the chips assembling process whereby the post Ultra Violet curing process on Die Attach film, DAF tape have been experimented by using Taguchi approach for the process to produce better chips on stacked die package. An application of experimental design, based upon the works of Dr.Genichi Taguchi was conducted at the die attach film (DAF) curing operation. The experiment focused on parameter design, the determination of the DAF operation parameters that significantly affect the quality and semiconductor chip reliability of the wafer mounted on wafer ring during curing and selecting the optimum parameter level combination. In semiconductor manufacturing industry, the usage of epoxy resin bleed is no longer convenient in producing thin die stacked package with high volume. Hence, industry in about to move to the Die attach film (DAF) tape type to replace with the epoxy resin bleed. The new process should the tape go through is UV curing process, indeed the characteristics of the tape adhesion affecting much to yield and quality. Parameter optimization has resulted to a reduction in die defects and adjustment of the mean to the nominal of zero defects for all the quality characteristics. Continuations on the optimizing UV curing DAF tape process is moving on with the inspection data gathered which is die shear strength, top and flip side chipped and tape residue whiskering. Furthermore, evaluation effect onto the process which is the die shear strength test, inspection has been taken into account particularly. Proper planning on the

control factors and responses for the process were managed accordingly by using Taguchi approach for necessary information. Implementation of the optimum condition has resulted to about 50% reduction of defects and failures.

ACKNOWLEDGEMENT

First of all, I would like to express my deepest gratitude to God The Mightiest for His blessing and guidance for me in completing my final year project in UTP.

My honest appreciation goes to UTP, mechanical engineering department, final year project coordinator, my Supervisor; Mr.Hj Kamal Ariff Zainal Abidin for their effort in supervising and guiding me towards being a final year student to finish my final year project. They deserve my respect for their fair assessment and intensive assistant throughout these final year semesters.

My sincere thanks to Pn. Zurina Zulkiffly, engineer from Texas Instruments (M) Sdn.Bhd for her guide and gives opportunity to me to finish my final year project. I really appreciate her precious guide throughout implementing the experiment in the real industry.

Thousand of appreciations are also extended to all staffs from Texas Instruments (M) Sdn.Bhd for their full support, kindness, assistance, guidance and criticisms during ongoing my final year project there.

Last but not least, to anyone who has assisted me directly or indirectly in making my final year project a success, thank you very much. May God repay your kindness.

TABLE OF CONTENT

LIST OF FIGURES AND TABLES

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Design of experiments is a systematic approach to solving problems and improving processes using statistical principles and scientific experimentation methods. Design of experiment is a way to obtain maximum information about a process or problem in order to make a good business decision, but achieves this through minimum expenditure of resources. The design of experiment is most efficient way to optimized product and process settings. Furthermore, it is a basic concept and relatively easy to learn. Additionally, the design of experiment is effective at several stages of improving quality and development process where it can drastically reduce costs. On the whole, this technique is one of the major quantitative tools in industrial decision making.

In conjunction with supporting future highly growth in electrical technology field making the expertise integrated circuit industry keep on struggle to create higher speed, various functional, smaller, highly integrated and more reliable and powerful chips for various needs. Demand for software embedded in semiconductors is expected to grow in fields such as automotive electronics, mobile handsets and information appliances. This industry has been exposed to global competition which thus thrown a challenge to produce world class quality products at globally competitive price. The new technology in making chips process continuously developed to produce goods semiconductor to reach competitive advantage. In this manner, the Semiconductor manufacturing industry aims to improve its operating results by offering innovative solutions, while boosting development and production efficiency. Therefore, Product and process optimization was a crucial part in manufacturing production line to produce high volume throughput with reducing in lead times, engineering changes and development cost but with higher quality. Engineering particularly decisions be the most important side in making the process properly in reaching the zero defect target. Inside of semiconductor manufacturing assembly line, there were a sequence processes to build up the various package of semiconductor chip. One of the new packages is stacked die thin quad flat no-lead, which small thin die will be stacked with larger thin die whereby research and development focused on high performance packaged products.

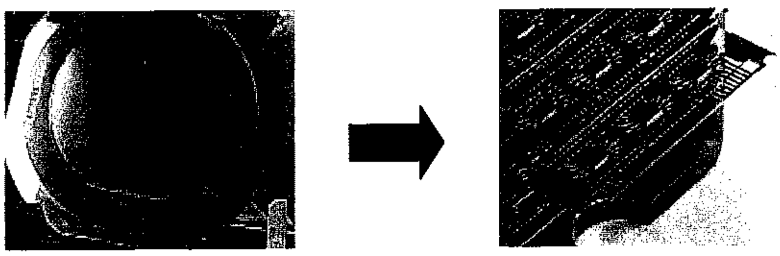


Figure 1: die attach processing

A review of past die attach technology will establish a fundamental understanding of the importance of die attach adhesive to the majority type of package array. However, nowadays they are looking for higher alternatives material to eliminate bake process after attach die with epoxy. The application of die attach paste resin is no longer go well with certain type of package such thinned and stacked die package type. Hence, developing the new die attach film (DAF) engineering technology for thinned and stacked die package would be an extensive development process of die attach adhesives. The improvement is to resolve outstanding issue and provide total solution regarding the die attach adhesive to attach die with leadframe are well fit.

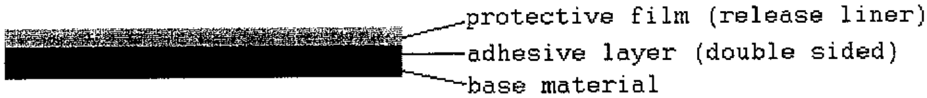


Figure 2: Die attach film tape structure

Die attach film (DAF) is one of adhesive materials in film types. The structure of DAF is as shown in figure 1 above. These adhesives have been developed as multifunctional tape with consist of the double function which is providing adhesion for the wafer during dicing and providing the adhesive for die attach to substrate. The die attach film (DAF) applied to the backside of wafers prior to saw offers a breakthrough in die attach technology by eliminating the epoxy dispense process step in the assembly line. DAF available in two forms, which is DAF with dicing tape: 2-in-1 tape and do not need to be mounted onto a separate dicing tape and DAF without dicing tape: must be additionally mounted to another dicing tape. The die attach film used to be applied in stacked die package since the die is very thin to hold up the failure cause by thin die. Stacked die package is the package where the smaller die is being stacked on top of bigger size of die and has the advantage of higher packaging density and better performance. Furthermore, stacked dies bonded with DAF have a 20% higher die strength than stacked dies bonded by paste material.

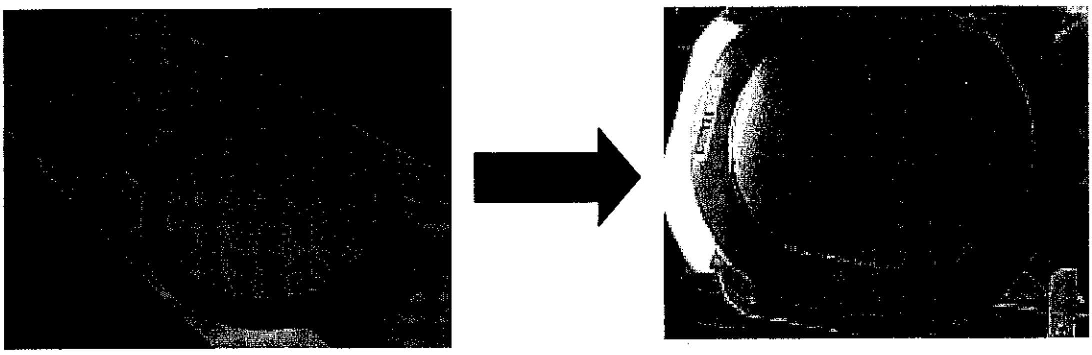


Figure 3: Mounted wafer on DAF tape and precut DAF tape

Die attach film (DAF) is a new generation of die attach material use for thin die stacked package with thickness below than 100μm. Replacing paste bleed resin with film type adhesion in stacked die package for its good control of paste bleed, creeping effect to die edge and also consistent bond layer thickness at desired thickness. The adhesive on these tapes have the double function of providing adhesion for the wafer during dicing and also providing the adhesive for die attach to substrate. DAF has many advantages including no die tilt, no voids, consistent bond line, no bleed-out, and no fillet which improves the real estate on the substrate. The critical criteria of the DAF tape are the heat resistant. Moreover, to ensure every unit of the chips pass the delaminating test analysis, hence, we need to avoid pore pressure, because it will cause delamination and heat trap. A fully cured DAF tape will exhibit a constant reaction ratio at 100% indicating no-cross linking is taking place. The purpose is to minimize delamination between die to die interfaces.

UV curing technology is very effective for controlling the pressure sensitive adhesive properties of acrylic adhesive, because mechanical properties, surface tension and miscibility are dramatically changed by UV irradiation. The input factors affect the response and necessary to quantify the effect. Manipulating the levels of the control factors will gives different response to the workpiece. Thus, we could conclude which level gives best quality result to the workpiece. The input controllable factors for this experiment are power, temperature, intensity and time.

The response of the experiment is the top and flip side chipped, die shear strength and tape whiskering. We will measure the defects on both sides of die having chipped which is top and flip side. There will be 30 reading per run. Another response is die shear strength testing, upon the strength of adhesion of a semiconductor die to the package's die attach substrate which is lead frame., by subjecting the die to a stress that's parallel to the plane of die attach substrate, resulting in a shearing stress between die-die attach material interface and the die attach material-substrate interface. Last response is whiskering,

Standard process

For current standard process the grinded wafer will undergo normal mount process with conventional tape. The workpiece then will be bake to strengthen the adhesiveness between back wafer and the tape. Next, mounted wafer is to be cut to the specific die size followed by die bond process whereby the die is being transfer from workpiece and place on the leadframe by fully automatic equipment.

