UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

IMPROVEMENT OF MOLD ABILITY AND WIRE SWEEP IN SEMICONDUCTOR DEVICES USING DOE STATISTICAL APPROACH

Mohd Hirzarul Hafiz bin Mohd Tahir

Master of Manufacturing Engineering
(Manufacturing System Engineering)

2016

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MOHD HIRZARUL HAFIZ BIN MOHD TAHIR

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

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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SESI PENGAJIAN: **2015/16 Semester 1**

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Disahkan oleh:

Hafiz

Alamat Tetap:

Lot 1665, Kg. Permatang,

32040 Seri Manjung,

Perak Darul Ridzuan.

Tarikh: 25 Februari 2016

Cop Rasmi:

DR. MOHD SANUSI BIN ABDUL AZIZ
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

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Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

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I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature : ....

Supervisor Name : ....

DR. MOHD SANUSI BIN ABDUL AZIZ
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Date : ....

DEDICATION

To my beloved wife, children and parents

ABSTRACT

Molding, also known as encapsulation in semiconductor industry, is one of the main processes in semiconductor manufacturing. In semiconductor industry, encapsulation is usually done using transfer molding due to very high accuracy of transfer molding tooling and low cycle time of the molding process. In order to optimize and obtain the perfect molding process, molding simulation is necessary to check the mold flow and possibilities of voids and air trap inside the mold tools. However, simulation alone could not guarantee the perfect molding process. Usually simulation have some limitation such as to match the exact mold compound properties, and when this happen few potential defects may be produced such as incomplete mold, crack mold, mold chipped, uneven surface and many more. These defects are also called mold ability issues. Normally, the mold ability defect will result on drop of function performance or reliability issue during application of the product. Another defect that can be produced if the parameter is not optimized is wire sweep. Wire sweep is defined as the ratio of the maximum wire deviation or deformation to the wire span. In other words, if observed the wire from top view, the straighter the wire, the less wire sweep index ratio obtained. This research aims to investigate and optimize molding parameter by using Design of Experiments approach to achieve zero mold ability issue and good wire sweep index, which will improve the molding process yield and further reduce the molding defect produced. Effects of molding parameters to the mold ability and wire sweep performance will be study and based on the analysis, best molding parameter will be defined and recommended to minimize the yield loss and improve the company profitability. Generally, every molding parameter (Mold Temperature, Transfer Pressure, Transfer Time) having effects and interaction to mold ability and wire sweep output. The statistical calculation was done using Cornerstone software, and based on the analysis, the best parameter was suggested. This study only focused on mold parameter optimization, so in order to further increase the robustness, it is recommended to study other related factors such as mold compound characteristics and mold tool design.

ABSTRAK

Pengacuan adalah salah satu proses utama dalam pembuatan semiconductor. Dalam industry semiconductor, proses pengacuan biasanya menggunakan pengacuan pindah kerana acuannya yang sangat jitu dan kitaran masa yang rendah. Bagi mengoptimumkan proses pengacuan, simulasi diperlukan untuk menganggar aliran pengacuan dan memeriksa kemungkinan produk mengandungi void dan udara yang terperangkap di dalam acuan. Namun, simulasi semata-mata tidak dapat memastikan proses pengacuan yang sempurna. Terdapat beberapa had yang perlu diambil kira jika mahu menggunakan simulasi. Antaranya adalah untuk memadankan simulasi dengan kandungan sebatian yang digunakan. Apabila sebatian dalam simulasi dengan yang sebenar adalah berbeza, kemungkinan untuk berlaku kecacatan produk seperti ketidaksempurnaan, keretakan dan produk pecah adalah tinggi. Kecacatan ini juga digelar masalah keboleh-acuan. Biasanya masalah keboleh-acuan akan menyumbang kepada ketidakupayaan produk untuk berfungsi seperti yang ditetapkan. Kecacatan lain yang mungkin terhasil apabila parameter tidak optimum ialah wayar pesong. Wayar pesong didefinisikan sebagai nisbah maksimum kepesongan wayar terhadap panjang wayar. Kajian ini bertujuan untuk menyiasat dan mengoptimumkan parameter pengacuan menggunakan pendekatan Design of Experiments bagi menjamin masalah keboleh-acuan sifar dan wayar pesong yang minimum. Kesan parameter pengacuan terhadap keboleh-acuan dan wayar pesong akan dikaji dan berdasarkan analisa yang dibuat, parameter terbaik akan ditentu dan disyorkan bagi memaksimumkan produk hasil buatan syarikat. Secara keseluruhan, semua parameter pengacuan (Suhu pengacuan, Tekanan pindahan, Masa pindahan) mempunyai hubungan dan interaksi terhadap keboleh-acuan dan wayar pesong. Kiraan statistik dilakukan mengguna perisian Cornerstone dan seterusnya parameter terbaik telah ditentukan. Kajian ini hanya menumpu kepada pengoptimuman parameter pengacuan. Oleh itu untuk meningkatkan keteguhan dan keupayaan produk, dicadangkan untuk meneruskan kajian mengenai faktor lain seperti sifat kimia sebatian dan rekaan alat pengacuan.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Mohd Sanusi Bin Abdul Aziz from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this project.

