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EFFECT OF EPOXY NOZZLE SEPARATION ON DIE ATTACH ADHESION AT CHIP / SUBSTRATE INTERFACE

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(Manufacturing System Engineering)

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EFFECT OF EPOXY NOZZLE SEPARATION ON DIE ATTACH ADHESION AT CHIP / SUBSTRATE INTERFACE

YEO KIAN HONG

A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Manufacturing System Engineering)

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DEDICATION

To my beloved mother, father, wife and children

ABSTRACT

Semiconductor products utilized in the automotive application need to be in high quality and more robust to ensure safe driving for the user. Thus, the semiconductor product manufacturers are moving toward zero defects target to gain the upper hand of the automotive market. One of the targets is to eliminate defects related to the die attach process. Epoxy glue void formation at the chip/substrate interface happens when multi nozzle shower is used for the glue distribution as an adhesive layer. The epoxy unable to flow uniformly, thus air is trapped in the epoxy layer at the chip/substrate interface. The current study investigates the effect of the shower head nozzles' separation (wall space) on the epoxy void formation and die shear strength. It was found that the nozzle separation has a significant and positive correlation on the void formation, but not on the shear strength of the die attach chip/substrate interface. Thus, it is recommended that the nozzles' separation (wall space) dimension to be increased by reducing quantity of nozzle used in order to reduce the void percentage to be equal or less than five percent.

ABSTRAK

Produk semikonduktor digunakan dalam aplikasi automotif perlu berada dalam kualiti yang tinggi dan lebih mantap untuk memastikan pemanduan yang selamat untuk pengguna. Oleh itu, pihak pengeluar semikonduktor tersebut bergerak ke arah kecacatan sifar sasaran untuk mendapat kelebihan pasaran automotif. Salah satu sasaran adalah untuk menghapuskan kecacatan yang berkaitan dengan proses 'die attach'. Pembentukan lubang pada gam epoxy di antara-muka cip/substrak berlaku apabila kepala pancuran digunakan untuk pengedaran gam sebagai lapisan pelekat. Gam tersebut tidak dapat mengalir dengan seragam, menyebabkan udara terperangkap di dalam lapisan gam tersebut di antara-muka cip / substrak. Kajian ini menyiasat kesan jarak muncung kepala pancuran (ruang dinding) pada pembentukan lubang di lapisan gam dan kekuatan ricihan 'die'. Adalah didapati jarak muncung mempunyai hubungan bererti dan positif terhadap pembentukan lubang di lapisan gam, tetapi tidak pada kekuatan ricihan 'die' pada antara muka cip/substrak. Maka, adalah disyorkan bahawa dimensi jarak muncung (ruang dinding) ditambah dengan mengurangkan bilangan muncung yang digunakan, bagi untuk mengurangkan peratusan lubang ke lima peratus atau kurang.

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LIST OF ABBREVIATIONS

ACRONYM	DEFINITION
Ag	Silver
Al	Aluminium
Au	Gold
BeO	Beryllium Oxide
BIFE	Business Intelligence and Financial Engineering
BLT	Bond Line Thickness
CPMT	Components, Packaging and Manufacturing Technology
DA	Die Attach
DAP	Die Paddle
DBC	Direct Bonded Copper
DFMEA	Design Failure Mode and Effects Analysis
FOL	Front of Line
IC	Integrate Circuit
ICEPT	International Conference Electronic Packaging Technology
ID	Internal Diameter
IEEE	Institute of Electrical and Electronics Engineers
IEMT	International Electronic Manufacturing Technology Symposium
LED	Light Emitting Diode
Pb	Lead
SiC	Silicon Carbide
Sn	Tin

CHAPTER 1

INTRODUCTION

1.1 Background

In the demand of better heat dissipation and power efficiency, robust package, super high thermal and electrical conductivity adhesive become more important in semiconductor market. Todays, product quality in the semiconductor industrial requirement is getting more stringent due to applications in automotive industry. Currently trends are more and more semiconductor products are widely using in automotive to replace conventional type mechanism use in vehicles. Thus, quality is very important or else it will cause safety issue that can threaten to human life if component malfunction when it install in some important part of vehicle when it moving.

Die attach is a semiconductor backend front of line process and it located in between die dicing and wire bond process. In the demand of better heat dissipation and power efficiency, green robust package, super high thermal and electrical conductivity adhesive become more important in semiconductor market (Tan et al., 2014). Super high thermal adhesive generally has low basic resin content, therefore it is important to study the mechanical strength is maintained over the reliability condition and duration to prevent adhesive delamination and other assembly issue (Wang and Yeo, 2012).