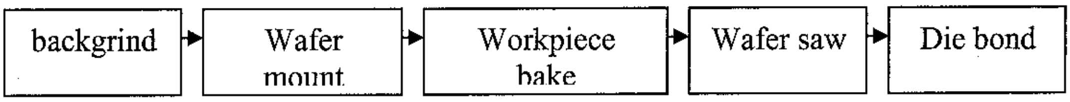


Figure 4: standard conventional flow

New technology process

For the new technology to produce a large volume of number for stacked die the stable equipment was the one of the factor to realizing the robust production cycle. Meant for that to cover up the backgrind, DAF mount process and UV cure it will be done under integrated equipment which is Accretech PG200RM. Equipment Accretech PG200RM is also working on to the next step after the wafer has been thinned or the standard process grinding to produce stacked packages. For die attach film, the UV cure for standard process is still an issue, heat resistance protection tape is under development.

Figure 5: Proposed Thinned and Stacked die process flow

1.2 Problem Statement

The manufacture of integrated circuits or IC involves a die attach stage in its assembly process. Additionally, in developing stacked die package, the critical part is on how to stack the die without giving problem on resin bleeding, inconsistent bondlines thickness, voids and fillet around the side wall. Die attach adhesives has die thickness limitation to allow it to be used for die bond process, meanwhile die attach film has specialization on handling very thin die. The thin die is easier to handle with mounted to die attach film as the wafer will go through assortment of processes. Furthermore, bleeding, rolling up, inclination and popcorn problem are the obvious defects occur in current processing for die attach process.

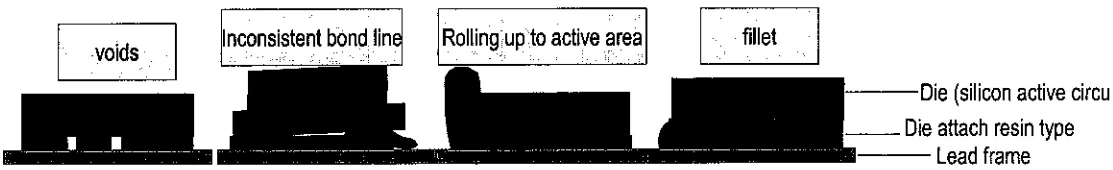


Figure 6: Problem in current processing for stacked die package

In addition, the die attach epoxy type will contribute to delamination problem especially on stacked die package. Delamination is the condition in which a gap forms in the interface between two previously bonded surfaces on stacked die. Delamination is a serious problem because it causes failure in wire bonds, 'pop corn' type failures due to moisture entrapment and sometimes electrical failure due to a reduction in thermal or electrical conduction. However, the factors which evolve from the die attach epoxy, also contribute to delamination such as voids, moisture absorption, resin bleed, volatile deposition, modulus of elasticity and the adhesion.

The thin wafers mounted on die attach film (DAF) for stacked die package were subjected to proper UV curing to avoid issues like dies flying off from the wafer during dicing, adhesive whiskering and adhesive merging after dicing. Therefore, the UV cure is the crucial process step the wafer should undergo to ensure the ideal adhesiveness of die attach film (DAF) is achieve. Design of experiment on the UV cure process will be implement to get the best process parameter on it.

The overall performance between the both systems has been observed for further studies. From the observation, found that DAF tape system gives better performance compared to conventional resin paste method. Therefore, its worth to develop the DAF tapes technology to increase quality. The observation result is as follows:

Item	DAF tape system	conventional resin paste method
Die bonding adhesive	Not necessary	Required
Storage condition of adhesive	Room temperature	Freeze
Formulation of adhesive layer	Uniformity of amount	Dot patterning
Adjustment of bonding tool for chip size	Not necessary	Required
Die mounting condition (Method, Temperature)	Direct bonding after picking up process, required	Not necessary
Bleeding	No	Possible

Table 1: The comparison between DAF tape system and conventional resin paste method

1.3 Objectives

The purpose of product and process development is to improve the performance characteristics of the product or process relative to customer needs and expectation. The purpose of experimentation should be to reduce and control variation of a product or process, subsequently, decisions must be made concerning which parameters affect the performance of a product or process. In general, the objectives of the design of experiments are to identify and confirm which input factors have effects on our processes and products, determine process settings for optimal results, and allow developing robust products and processes. The present work aims at studying the optimum parameters for UV curing operation on DAF tape for stacked die package, for robust design so that it achieve a minimum reliability performance under IPC/JEDEC moisture sensitivity level 3 (MSL3) at reflow 260°C which is the standard analysis reliability test for semiconductor. The DAF tape has to be fully cured so that the material property reach optimum hardened level to endure the repeated heat cure during die attach process which may effect the material property. Thus, heat resistance of a DAF has always been the key material property that is taken care of. Low modulus DAF is desired for the die package in this experiment to reduce warp and for better stress relaxation during temperature cycle test. From the objective stated above, the project has high relevancy to the problem and the scope of research is done focusing on developing process parameter by using Taguchi approach. The author will also study on the elements, factors and effects that will make a good design of experiment and how to reflect the company development for new packaging.

After identifying the problems, the author would like to come up with a set of the process parameter for the curing die attach film process in stacked die package to optimize the overall process involved in manufacturing semiconductor.

The objectives of research project are:

1. To understand the different between DAF and epoxy paste
2. To study the Ultra Violet curing processes of die attach film (DAF) and its responses.
3. To study the Taguchi Method and its application in product and process optimization
4. To apply Taguchi method in optimizing process parameter for better quality and allow for lowering cost and time for research and development application.
5. To plan strategically on testing, experimental, measurement and forecast process for data acquisition purposes.
6. To determine the good combination of parameters of the UV cure process by using Taguchi method of designing experiment

From the objective stated above, the project has high relevancy to the problem and the scope of research is done focusing on developing process parameter by using Taguchi approach. The author will also study on the elements, factors and effects that will make a good design of experiment and how to reflect the company development for new packaging.

1.4 Scope of Study

Basically the scope of work under this project is on the designing the experiment up to the analyzing data acquisition taken from the experiment. Hence, Taguchi method has been used to determine the significance parameters affects the process and vary the range according to the array in Taguchi technique. Moreover, to executing the experiment successfully, the proper plan has been arranged to avoid loss and ensure the workpiece undergo ideal condition. In addition, the understanding on DAF tape and UV cure process were the essential in order to implementing the experimental.

Control factors	*Number of levels*	*Level 1*	*Level 2*	*unit*
Power	2	120	140	mW/cm^2
Time	2	2	4	seconds

Table 2: Control factors and their range of settings for the UV cure experiment

The scope of this study covered Taguchi quality engineering method of parameter design and applies to the ultra violet curing process and Table shows the parameters that will involved in the research. Orthogonal arrays will be used in the parameter design stage. Four control designs are assigned to an L16 inner array. All of the parameters involved are software controlled by the ultra violet curing PG200RM machine. Basically the scope of work under this project is on the designing the experiment up to the analyzing data acquisition taken from the experiment. Hence, Taguchi method has been used to determine the significance parameters affects the process and vary the range according to the array in Taguchi technique. Moreover, to executing the experiment successfully, the proper plan has been arranged to avoid loss and ensure the workpiece undergo ideal condition. In addition, the understanding on DAF tape and UV cure process were the essential in order to implementing the experimental.

CHAPTER 2
LITERATURE REVIEW

2.1 Literature Review

Taguchi is a Japanese engineer, proposed several approaches to experimental designs that call "Taguchi method". This method had been widely used in manufacturing to reduce lead times, engineering changes, development costs and optimizing process. The goal of experimentation in manufacturing is to devise ways to minimize the deviation of quality characteristics from some target value. This can only be done by identifying those factors which impact the quality characteristic in question and changing the appropriate factor levels so that the deviations are minimized. In other words, from a quality perspective, experimentation seeks to find what are the best parameters or formulation which will operate in concert with our process to produce desired products.

Taguchi techniques for quality engineering is intended as a guide and reference source for industrial practitioners (managers, engineers, and scientist) involved in product or process experimentation and development. By using and understanding the Taguchi methods, managers and engineers will realize what is required to put western product development and quality back into the competition. Nowadays, managers and engineers must have a certain amount of exposure to these methods before they can appreciate how much improvement in testing and development strategies can be made.

Quality has been defined by many as, being within specifications, zero defects, or customer satisfaction. However, these definitions do not offer a method of obtaining quality or a means of relating quality to cost. Taguchi proposes a holistic view of quality which relates quality to cost, not just to the manufacturer at the time of production, but to the customer and society as a whole. Taguchi defines quality as, "The quality of a product is the minimum loss imparted by the product to the society from the time product is shipped". Taguchi's quadratic loss function is the first operational joining of cost of quality and variability of product that allows design engineers to actually calculate the optimum design based on cost analysis and experimentation with the design. Product/process design has a great impact on life cycle cost and quality. Taguchi emphasizes pushing quality back to the design stage since inspection and statistical quality control can never fully compensate for a bad design. Taguchi views the design of a product or process as a three-phase program:

1. System design
2. Parameter design
3. Tolerance design

System design is the phase when new concept, ideas, methods are generated to provide new or improved products to customers depending on market demand. The parameter design phase is crucial to improving the uniformity of a product and can be done at no cost or even at a savings. Typically, when a problem is detected in product development, an engineer may jump directly to tolerance design, when tolerances are tightened, variation will be reduced and quality improved.

As the semiconductor industry moves into the next millennium, three key drivers are moving technology forward. First, the drive for improve performance. This includes faster and more highly integrated devices for increased performance capability, smaller packaging size to fit into smaller form systems, more robust packaging that eliminates baking prior to attachment, and eventual elimination of hazardous constituents from the finished product.

The second technology driver is productivity. The ability to manufacture an increasing number of devices with diminishing resources, which primarily equipment, labor, and facilities. The objective is to optimize the facilities capacity capability through design. This includes selection of the most efficient equipment as defined by the throughput, uptime, machine cost, operator cost, maintenance cost, and power usage cost. Another important component of capacity maximization is yield loss reduction in all areas of production, which will rely on application of best practice models to equipment, materials and operational procedures.