I would also like to express my greatest gratitude to Mr. Fang Chee Hong from Infineon Technologies Discrete Segment, coach of this project for his advice and suggestions in improvement of mold ability and wire sweep in molding process. Special thanks to Infineon Technologies (M) Sdn Bhd for the financial support throughout this project.

Particularly, I would also like to express my deepest gratitude to Mr. See Beng Keh, Director of Development in Discrete Segment for his advice, moral and also technical support in all the experiments and analysis works.

Special thanks to all my colleagues, my beautiful wife, adorable children and beloved parents and siblings for their moral support in completing this degree. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

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dpm	-	Defect per millions
^{o} C	-	Degrees celcius
h	-	Hour
kPa	-	Kilo Pascal
%	-	Percent
psi	-	Pounds per square inch
sec	-	Second

CHAPTER 1

INTRODUCTION

1.1 Introduction and background

Recently, semiconductors industries have had a monumental impact in our society. It is found out that the semiconductor devices have been used extensively in daily lives. Without semiconductors technology, electronic devices such as television, air-conditioner, personal computer, microwave oven and others will not be able to do complex calculation and will have very limited function. Anything that is computerized or uses radio waves depends on semiconductors product. Among semiconductor products inside the electronic equipment are such as Integrated Circuit (IC), transistor, diode, LED, capacitor and sensor. It is well known that the nature of the semiconductor products are very small and billions quantity of product is manufactured and used globally all around the world. Some example of semiconductor products is shown in Figure 1.1.

Figure 1.1: Example of Semiconductor Products (Infineon, 2012)

Even though the semiconductor business is greatly profitable, it is one of the most challenge industries in the world. There are a lot of small competitors which keep competing with larger and established Original Equipment Manufacturer (OEM) companies such as Intel and Infineon. It is not strange that recently there are few mergers between small and OEM companies due to extremely challenged situation and in some cases merely to expand into different market. As shown in Figure 1.2, it could be observed that the global industrial semiconductor market have very bright future and consistently increasing towards year 2018. By year 2018, market worth more than 50 billion dollars is expected to be achieved in global industrial semiconductor.

As a result of the continuously increasing integration density and decreasing unit costs, the semiconductor industry has been one of the fastest growing sectors in the worldwide economy. Current industry trend is towards portable, wearable, ability to do complex function and very powerful computing devices to execute daily life jobs.