1.2 Statement of the Purpose

The purpose of this research study is to investigate the effect of dispense nozzle position on glue void formation at chip 'die' and substrate interface during epoxy die

attach process. The epoxy die attach dispense tool as call in semiconductor industrial is "multi nozzle shower head", the design of this type dispense tool multi nozzle shower head contains of nozzle to nozzle distance and nozzle size selection which must match with the chip 'die' size using in the product. Thus, in this research study will be address the guideline or reference for new product of integrated circuit in the development state to save for timeline and cost and also to prevent unnecessary quality issue happen. It was believed that it will be greatly help when there is a project for product kick off and can be as a guideline or reference and include it for design failure mode and effects analysis (DFMEA).

1.3 Problem Statement

Silicon chip 'die' is bond on substrate using die attach process, before undergoes wire bonding process. Three types of die attach (DA) processes are common used by semiconductors, they are: (i) epoxy, (ii) eutectic & (iii) soft solder DA processes. They are distinguished by the materials used in the DA process. Chip 'die' is placed on the top of epoxy glue that sits on substrate. DA process ensures chip 'die' is permanently attached to substrate material and have to withstand temperature extremes without degrading.

Common defect observed in sample underwent epoxy die attach process is glue void (air trap) (see Figure 1.1). Formation of the epoxy glue void happens when glue released from multi nozzle shower head with different nozzle to nozzle distance unable to flow uniformly and coalesce into becomes thin layer along the chip 'die' to substrate interface. Air is unable to be fully evacuated when the DA and curing processes is complete.

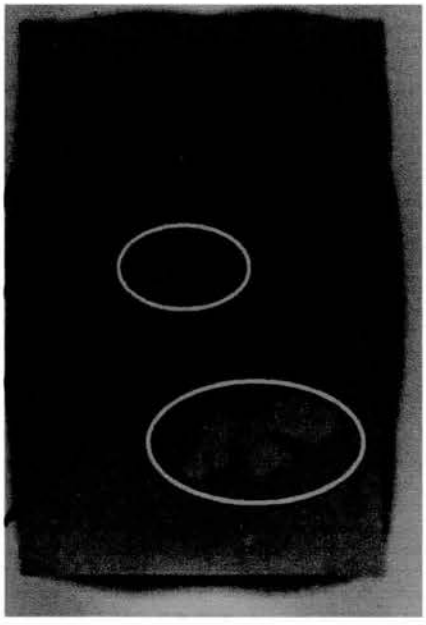

Figure 1.1: Epoxy glue void inspect with X-ray scanning at 0hr

Size of glue void should be kept in minimum size if possible in order to ensure must not transmit destructive stress to the fragile chip 'die'. Although there is alternative way to remove this glue void after epoxy die attach process like using high vacuum pressure type oven which involves actual removal of the air surrounding epoxy by allowing the air that is trapped within the epoxy to easily escape. Due to consideration of safety issue with this type of high vacuum pressure oven which may causing the explosion when there is no proper handling or well maintenance, most of industry are trying avoid using this type of oven. Furthermore, transfer of product from DA process to curing process may involve staging time, thus epoxy glue may harden at surface layer. Thus, vacuum oven will not be effective to remove the glue void.

The dies attach process also influenced by dispensing method (pattern). There are many types dispensing pattern or method in the market by epoxy glue writing and epoxy glue inkjet, but unfortunately the process increase DA process time. Larger chip 'die' size

involves longer travel distance and requires larger glue amount to achieve better epoxy coverage, minimum glue void (air trap) and more even bond line thickness (BLT).

It is also possible to use disposable dispense nozzle to perform epoxy writing. However, it needs to be change each time once reaches pot life of epoxy glue. Despite of this type disposable dispense nozzle is given convenience for user due to it do not need to wash or cleaning, can be throw away after used but unfortunately it will create lot of wastage and need to pay some cost for it. From here, we can know that it has certainly impact to environmental since it need energy consumption to recycle and remanufacturing.

The current research study on the effect of glue nozzle design (i.e. 'nozzle to nozzle' position or 'wall space') on void formation during DA process. Until recently, there is not study of relationship of dispense nozzle design on the void formation. Single nozzle had been used for DA process, but it causes lower productivity in DA process. Thus, multi-nozzle design is preferred. Author in this research study found that there is alternative way to achieve minimum epoxy glue void, increasing productivity capacity and cost saving with reusable extraordinary glue dispense nozzle design with multi nozzle shower head.

1.4 Objectives of the Study

The main objective of this research study are show as follows :

- To investigate influence of epoxy multi nozzle shower head's wall space (nozzles separation) toward glue void formation between chip 'die' and Ad-plated substrate.
- To investigate influence of the glue void toward die shear strength of die attached chip 'die' - substrate.

- To recommend wall space (nozzles separation) for epoxy multi nozzle design.

1.5 Scope of the Study

This research study will be performing by experimental investigation in order to verify the result. Material use in this research will be limited by using the conductive epoxy glue as adhesive material in order to gluing die with substrate. X-ray scanning will be performed to characterize glue void. X-ray is a more efficient method to inspect glue void than cross sectional microstructure observation. Because the latter is subjective to location where is perform.