The third and most significant technology driver for the semiconductor industry is profitability. That is, the ability to balance sales and costs through effective management in order to meet the financial objectives of the company. In its simplest form, reducing costs can always increase profitability. Therefore, improved profitability is the best result of the effective application of productivity enhancing methods.

In this paper the author will use Taguchi's Quality Loss Function, which is quantifies the variability present in a process. The Taguchi loss function recognizes the customer's desire to have products that are more consistent, part to part, and a producer's desire to make a low-cost product. The loss function quantifies the need to understand which design factors influence the average and variation of a performance characteristic. Below is defined about Taguchi loss function.

- To quantify loss to society, Taguchi used the concept of a quadratic loss function.
- Any deviation from the nominal value (target) results in "loss to society" → loss to the company and customers.
- Losses may include maintenance costs, loss of customer goodwill, and cost of rework, cost of refunds and cost of discounts to recapture sales.

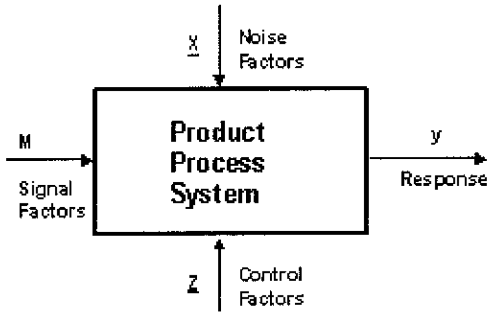


Figure 7: Parameter diagram of a product, process or system on Taguchi's Robust Design

Figure 4 shows the robust design diagram, which is a product or process that can function well despite the presence of noise to immune to noise. Noise is the variables / factors causing variation and which are impossible or difficult to control to outer noise (operating conditions, environment) and inner noise (material deterioration, manufacturing imperfections). Signal is the input parameters. Control factors are the controllable factors that need to be set at optimum levels. Response is the output get from the process.

Analysis of variance (ANOVA)

The purpose of product or process development is to improve the performance characteristics of the product or process relative to customer needs and expectation. The purpose of experimentation should be to reduce and control variation of a product or process; subsequently, decisions must be made concerning which parameters affect the performance of a product or process. By properly adjusting the average and reducing variation, the product or process losses are minimized. Since variation is a large part of the discussion relative to quality, analysis of variance (ANOVA) will be the statistical method used to interpret experimental data and make the necessary decisions. ANOVA is a statistically based decision tool for detecting any differences in average performance of groups of items tested.

The stacked die package

Figure 5 shows that stacked die package which die 2 was first placed on the leadframe after epoxy has been marked. Followed by die 1 with DAF tape then placed on top of the die 2. In order to produce a large volume of number of stacked die package, the usage of DAF tape was much better to reduce the production cycle and cost by eliminated the usage of epoxy marked process on the leadframe.

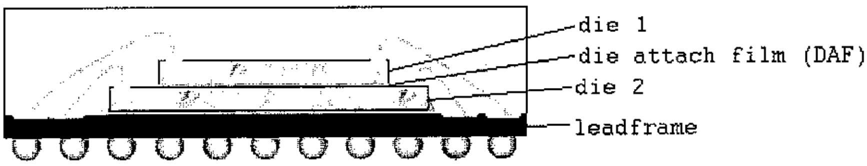


Figure 8: stacked die package with die attach film between the dies

To accommodate the ever-increasing pressure of reduction in size, weight and cost, while provide more functionality and better reliability, Many innovative electronic packaging solutions have been developed. Among them, stacked die packages offer smallest foot-print and thinnest profile in a cost-effective way and have been widely implemented in ASIC, memory, Ethernet controller, and other packages. However, new challenges keep emerging as more dies are stacked up and die thickness decreases to 50 to 75 micron levels. Die Stacking is the process of mounting multiple chips on top of each other within a single semiconductor package. Die stacking, which is also known as 'chip stacking', significantly increases the amount of silicon chip area that can be housed within a single package of a given footprint, conserving precious real estate on the printed circuit board and simplifying the board assembly process. Aside from space savings, die stacking also results in better electrical performance of the device, since the shorter routing of interconnections between circuit's results in faster signal propagation and reduction in noise and cross-talk. Die stacking naturally started out with a pyramid style of piling up smaller die on top of larger ones.

Die attach film type is the material use to stack the die rather than paste or epoxy. Adhesive films show better performance reliability, conductivity and consistency than liquid solder paste. Also, for stacked packages, adhesive film provides a more uniform placement and better alignment than paste. Another advantage of using film adhesive is that paste tends to bleed, creating problems in the bond area. In addition to assembly process related challenges, materials property selection is another challenge faced by assembly engineers. The modulus and thermal expansion (CTE) of packaging materials to silicon dies vary dramatically. The assembly engineer need to control the effects of the die attach film occur to the various processes.

After curing process of packaging adhesives, severe residual stresses can be built up in the package. In stacked die packages, the trend of multiple dies and thinner package only makes the situation worse. For example, in the same die size stacked die packages, a dummy die has been used to provide necessary gap between dies for wire bonding. As the thinner package trend continues, the gap allowed for wirebonding has been decreased to 75 um level. Low loop wirebonding method has been developed. Molding compound with good flowbility has to be used to flow into the overhang area and provide sufficient. Nevertheless, the narrow overhang area is the interface among multiple dies, die attach and molding compound. Molding compound and die attach delamination have been observed initiated in this area. Because of the delamination problem, the good result of die attach process should be achieve in assembly line to lowering cost and can operate an ideal flow without any problem.

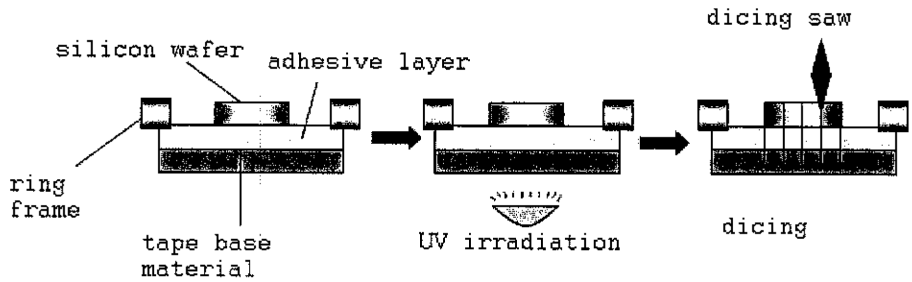


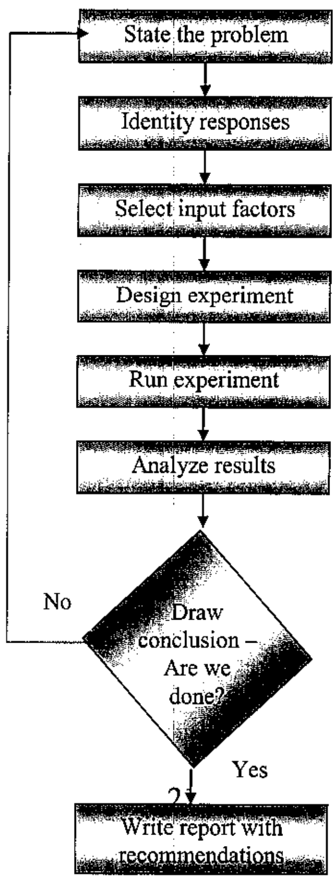
Figure 9: Flow chart of semiconductor product process

Other than that, factors that effecting adhesiveness of the film is UV cure process which right after the grinded wafer is mounted. The target of the UV cure process is to get the film more stable thermally and possess the ability to bond to non-standard substrates and metal component. The factors are intensity, power, timing and temperature of the particular UV cure process. Although there are four variable factors integrated in the equipment, the light intensity and temperature have been fixed for curing the DAF tape because its does not gives any affect to the DAF tape desired output.

CHAPTER 3
METHODOLOGY

3.1 Overview

In developing this final year project, Taguchi method was used in implement the design process, which the lowest loss to society represents the product with the highest quality. Here, the higher product quality by definition means less variation of a product characteristic. In this project, the quality is targeted by finding the best machine performance parameter to allow ideal result to the item to be process which in order to producing with desired cycle time. The Taguchi method on designing experimental and analyze the data acquisition will be followed.



The designed matrix experiments obtain to conduct the experimental was obtain by study the process and Taguchi technique concerning in improving the UV cure process. As far as the guidelines of Taguchi technique is concern, I end up to implement the experiment by matrix array 2 factors with two levels. The materials of the experiment were set up properly to avoid error. The equipment used is Accretech PG200RM machine. The material used is 8 inch mirror wafer which is grinded to 7.5mil.

3.2 Experiment

Blank 150mm diameter silicon wafers are procured at a standard thickness of 0.725mm to be thinned down to 50μm using PG200RM Accretech backgrinding machine. Grinded wafers are then going through polishing process for stress relief. This additional polishing smoothen the backgrind surface by removing the damaged topmost 2μm layer. The polish process provides a mirror finish to minimize stress build-up and wafer breakage during handling. Polish process done using PG200RM in-line machine. All wafers are mounted on DAF tapes and cured according to the parameters designed. One particular DAF tape (LE-5000) was exclusively used for this evaluation. The total tape thickness of this LE-5000 DAF tape is 110μm and it requires ultra violet light exposure for curing prior to dicing. The ultra violet cures the adhesive and increases the adhesion between the wafer backsides to the DAF. These wafers were subjected to proper UV curing to avoid issues like dies flying off from the wafer during dicing, adhesive whiskering and adhesive merging after dicing. The taped wafer was then diced using Disco DAD340 saw. The setting for wafer saw process is setup to the ideal settings within the manufacturer's recommendation range. The rectangular die size after rectangular die size after singulation was 1.5mm X 1.0mm. This dicing wafer was performed to evaluate process problem with die strength, adhesion and whiskering. The dies were undergoing die shear strength test and the force at fracture is recorded for a sample size with 10 reading of the 16 runs. The detail of the die shear test set-up is shown in figure below.