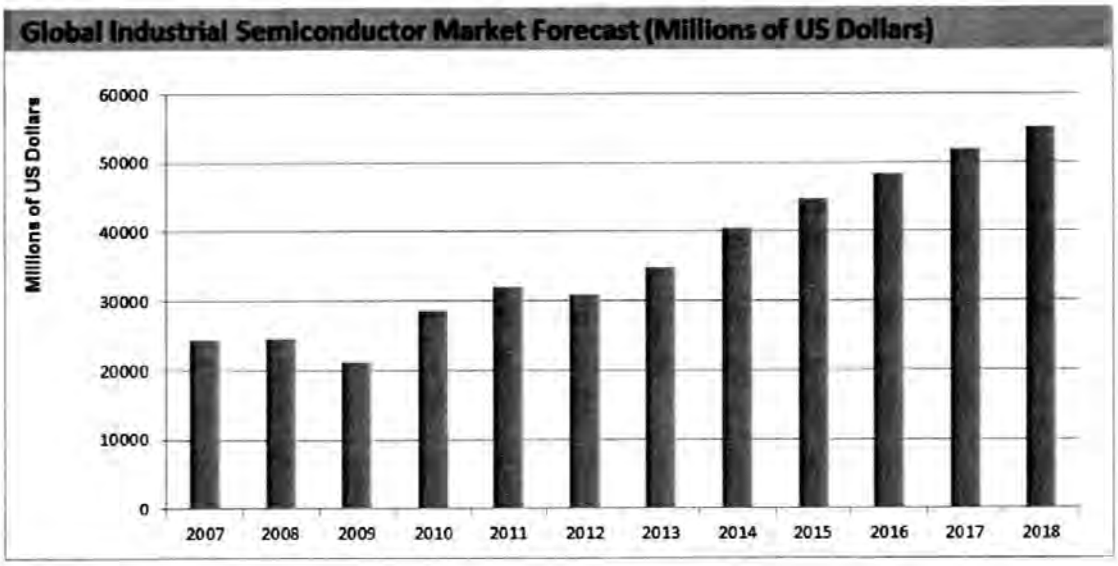

Figure 1.2: Global industrial semiconductor market forecast (HIS Inc., 2014)

But then how do small companies survived with all the challenges? There are few factors that could determine the survivability of the companies. One of the main key which differentiates one semiconductor manufacturer to the others is the quality of its delivered products. When the qualities are high, fewer defects will be produced, the customer would be exceptionally happy and the company will gain good reputation which indirectly increased their profit margin. This will ensure the survivability of the manufacturer that is already in the competitive market.

Encapsulation, which is also known as molding, is one of the main processes in semiconductor manufacturing. In the semiconductor industry, encapsulation process is usually produced with transfer type molding due to the high accuracy of transfer molding tooling and low cycle time of the process. This research aims to investigate and propose an optimal molding parameter to achieve zero mold ability issues and good wire sweep index, which will improve the molding process yield and further reduce the molding defect.

1.2 Problem Statement

The reality now is the manufacturers are still producing the defects and spending lots of money on improving their process to minimize the problems at the lowest level. Commonly, defect that occurs in semiconductor products are encapsulation related defects. Several billions were lost during manufacturing of the semiconductor devices. Every semiconductor manufacturing company spends high effort in order to take lead in the electronic markets. They are competing with each other to be the pioneer and the dominator of electronic markets. In semiconductor industry, there are few core processes in fabricating the electronic component. It includes wafer fabrication, wafer sawing, die bond process, wire bond process, molding process, plating process, trim and form process and electrical testing process.

In this research, molding process or also called encapsulation process will be picked and focused. Generally, common type of molding use in semiconductor is transfer molding technology. Transfer molding technology is attractive because it has some advantage of low cost, high productivity and high reliability (Noda, 1997).

The ideal process of encapsulation is to achieve good mold ability, perfect molded packages, and stable wire sweep index. As the complexity of semiconductor devices increases, the design and molding of such package becomes more important. Molding simulation is necessary to check the flow front, gate design option and the possible voids track (Lee, 2008). However, simulation alone could not guarantee the perfect molding process.

When simulation is not correctly done or molding parameter is not optimized, few potential defects may be produced such as incomplete mold, crack mold, mold chipped, uneven surface and many more. These defects are also called mold ability problem. Normally, the mold ability defect will result on drop of function performance or reliability performance issues soon or later.

Another defect that could be produced if the parameter is not optimized is wire sweep. Wire sweep is defined as the ratio of the maximum wire deviation (deformation) to the wire span. In this case, companies will target to have lowest wire sweep index to avoid quality issues. This proposed study will setup a guideline on how to optimize molding transfer parameter and obtain the best mold ability, perfect packages and low wire sweep index.

1.3 Research Objectives

There are several defects that could be related to encapsulation process in the semiconductor manufacturing. In order to improve the yield and minimize the molding defect, mold ability and wire sweep are chosen as main output parameters. The objectives of this research are:

i. To study the effects of significant molding parameters (Molding Temperature, Transfer Time and Transfer Pressure) on the mold ability and wire sweep performance.
ii. To recommend the best selection of molding parameters for achieving good mold ability and wire sweep index by using Design of Experiment (DOE) approach.