Chip 'die' size use for this research study shall within range of 1.5mm^2 to 6.5mm^2 as existing can be found within my workplace. The substrate type using in this research study will be in strip type platform substrate instead of reel type platform substrate which is more convenience to perform assessment anytime without doing any cutting sample from whole reel. Design of dispensing multi nozzle covers number of nozzle, their distances and pattern. It is a stamp nozzle which also called multi nozzle shower head stamp tool, design of this tool will subject or depend chip 'die' size use in the study which will be custom make.

Oven type using to curing the material after epoxy die attach will be mechanical convection and standalone type oven which common use in semiconductor industrial with brand of "Blue M". Chip 'die' shear strength is to checking the cohesion condition of the product after epoxy die attach and oven curing process as we called it "Die Shear Tester".

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, in the semiconductor industry quality requirement is getting more stringent due to some of application are widely used in automotive and existing trend is more and more semiconductor products are widely used in automobiles to replace the conventional type mechanism use in vehicles.

With this scenario, the quality of semiconductor products will be needed more and more robust in order to ensure its working fine all the time. Some of semiconductor product can threaten human life, especially if it was used in automotive engine with high temperature and not functioning well. Therefore, the quality of product is getting important and need to be close to the zero defects if possible. In this research study, will be mainly focusing in the epoxy die attached glue void improvement by dispensing shower's 'nozzle to nozzle' position in order to achieve automotive industry goal of glue void (air trap) allowance smaller or equal to five percent.

2.2 Semiconductor Packaging: Latest Development In Automotive

The demand for high power package has increased tremendously in applications such as light emitting diode (LED), automotive microcontrollers and portable communication devices which in turn require more extensive development to improve electrical and thermal performance of semiconductor packaging to meet the increasingly stringent requirements (Chang et al., 2013). Thus, high thermal conductive epoxy using is

essential to develop in robust die bond process. Most high power semiconductor devices for electrical connection, heat dissipation and stress management are commonly using solder alloys, both high lead (Pb) and lead (Pb) -free (Dietz, 1998).

However, they usually come with voids, which have an adverse effect on (Dietz, 1998) (Katsis, 2001). Hence, this has driven the demand for solder replacement using metal-filled adhesives in power semiconductor devices. Commonly used metal filler include silver, gold, nickel and copper.

2.3 Die Attach Machine

Die attach machine is equipment contains of the five major modules: pick-and-place, component presentation, substrate presentation, vision, and epoxy dispensing. Equipment serving in the market must be particularly flexible to bond many different semiconductor devices while dispense two or more different epoxies, in a single pass. It must be able process the smallest to the largest and also ultra-thin chip 'die'. Various single-pass component presentation methods are required and the equipment must work with many different substrate (leadframe) types. Chip 'die' placement accuracy, bond-line thickness, die tilt, epoxy coverage and fillet are the key bond process parameters that must be fulfil the requirement of customer. However, this equipment also having two kinds of platform in order to handling the different design of the substrate platform (i.e. 'reel type' or 'strip type').

2.3.1 Standalone Platform Die Attach Machine

Standalone type die attach machine is the equipment which is more flexible in the production and suitable for batch production. It is independence equipment without any linking to previous process or subsequent process equipment, this type of equipment is

commonly used in the semiconductor industry to handling the substrate which in strip forms. The basic configuration of this equipment in material handling consists of an input magazine handler, indexing track and output magazine handler, the substrate need to be inserted into the magazine slot before loading into input magazine handle and substrate will be kicked out by a kicker which install on input magazine handler into the indexing track. Once the substrate was on the indexing track and arrive on epoxy station, then it will be performed dispense epoxy dot on the substrate. Again, when it finishes processing in epoxy station and substrate arrive on bonding station, then it will start bond chip 'die' on epoxy dot. The substrate once done for both processors in this equipment will be kicked into output magazine handler.

2.3.2 Reel Platform Die Attach Machine

This type of equipment normally uses an in-line system which consists of multiple different equipment processors (i.e. 'die attach', 'die cure', 'wire bond' & 'encapsulation'). Due to substrate is in reel form, the whole reel form substrate is connected thru all the processor equipment, Therefore, in this kind platform of die attach machine does not need the input and an output magazine handler. However, an indexing track with index roller or gripper is needed in this type of equipment in order to index the substrate thru epoxy station to bonding chip 'die' station.

2.4 Die Attach Techniques and Methods

Die attach, also known as die bonding is the process of attaching (bonding) the semiconductor chip 'die' either to its package or to some substrate or on top of another die. It is can take on many forms and can be applied in many different ways by this process. These discrepancies are entirely dependent on the desired application of the user. The most