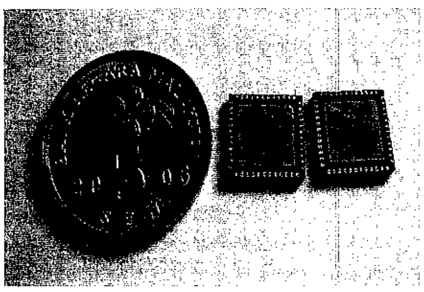


Figure 10: size comparison of finished semiconductor chip

Trial#	Power	Time
1	120W	2 sec
2	120W	4 sec
3	140W	2 sec
4	140W	4 sec

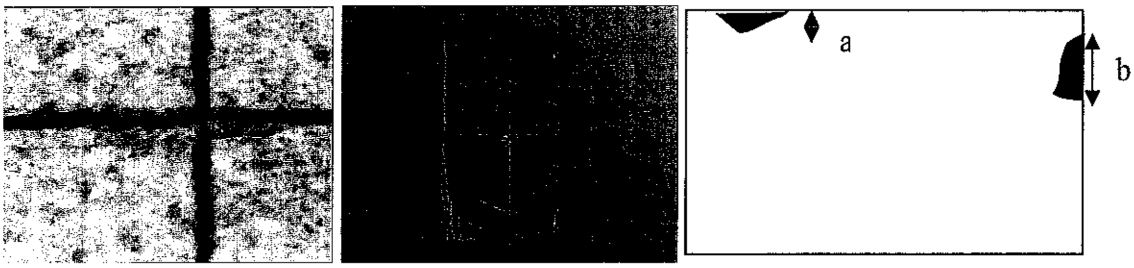
Table 3: Evaluation matrix array for the experiment

3.3 Inspection

To evaluate the experiment implemented we come up with three responses. There are three responses constitute to the experiment, which is top and flip side chipped, die strength and whiskering. However, we had worked for further inspection on delamination, to check the delamination of the semiconductor chips.

Top and flip side chipped

It is possible to inspect the topside chipped by using optical inspection uses a stereomicroscope to evaluate the size. By using Mahr scope, I has been inspect the most major chipped occur on top of the die and taken the size of it to be documented based on the standard pattern of measuring it as shown in figure 9(c).



a b c

Figure 11: a) Die chipped after wafer saw process. b) Chipped die c) The standard pattern of measuring chipped of saw die (a- chip out, b-kerf width)

The specification for inspecting chipped die is any chipped, cracks, scribe line or fracture which extends into or crosses a metal lead or active junction area will be rejected and noted as defects.

Die shear strength

Die Shear Testing is the process of determining the strength of adhesion of a semiconductor die to the package's die attach substrate (in the experiment was used die pad of a lead frame) by subjecting the die to a stress that's parallel to the plane of die attach substrate, resulting in a shearing stress between: 1) the die-die attach material interface; and 2) the die attach material-substrate interface. The general purpose of die shear testing is to assess the over-all quality of the die attach process, including the integrity of the materials and the capabilities of the processes used in mounting the die to the package substrate. In addition, care was taken to avoid samples with incomplete DAF coverage such as shown in Figure.

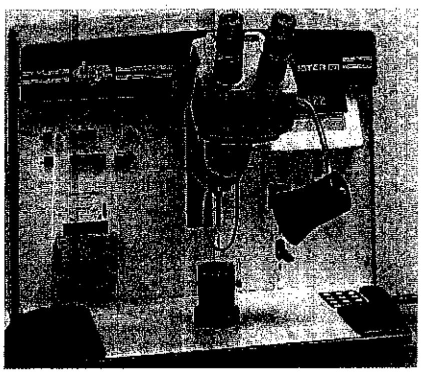


Figure 12: die shear test measurement tool

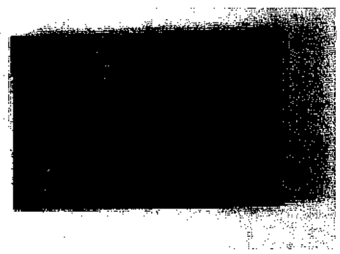


Figure 13: Open up DAF tape on die backside during die shear test

The purpose of this test is to determine the integrity of materials and procedures used to attach semiconductor die or surface mounted passive elements to package headers or other substrates. This determination is based on a measure of force applied to the die, the type of failure resulting from this application of force and the visual appearance of the residual die attach film and substrate/header metallization. The test equipment consists of a load-applying instrument with an accuracy of ±5% of full scale or 50 grams, which is the greater tolerance. For this die shear testing we used a circular dynamometer with a lever arm or a linear motion force applying instrument to apply the force required for testing as shown in figure.

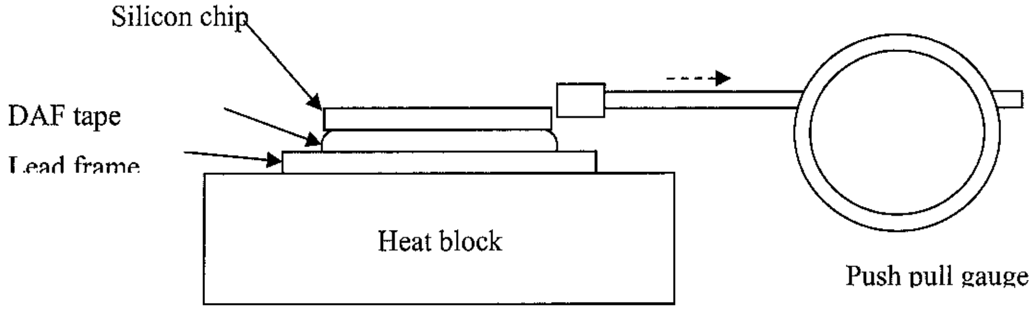


Figure 14: Outline of the test method for die shear strength

The die shear strength test conducted by applying a force sufficient to shear the die from its mounting or equal to twice the minimum specified shear strength. A unit which fails the die strength requirement criteria constitutes a failure. The minimum force of strength requirement is shown in the figure below.

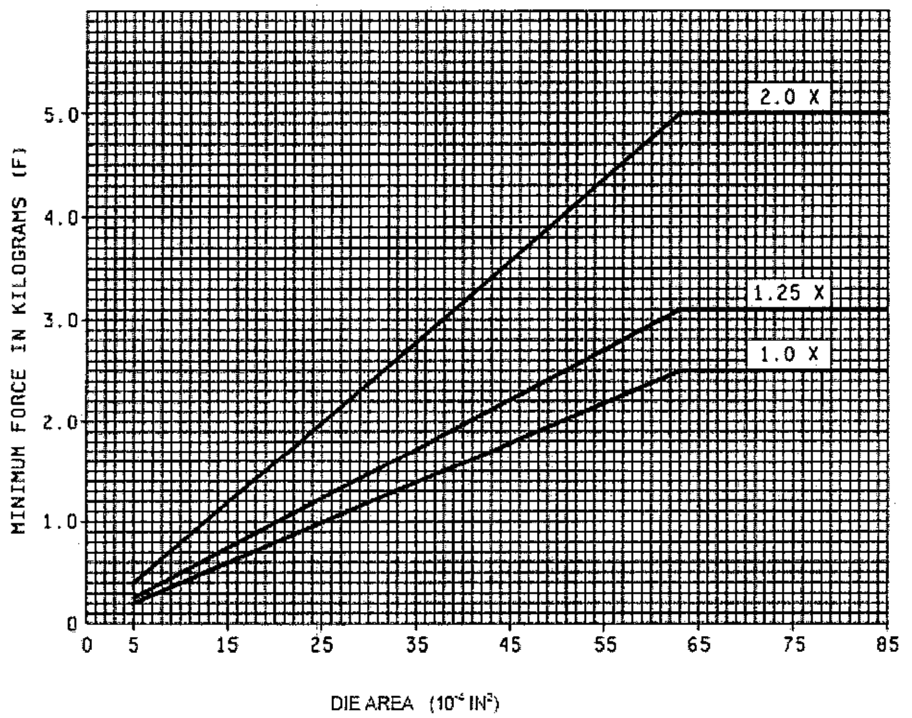


Figure 15: Die shear strength criteria (minimum force versus die attach area)

Meanwhile, we shall determine the die strength requirement for the experiment. The die size for the experiment is;

Die size = 0.058 IN x 0.035 IN = 20.3 x 10^{-4} IN^2

Therefore, because die size is between 5 X 10^{-4} (IN^2) and 64 X 10^{-4} (IN^2) use the value of minimum force required is to be determined based on the chart. The values for die size 20.3 X 10^{-4} (IN^2) are found on the chart by reading 20 on the (10^{-4} IN^2) scale, then finding the coordinating force value on the (F) scale. Doing so provides minimum forces required as 0.8 kg at (1X), 1.0 kg at (1.25X), and 1.6 kg at (2X). Moreover, 10 result of the die adhesive strength per trial has been taken to evaluate the various result vary from the experiment designed.

DAF residue (Whiskering)

The variable parameters of wafer saw process is in ideal condition while performing the UV cure evaluation to ensure the affects of UV cure parameters are the main subject of doing the experiment. The undesirable presence of whiskering (Figure 10) and sidewall chipping was empirically noted and the results shown in Table 3.