1.4 Scope of Research

The scopes of the research are as follows:

i. Machine: HANMI AutoMold S1000 machine
ii. Package type: Plastic-Green-Single-Small-Outline-Magnet (PG-SSOM-3-11)
iii. DOE: Response Surface Methodology (RSM), Central Composite Design (CCD)
iv. Variable factor: Molding Temperature, Transfer Time and Transfer Pressure.
v. Constant factor: Epoxy Mold Compound (EMC), Lead Frame, Mold Tool Design.

1.5 Research Benefit

There are several benefits that are gained from this research:

i. New benchmark data on the effects of molding parameter for achieving good performance in molding process.
ii. Optimal molding parameter which produces minimum defect and high yield.
iii. Higher process yield will contribute to better company profit margin.

CHAPTER 2

LITERATURE REVIEW

2.1 Semiconductor

Semiconductor is composed of two words "Semi" and "conductor". Semi means not completely, while conductor is a material which could conduct electricity through it. Thus, in other word, semiconductor means material that could conduct electricity to some extent, but not full as conductive material. Semiconductor material has unique physical properties somewhere between conductor and an insulator. Generally, it has been realized by doping process, which is process of adding small amounts of impurities to pure semiconductors causing the changes of conductivity of the material. The semiconductor devices could be found everywhere; it consists in a matter of electrical appliances at home or anything that used electricity as its main source.

2.2 Semiconductor Packaging Assembly Technology

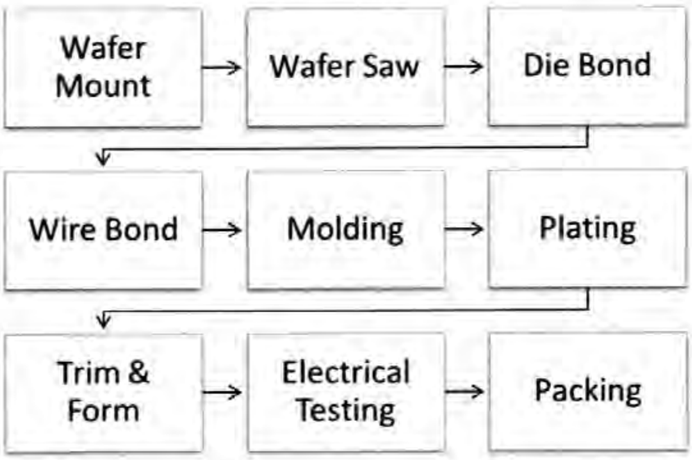

Figure 2.1: Common semiconductor packaging assembly process flow

Figure 2.1 shows common semiconductor packaging assembly process flow. Wafer mount is the first step of a package assembly in semiconductor fabrication. During this step, the wafer is mounted on a Mylar (type of adhesive plastic) that is attached to a ring. The adhesive film of the Mylar ensures that each dies remain firmly in place and ready for next process.

Wafer sawing is a cutting process which separate dies from Mylar mounted wafer. This process could be achieved by scribing and breaking, by mechanical sawing machine or by laser cutting machine. All methods are typically automated to ensure the accuracy and precision of the cutting.

Die Bond is a process that attaching die (Silicon chip) to the die pad of lead frame or substrate. Normally the adhesive material used to attach the die is polyimides, epoxy or silver-filled glass or glue. First the adhesive glue material will be dispensed in controlled amounts on the die pad, and then the dies are removed from the wafer and positioned it on the adhesive material. These processes use advanced automated die bond machine.

Wire Bond is a process which provides electrical connection between die and external leads of semiconductor devices using ultra fine bonding wires. Two common wire used in wire bond processes are gold (Au) wire and copper (Cu) wire. First, a gold ball is formed by melting the end of the wire by using spark and then it been brought into contact with the bond pad by applying adequate pressure, heat and ultrasonic forces for specific amount of time. Wire is then run to the corresponding lead of substrate forming a "loop" between bond pad and external lead. Again, pressure and ultrasonic forces are applied to the wire to form the second bond.

Molding or encapsulation process is a process of encapsulating a semiconductor device by using thermoset polymer (epoxy mold compound) material which will protect the inner die and bonded wire from damage. One of the major encapsulation technique