Figure 16: whisker on die

CHAPTER 4
RESULT AND DISCUSSION

4.1 Findings

Table 4 and 5 indicate the comparison die shear strength between using resin paste type and die attach film (DAF) tape type. From the table die attached with die attach film (DAF) is much stronger than die attached with resin paste type.

unit	lot 1	lot 2	lot 3	lot 4
1	3.1	2.8	3	1.2
2	3.1	3	3.1	2
3	2.5	2.5	2.3	2.2
4	2.9	2.5	1.5	1.6
5	3	2.6	3.6	2
6	3.1	2	3.2	1.7
7	2.8	2.8	2.5	3.4
8	3.3	2.7	1.9	2
9	2.5	2.7	2.9	2.1
10	2.1	2.3	3.5	5.5
11	2.8	2.4	2.8	3.6
12	2.6	1.9	4	2.1

Table 4: die shear strength result using resin paste

Trial #	Trial 1	Trial 2	Trial 3	Trial 4
1	5.26	7.16	8.08	4.23
2	5.91	6.79	7.75	6.02
3	4.72	4.61	5.02	3.9
4	7.3	5.17	9.2	7.01
5	5.83	4.7	6.91	5.9
6	4.87	4.6	4.2	4.26
7	4.56	4.39	9.24	7.35
8	4.14	7.68	8.63	5.37
9	6.95	4.31	8.9	4.2
10	5.52	4.78	9.19	9.28

Table 5: die shear strength result using DAF tape

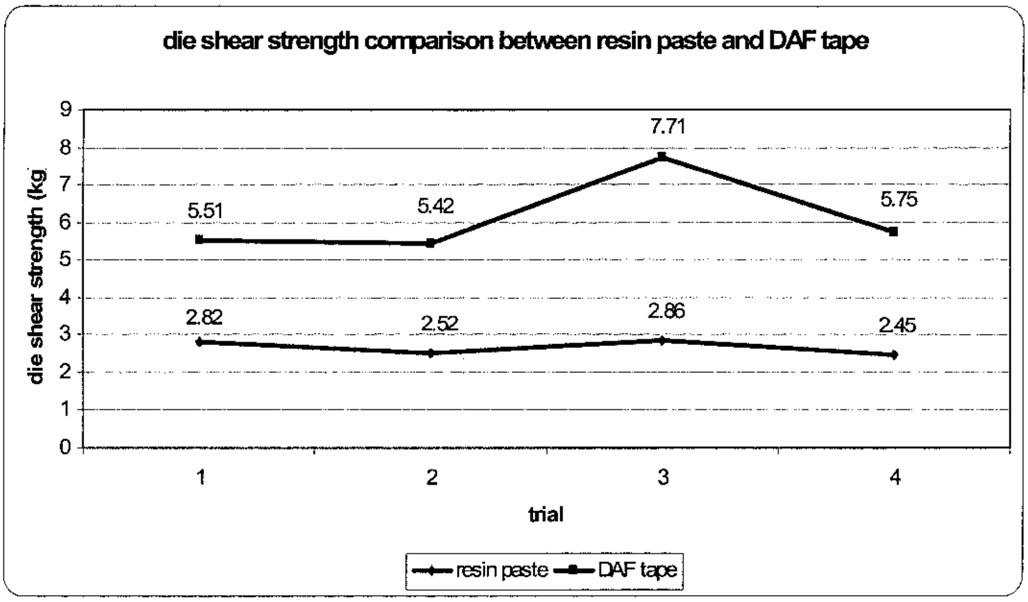


Figure 17: die shear strength comparison between resin paste and DAF tape

By gathering the die shear strength information of die attached to resin paste and die attached to die attach film tape, the comparison between them can be calculating to evaluate the property carry for both material use. Figure 17 indicate that die attach film tape type constantly gives better performance than resin paste type.

Furthermore, while searching for semiconductor solution for better quality die attach material with ultra low modulus, high adhesive strength, high thermal reliability, and low moisture absorption, they found that LE5000 type of die attach film tape series give better quality to the chips. The characteristics of the DAF tape used were found to study the range of the variability parameters input which affects the performance of the overall unit (chip) quality.

Figure 17 indicate the characteristics of die attach film (DAF) tape that has been used to implement this product and process improvement. The die attach film is pre-applied onto wafer by lamination and offer with no die flying off with chip size 2mm. It is applicable for dicing with UV-release tape. This DAF tape offer low elastic modulus which is 38 MPa at 250°C. Low moisture absorption which is 2.2-

2.6 % of the tape is good to achieve soldering of components without pre-baking. The die attach film adhesives tape are engineered to have a balance of high temperature bond strength to allow wire-bonding operations up to 275°C and are able to with stand high temperature without degradation.

Table Specification of LE5000

		LE5000	Remarks
Total thickness (um)		120	• Base material : 100 μ m • Without release film
Dicing process		No die flying off	• Wafer : 4 inch size • Chip size : 2mm□
Adhesion strength (N/25mm)		0.1	To face material after UV irradiation
Pick up strength	N/5mmx5mm	0.8	Expanding : 18mm(CPS unit)
	N/10mmx10mm	2.4	Expanding : 8mm(CPS unit)
Die shear strength at evaluated temperature (N/2mm□)	r.t	111.2	
	250deg.C	7.4	• Heating condition : 250deg.C×30sec., on hot plate
Peel strength N/10mm	Ordinary	7.8	----------
	Moisture/heat	4.4	85deg.C,85%RH,168hr
Extracted ions (ppm)	Na^+	0.7	• Extract condition : Sample 1g/water 20ml, 121deg.C, 24hr.
	$NH4^+$	12.4	
	Cl^-	8.5	
Glass transition temperature : Tg (deg.C)		128	• Elastic data
Elastic modulus (MPa)	25deg.C	1660	Rate of rising temperature : 3deg.C/min Measured mode frequency : 11Hz
	100deg.C	573	
	150deg.C	45	
	200deg.C	37	
	250deg.C	38	
Water absorption (%)		2.2~2.6	85deg.C,85%RH,168hr
Poisson's ratio		0.26	
Weight loss on curing (%)	140deg.C	-	Rate of rising temperature: 50deg.C/min Curing time : 60min
	160deg.C	0.68	
	180deg.C	-	
Weight loss After curing (%)	200deg.C	0.39	Rate of rising temperature : 5deg.C/min
	250deg.C	0.67	
	300deg.C	1.23	
	350deg.C	3.58	
	400deg.C	>20	

Curing condition : 160deg.C×60 min., oven

Die mount condition : 150deg.C, 100g/chip

Adherent : Copper plate (JIS H3100 C1100P)

Die shear strength : 30mm×30mm , 300 μ m thickness

Peel strength : 10mm×50mm , 150 μ m thickness

Figure 18: Characteristic of DAF tape used

4.2 Results

Topside chipped

As mentioned in the methodology measuring of the chip out is used to evaluate topside and flipside die chipped resulted from the experiment. Result for top side chip is shown in the table 6 below. Instantly observation can be made from this result is not much different between the 4 trials. By the way, all runs passed which is any of the parameter range selected would give results within process specification. Nevertheless, trial 4 give better performance also with less distribution result. Top side chipped results are best for trial 4 followed by trial 1, 2 and 3. To optimize the experiment, higher power seems to be advantage.

Table 6: Top side chipped in micron unit

Matrix			top side chipped		
Trial	Power	Time	min	max	average
1	120W	2sec	5.1	10.6	7.27
2	120W	3sec	5.6	12.8	8.06
3	140W	2sec	5.3	9.6	9.4
4	140W	3sec	5.3	9.4	7.09

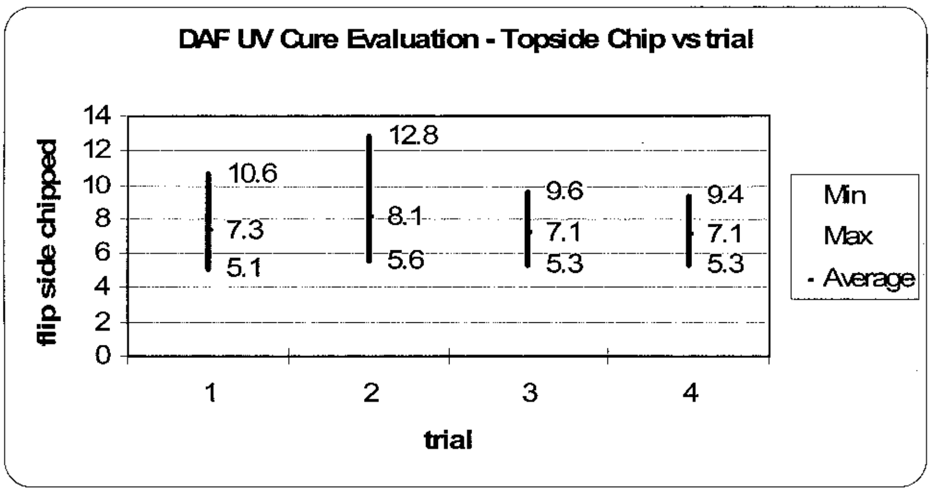


Figure 19: The average of chip out of topside

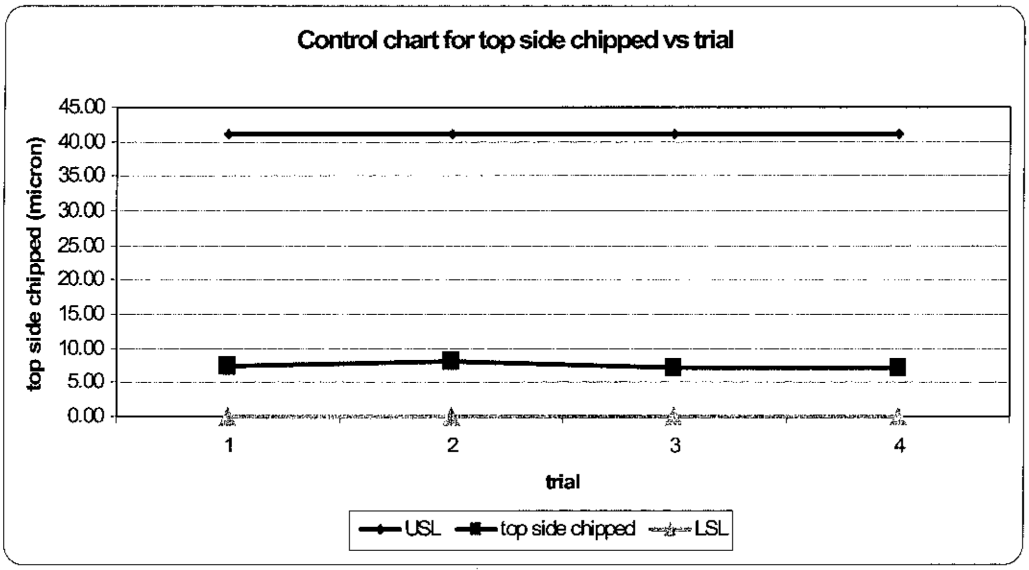


Figure 20: Control chart for top side chipped

Control chart for top side chipped indicated in figure 19 was revealed that die attach film type constantly perform within specification. Thus, all trials acquire good result in top side chipped response.

Flip side chipped

For flip side chipped trial 4 give better performance also with less distribution result. Overall, flip side chipped results are best for trial 4 followed by trial 1, 2 and 3, whereby acquire same result with the top side chipped.

Table 7: Flip side chipped in micron unit

Matrix			flip side chipped		
Trial	Power	Time	min	max	average
1	120W	2sec	2.24	7.21	4.36
2	120W	3sec	2	8.06	5.28
3	140W	2sec	2.06	9.43	5.6
4	140W	3sec	2.83	6.32	4.52

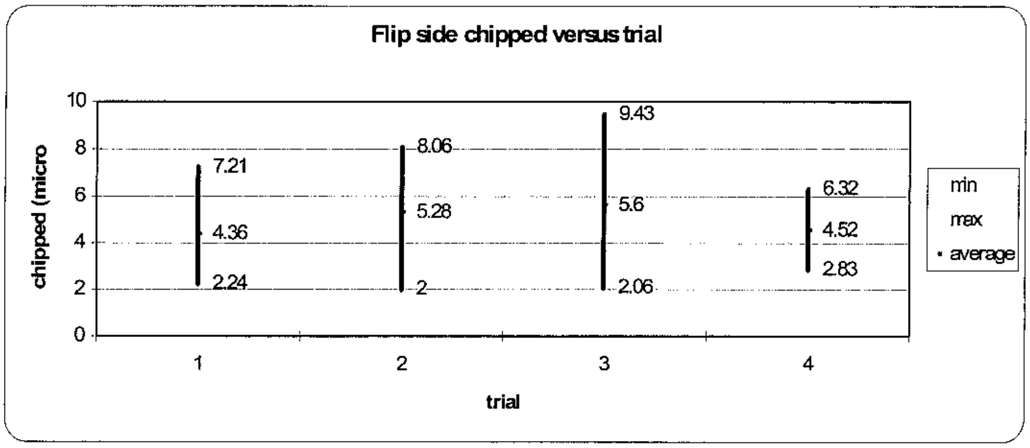


Figure 21: Average result of Flip side chipped versus trial

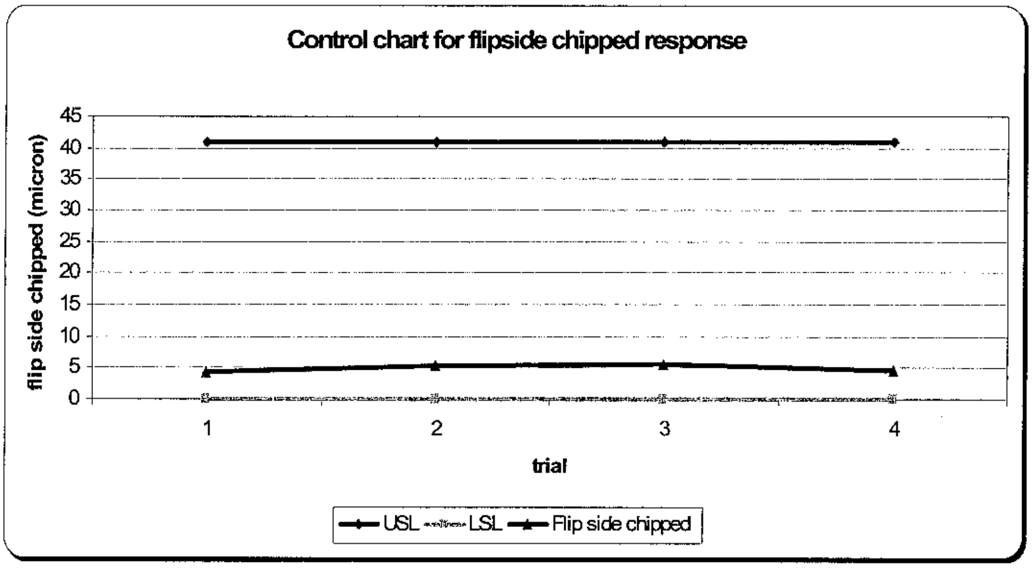


Figure 22: Control chart for flip side chipped

Control chart for top side chipped indicated in figure 22 was revealed that die attach film type constantly perform within specification. Additionally, the result distributed in low range on chipped defects. Thus, all trials obtained good result in flip side chipped response.

<u>DAF tape residue (whiskering)</u>

The result for DAF tape whiskering as shown in table 8 below. It is indicates lower power and time is better. Furthermore, trial 4 offer worst result with 21 whiskering, may be because of the die attach film tape was not stable and not fully contact with wafer. In this experiment, from my point of view the idea is to maintain the elasticity of the material so that the desired output can be achieved. Thus, Trial 1, 2 and 3 gives optimal result while trial 4 present worse result in whiskering presence.

Table 8: Number of residue (whiskering) occur

Matrix			whiskering
Trial	Power	Time	no. of residue
1	120W	2sec	2
2	120W	3sec	1
3	140W	2sec	1
4	140W	3sec	21

Die shear strength test

Result for shear strength are shown is table below, whereby I think only long and high power exposure would give significant risk to process.

Die size X = 0.058 IN

Die size Y = 0.035 IN

Die shear specification (Lower) = 0.8

Table 9: The result for die shear strength in unit kg

Trial #	Trial 1	Trial 2	Trial 3	Trial 4
1	5.26	7.16	8.08	4.23
2	5.91	6.79	7.75	6.02
3	4.72	4.61	5.02	3.9
4	7.3	5.17	9.2	7.01
5	5.83	4.7	6.91	5.9
6	4.87	4.6	4.2	4.26
7	4.56	4.39	9.24	7.35
8	4.14	7.68	8.63	5.37
9	6.95	4.31	8.9	4.2
10	5.52	4.78	9.19	9.28

Table 10: Shows the average shear force in unit kg

Matrix			die shear strength		
Trial	Power	Time	min	max	average
1	120W	2sec	4.14	7.3	5.5
2	120W	3sec	4.31	7.68	5.2
3	140W	2sec	4.2	9.24	7.54
4	140W	3sec	3.9	9.28	5.9

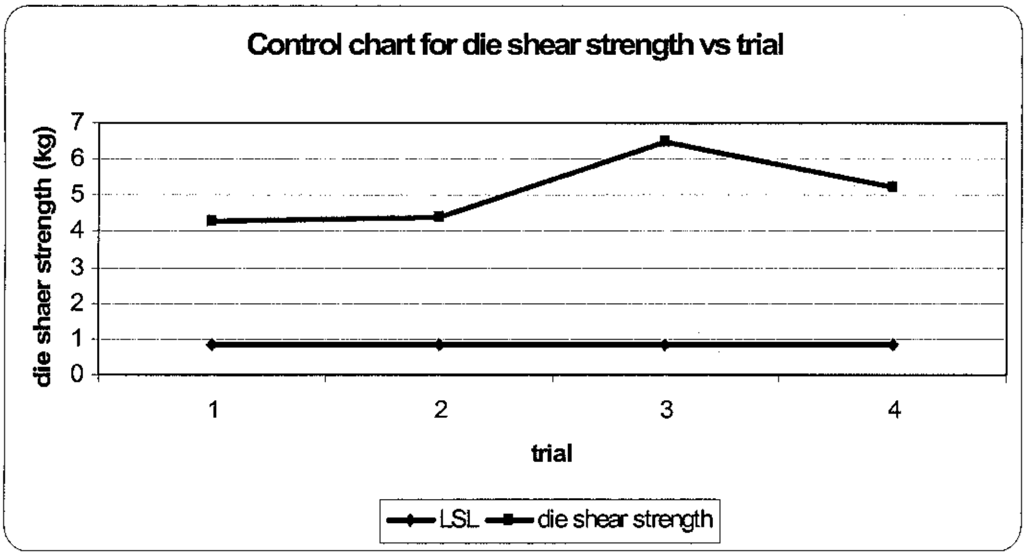


Figure 23: control chart for die shear strength versus trial

Since die shear strength is most significant to evaluate the die attach material, it's important to ensure that the value is as high as possible to get stronger die attached to the lead frame. From table 10 and figure 23, we can see that trial 3 gives higher shear strength followed by trial 4, 1 and then 2.

Process capability index C_{pk}

Process capability index or C_{pk} measures the difference between the desired and actual dimensions of the UV curing die attach film process. The formula of C_{pk} is

$$\text{Process capability index } (C_{pk}) = \frac{\text{Upper specification limit - mean}}{3\sigma}$$

σ = standard deviation of the process population

C_{pk} is useful for indicates how well the process distribution fits within its specification limit as well as to know the desired or capability of product and process to produce with low defects. We say that a process is capable if virtually all of the possible variable values fall within the specification limits. It summarizes the UV cure process potential to meet the specification. Table 11 below shows the C_{pk} for every response.

Table 11: C_{pk} obtained from all responses

Matrix			top side chipped	flip side chipped	die shear strength	whiskering
Trial	Power	Time	C_{pk}	C_{pk}	C_{pk}	# of residue
1	120W	2sec	8.15	9.35	1.53	2
2	120W	3sec	6.42	9.69	1.20	1
3	140W	2sec	10.49	7.56	1.27	1
4	140W	3sec	10.62	10.99	0.95	21

rate	1	2	3	4	5	6	7	8	9
C_{pk}	>10	8.5-10	7-8.5	5.5-7	4-5.5	2.5-4	1-2.5	0.0-1	<0.0

Table 12: Summary of responses

Matrix			Rating				Score
Trial	Power	Time	Topside chip	Flipside chip	Die shear	Whiskers	
1	120W	2sec	3	2	7	1	13
2	120W	3sec	4	2	7	1	14
3	140W	2sec	1	3	7	1	12
4	140W	3sec	1	1	8	9	19

By giving rating from 1 to 9 to every responses based on the results taken and C_{pk} calculated above we can calculate the score carrying for each trial, whereby the least score will be chosen and gives better quality up to the point. Therefore, trial 3 gives better performance than others and it is recommended to use the parameters for the Ultra Violet process. From all the overall evaluation above, I have decided to select trial 3 as the best combination parameters to be use to the Ultra violet die attach film process which giving better quality in terms of top and flip side chipped, die shear strength and whiskering responses.

Full factorial

In constraint of time, I managed to conduct 4 factors and 2 levels with respect to 1 response with matrix array L16, which the result is shown in table 10 below. The experiment result is analyzed using Taguchi statistical method to determine the most significant parameter in minimizing chipped and whiskering defects and maximizing minimum force could be applied on die attach film and lead frame interface. From the result of table below, intensity and temperature are showing the most significant effect. It can be concluded that a combination of low intensity and higher temperature give the best result with no delamination can be achieved. This is also an indication of good adhesion between the two bonding interface.

	power	intensity	temperature	time	delamination
Run	A	B	C	D	(between die to die)
1	120	70	120	2	Yes
2	140	70	120	2	Yes
3	120	200	120	2	Yes
4	140	200	120	2	Yes
5	120	70	300	2	No
6	140	70	300	2	No
7	120	200	300	2	Yes
8	140	200	300	2	Yes
9	120	70	120	4	Yes
10	140	70	120	4	Yes
11	120	200	120	4	Yes
12	140	200	120	4	Yes
13	120	70	300	4	No
14	140	70	300	4	No
15	120	200	300	4	Yes
16	140	200	300	4	Yes

Table 13: matrix array design and delamination result for experiment

From the table 14 below is the optimum levels of control factors are recommended.

Control factors	*Optimum level*
Power	Level 2(140 Watt)
Intensity	Level 1(70 mJ/cm²)
Temperature	Level 2 (300 °C)
Time	Level 1 (2 seconds)

Table 14: Optimal control factor settings

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As far as the new DAF material and technology is concern, DAF has been proved to reduce manufacturing process steps and improve productivity. The gain in productivity has improved total package cost, irrespective of the higher material cost when conventional die attach paste is replaced by DAF. Robust design method of UV cure experiment was being formulated into statistical matrix to start the experiment and evaluation. The control factors will be experimental into full factorial to identifying the significant effected parameters into the process. From the experiment, responses and analyses we have choose the optimal control factor setting as stated in the table 3 above.

As a nutshell Taguchi method has been studied to implement the experiment. it is important of using die attach film, DAF tape with UV cure process prior to dicing wafer process to strengthen the material of the die attach film. Consequently, developing the process of the product is the vital matters to get the robust or insensitive process. Hence, Taguchi method was a better method to develop and optimize the product and process to get the best parameters. By using matrix array L4, 2 factors and 2 levels, the best parameters for the process is:

Control factors	Optimum level
Power	Level 2(140 Watt)
Time	Level 1 (2 seconds)

5.2 Recommendation

As the author have learnt and study about the Taguchi method, and found that, the Taguchi method brings a lot of benefits to the manufacturer to highly decrease the cost and time neither to develop a new process nor optimize the current process to the standard level of quality. Taguchi method also gives solution in solving industry problem with the specific technique to solve the problem encountered in the particular industry arena as well act as the function for decision making tools. Other than that, the responsibility to finish this final year project makes the author experienced precious value while accomplishing this final year project.

Proper planning to design the experimental of particular product and process towards getting the best combination parameters is vital, in order to meet the objectives of the project development. By study and understanding the product and process in detailed as well as able to identify the responses and effects giving by the product and process the approach

To manufacturing industry and build up goods for people's usage, it's very important to focus on the quality with zero defects and target to meet the customers satisfaction. Meanwhile, the technique towards better quality, should parallel with the cost allocated to manufacture the goods and profitable. Taguchi technique offers results to the specific product and process design for best parameters to get better quality. Therefore, it should be excellent for research and development team to totally use it, to increase quality while saving in time and cost to develop the new and current product and process design.

LIST OF REFERENCES

[1] Ross, Philip J. (1989). "Taguchi Techniques for Quality Engineering – Loss function, Orthogonal Experiments, Parameter and Tolerance Design", McGraw Hill International Editions.

[2] Nelson, P. Terhoeve, A. (1994). "Design of Experiments Overview Handbook", Council for Continuous Improvement San Jose, California.

[3] Barker. Thomas B. (1990). "Engineering Quality By Design – Interpreting The Taguchi Approach", Marcel Dekker, Inc.

[4] Zurina Zulkifly, Ramp engineer of Research and development department. Texas Instruments, Kuala Lumpur. Personal Interview.

[5] Texas Instruments (M) Sdn.Bhd.

[6] http://www.ieeexplore.ieee.org/xpls/abs_all.jspisnumber=4417036, "Die attach films having high reliability performance".

[7] http://www.ieeexplore.ieee.org/xpl, "Adhesive properties of ultra curable – adhesive tape for semiconductor processing".

[8] Semiconductor manufacturing company

[9] http://www.globalspec.com/FeaturedProducts/Detail/AccuPlace/Film_Adhesive, Film Adhesive Assembly for Die Attach

[10] http://www.siliconfareast.com/diestacking.htm, Die Stacking structure

[11] http://ieeexplore.ieee.org/iel5/9340/29654/01346704.pdf

[12] http://www.jahm.com/, Temperature Dependent Elastic & Thermal Properties Database

[13] http://www.eit.com/instruments/PuckPlusManualNew.PDF, UV cure process

[14] http://en.wikipedia.org/wiki/Analysis_of_variance, Analysis of variance (ANOVA)

[15] R.C.Denney. http://www.coatings.de/radcure/reading/denney.htm "An introduction to UV curing and the UV inerted curing process", Fusion UV Systems Ltd. Ciba Specialty Chemicals. (2004). "UV curing technical principle and mechanism", Ciba Specialty Chemicals Inc.

[16] Edger, Thomas F. Himmelblau, David M. Lasdon, Leon S. (2001). "Optimization of chemical processes – second edition", Mc Graw Hill Companies, Inc.

[17] Berger, Roger W. Hart, Thomas H. (1986). "Statistical Process Control – A Guide For Implementation", Marcel Dekker, Inc.

APPENDICES

Appendix a

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11		12	13	14
1	Selection of Topic												mid sem break + hari raya			
2	Consult with supervisor about the selected topic															
3	Preliminary research work - research on taguchi method															
4	Submission of preliminary report															
5	Seminar 1 (optional)															
6	Project work ~ Application on Taguchi method ~ Determining on Process / product for the particurlar industry ~ Research on the process / product for the particular industry and work out for factorial involved															
8	Submission of progress report															
9	Seminar 2 (compulsory)															
10	Project work (continues)															
11	Submission of interim report															
12	Oral presentation															

Gantt chart – work flow for semester 1

Appendix b

No	Detail / Week	1	2	3	4	5	6	7	8	9	10	11		12	13	14
1	Project work continue	■	■	■									mid sem break			
2	Identify the number of factorial and alternative level exist for the process	■	■	■												
3	Design the matrix experiment and define the data analysis procedure	■	■	■												
4	Set up test equipment	■	■	■												
5	Conduct the matrix experiment and data collection	■	■	■												
6	Submission of progress report 1				■											
7	Submission of poster exhibition					■										
8	Do final report						■	■	■							
9	Do analysis and research	■	■	■	■	■	■	■	■	■	■	■				
10	Submission of progress report 2									■						
11	Submission of final report first draft										■					
12	Analyze the data and determine optimum levels for control factors											■		■		
13	predict the performance of the process at these level													■		
14	Submission of final report final draft													■		
15	recommendation														■	
16	EDX															■
17	Oral presentation															■
18	Submission of final report															■

Gantt chart – work flow for semester 2

Appendix c

	RUN 1			RUN 2			RUN3			RUN 4		
	Chip out	Kerf width	Chip+Kerf	Chip out	Kerf width	Chip+Kerf	Chip out	Kerf width	Chip+Kerf	Chip out	Kerf width	Chip+Kerf
No	a	b		a	b		a	b		a	b	
1	7.50	34.50	49.50	6.60	31.60	44.80	7.20	32.80	47.20	7.30	32.00	46.60
2	8.10	32.80	49.00	5.90	33.20	45.00	7.60	32.00	47.20	5.90	31.20	43.00
3	7.70	33.70	49.10	6.70	32.40	45.80	6.70	33.70	47.10	6.10	32.00	44.20
4	9.30	33.70	52.30	6.40	32.40	45.20	6.60	34.10	47.30	8.00	34.10	50.10
5	10.60	34.10	55.30	5.60	33.20	44.40	8.20	34.10	50.50	7.80	34.10	49.70
6	6.50	33.70	46.70	7.00	34.10	48.10	9.00	32.80	50.80	6.70	32.80	46.20
7	7.90	33.70	49.50	7.00	34.90	48.90	7.30	34.50	49.10	6.10	33.70	45.90
8	5.40	34.50	45.30	9.80	34.10	53.70	6.20	32.80	45.20	8.30	34.10	50.70
9	9.90	35.70	55.50	11.50	34.90	57.90	8.00	34.90	50.90	6.50	33.70	46.70
10	5.60	34.10	45.30	6.80	33.20	46.80	8.60	31.90	49.10	7.50	33.70	48.70
11	7.60	35.30	50.50	7.30	34.10	48.70	5.30	33.20	43.80	8.20	32.80	49.20
12	7.60	34.10	49.30	7.70	34.10	49.50	7.10	33.20	47.40	7.60	34.10	49.30
13	5.40	34.50	45.30	8.70	34.50	51.90	6.90	32.40	46.20	5.30	32.80	43.40
14	5.10	34.10	44.30	9.80	32.80	52.40	7.40	34.10	48.90	6.20	32.40	44.80
15	6.00	33.20	45.20	7.70	32.40	47.80	6.90	34.10	47.90	6.20	33.70	46.10
16	6.00	33.20	45.20	6.40	34.10	46.90	6.60	33.20	46.40	9.40	34.20	53.00
17	7.00	32.80	46.80	7.90	33.70	49.50	6.50	34.50	47.50	7.20	32.80	47.20
18	6.10	35.70	47.90	7.20	34.50	48.90	6.70	33.20	46.60	7.50	34.20	49.20
19	7.10	32.80	47.00	5.70	30.70	42.10	8.30	33.20	49.80	7.00	32.20	46.20
20	9.00	33.20	51.20	8.30	32.40	49.00	5.80	32.80	44.40	6.50	32.40	45.40
21	8.40	32.80	49.60	12.80	32.80	58.40	6.10	32.40	44.60	7.20	31.60	46.00
22	7.00	33.70	47.70	8.50	34.10	51.10	9.60	34.00	53.20	5.90	33.60	45.40
23	6.50	33.20	46.20	9.70	33.20	52.60	9.10	33.20	51.40	6.30	32.80	45.40
24	6.90	33.70	47.50	6.90	33.70	47.50	6.90	34.10	47.90	8.50	33.20	50.20
25	7.20	34.10	48.50	7.80	29.50	45.10	5.70	32.00	43.40	6.60	31.00	44.20
26	9.20	34.40	52.80	9.50	32.00	51.00	5.60	31.60	42.80	7.50	31.50	46.50
27	7.80	33.20	48.80	10.30	31.32	51.92	7.40	31.50	46.30	9.10	32.00	50.20
28	7.40	34.10	48.90	8.70	35.30	52.70	7.60	34.10	49.30	6.20	34.50	46.90
29	5.90	35.30	47.10	8.60	34.50	51.70	6.90	33.20	47.00	8.60	31.60	48.80
30	6.40	36.60	49.40	8.90	35.80	53.60	6.10	35.40	47.60	5.60	33.20	44.40
LSL	-	-	-									
USL	41.00	80.00	121.00	41.00	80.00	121.00	41.00	80.00	121.00	41.00	80.00	121.00
Target	0.00	35.00	35.00	0.00	35.00	35.00	0.00	35.00	35.00	0.00	35.00	35.00
Std	1.38	0.95	1.24	1.71	1.41	1.60	1.08	0.99	1.04	1.06	1.02	1.04
Min	5.10	32.80	44.30	5.60	29.50	42.10	5.30	31.50	42.80	5.30	31.00	43.00
Max	10.60	36.60	55.50	12.80	35.80	58.40	9.60	35.40	53.20	9.40	34.50	53.00
Average	7.27	34.02	48.56	8.06	33.32	49.43	7.13	33.30	47.56	7.09	32.93	47.12
Avg+3stde	11.41	36.88	52.27	13.19	37.54	54.22	10.36	36.27	50.67	10.28	36.00	50.23
Cpk	8.15	16.07	19.53	6.42	11.07	14.96	10.49	15.70	23.63	10.62	15.37	23.74
Judge	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Data gathered for top side chipped response

Appendix c

No	RUN 1	RUN 2	RUN3	RUN 4
1	5.83	5.66	5.00	3.16
2	4.24	5.83	6.09	5.83
3	2.83	4.47	6.32	3.16
4	7.07	4.47	9.43	4.47
5	4.47	4.24	6.40	3.61
6	3.61	6.32	5.00	6.00
7	2.24	3.61	5.39	4.47
8	4.00	5.10	6.32	4.24
9	2.83	5.00	5.00	4.12
10	7.21	5.66	7.28	3.00
11	5.83	5.39	6.40	3.61
12	5.00	5.39	6.32	3.61
13	3.61	4.12	5.00	5.39
14	5.09	6.40	6.40	6.00
15	5.10	6.08	6.40	4.24
16	6.13	5.66	7.07	5.39
17	5.39	4.47	3.69	3.16
18	3.61	2.00	5.66	5.39
19	3.16	6.08	4.47	3.61
20	4.24	8.06	5.00	3.61
21	5.39	4.12	5.66	2.83
22	2.24	4.47	6.40	5.00
23	3.61	5.00	7.28	5.00
24	2.83	8.06	6.08	6.00
25	5.00	6.32	7.07	4.00
26	3.16	6.40	2.06	3.61
27	4.12	4.47	5.39	5.83
28	4.12	5.39	2.83	6.32
29	5.10	5.65	4.24	4.47
30	3.61	4.47	2.14	6.32
LSL	-	-	-	-
USL	41.00	41.00	41.00	41.00
Target	0.00	0.00	0.00	0.00
Std	1.31	1.23	1.56	1.11
Min	2.24	2.00	2.06	2.83
Max	7.21	8.06	9.43	6.32
Average	4.36	5.28	5.59	4.52
Avg+3stdev	8.27	8.96	10.28	7.83
Cpk	9.35	9.69	7.56	10.99
Judge	**Pass**	**Pass**	**Pass**	**Pass**

Data gathered on flip side chipped response

Appendix d

Matrix						
Trial	***Power***	***Time***	***3***	***Whisker***	***Good***	***Total***
1	1	1	1	2	1762	
2	1	2	2	1	1763	
3	2	1	2	1	1763	
4	2	2	1	21	1743	
				25	7031	7056

Source	***SS***	***v***	***MS***	***F***	***Fcri***	***%***
Power	0.05116	1	0.05116	14.57959	3.84	30%
Time	0.05116	1	0.05116	14.57959	3.84	30%
Power-Tim	0.06250	1	0.06250	17.81053	3.84	37%
Error	24.74660	7052	0.00351			2%
Total	24.91142	7055	0.16833			

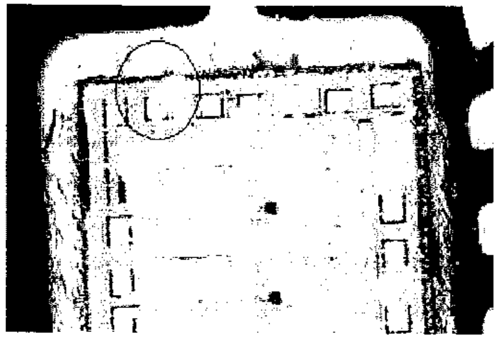
DAF residue (whiskering) data gathered

Appendix e

Unit	RUN 1	RUN 2	RUN 3	RUN 4
1	5.26	7.16	8.08	4.23
2	5.91	6.79	7.75	6.02
3	4.72	4.61	5.02	3.90
4	7.30	5.17	9.20	7.01
5	5.83	4.70	6.91	5.90
6	4.87	4.60	4.20	4.26
7	4.56	4.39	9.24	7.35
8	4.14	7.68	8.63	5.37
9	6.95	4.31	8.90	4.20
10	5.52	4.78	9.19	9.28
LSL	0.81	0.81	0.81	0.81
USL	-	-	-	-
Target	-	-	-	-
Std	1.02	1.27	1.81	1.74
Min	4.14	4.31	4.20	3.90
Max	7.30	7.68	9.24	9.28
Average	5.51	5.42	7.71	5.75
Avg-3stdev	2.44	1.60	2.30	0.54
Cpk	1.53	1.20	1.27	0.95

Data gathered on die shear strength test

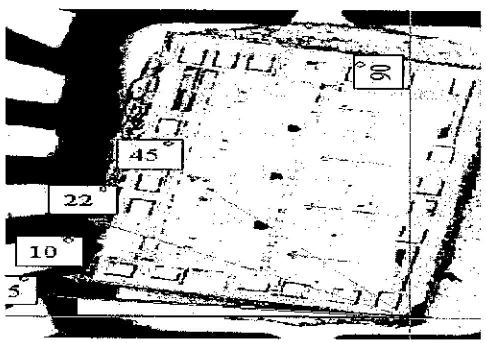
Appendix f



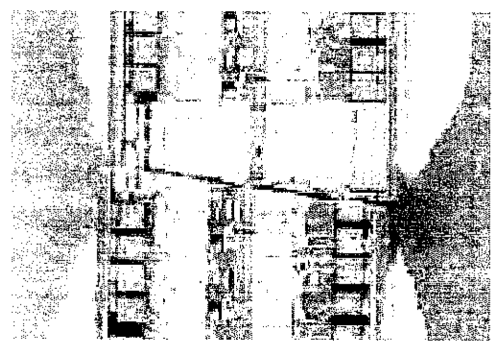
Epoxy on Die

Loose Die

Epoxy on Lead



Angular Displacement



Cracked/Broken Die

Peeling Silver

Current die attach process problem using resin paste onto thin die package

Appendix g

unit	lot 1	lot 2	lot 3	lot 4
1	3.1	2.8	3	1.2
2	3.1	3	3.1	2
3	2.5	2.5	2.3	2.2
4	2.9	2.5	1.5	1.6
5	3	2.6	3.6	2
6	3.1	2	3.2	1.7
7	2.8	2.8	2.5	3.4
8	3.3	2.7	1.9	2
9	2.5	2.7	2.9	2.1
10	2.1	2.3	3.5	5.5
11	2.8	2.4	2.8	3.6
12	2.6	1.9	4	2.1

Result of die shear strength on resin paste type