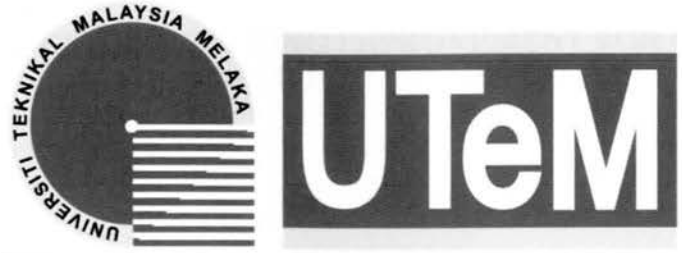

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

NON-STICKING ON GROUND RING IMPROVEMENT FOR COPPER WIRE BONDING WITH DMAIC APPROACH

Tan Kian Heong

Master of Manufacturing Engineering
(Manufacturing System Engineering)

2016

NON-STICKING ON GROUND RING IMPROVEMENT FOR COPPER WIRE BONDING WITH DMAIC APPROACH

TAN KIAN HEONG

A thesis 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

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Faculty Of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

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("Agreement")

by and between

Tan Kian Heong

with home address at No.8 Jalan Kasturi 1/8, Taman Kasturi Seksyen 1,
75050 Melaka,Malaysia.
- hereinafter referred to as "**Recipient**"

and

Infineon Technologies (Malaysia) Sdn. Bhd. (56645-D)

with office at Free Zone, Batu Berendam, 75350 Melaka, Malaysia
- hereinafter referred to as "**Infineon**"

- both may hereinafter be referred to as "**Party**" or "**Parties**"

Effective Date: 1st March 2014

Expiration Date: 31st January 2016

Survival Period: 5 years

WHEREAS, Infineon intends to engage in collaboration with the Recipient concerning the Master Project on "Non-Sticking on Ground Ring Improvement for Copper Wire Bonding with DMAIC Approach" by Tan Kian Heong (760411-05-5519) as a Master of Manufacturing Engineering (Manufacturing System Engineering) Degree project ("Purpose");

WHEREAS, in the course of such discussions and other activities (which may include line visits, presentations as well as the supply of services), it is anticipated that Infineon will disclose to the Recipient certain Confidential Information (as defined below) for the Purpose as set forth above;

NOW THEREFORE, the Parties agree as follows:

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15. **Governing Law**. This Agreement shall be subject to the substantive law in force in Malaysia without reference to its conflicts of law provisions.

IN WITNESS WHEREOF, the Parties have caused this Agreement to be executed by their duly authorized representatives on the dates specified below.

Tan Kian Heong

Signature: .....

Date: 12/5/15

NRIC number: 760411-05-5519

Infineon Technologies (Malaysia) Sdn. Bhd. (56645-D)

Signature: .....

Name: Adrian Tong Soon Hock

Title: Mr

Date: 12/5/15

NRIC number: 630416-04-5349

Company stamp:

INFINEON TECHNOLOGIES (M) SDN. BHD. (56645-D)
UNIT PROCESS DEVELOPMENT
FREE TRADE ZONE, BATU BERENDAM
75710 MELAKA, MALAYSIA.

Witnessed by: .....

Name: TAN WEE KIRN

Title: MR

Date: 12/5/15

NRIC number: 880518-04-5261

Witnessed by: .....

Name : Nor Azman bin Jaafar

Title : Senior Program Manager

Date: 20/5/15

NRIC number: 660806-05-5371

DECLARATION

I declare that this thesis entitled "Non-sticking on Ground Ring Improvement for Copper Wire Bonding with DMAIC Approach" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Tan Kian Heong

Date : 29/2/2016

APPROVAL

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 partial fulfillment of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature : .....

Supervisor Name : ASSOC. PROF. IR. DR. PUVANASVARAN A/L A. PERUMAL
Faculty Of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Date : 29/2/2016

ABSTRACT

Semiconductor industries are in the process of converting gold wire bonding to copper wire bonding because of significant cost saving from gold price. The conversion from gold to copper also gives rise to many challenges due to the copper wire properties. Copper wire bonding is very sensitive to the combination of wire type, wire bonder, capillary, bonding parameters, bond pad technology, lead frame plating, pretreatment and others materials or processes that directly or indirectly in contact with the interconnect wire. Typically in semiconductor, wire bond connect bond pad to lead finger. In some application, ground bond is needed to connect ground ring to lead finger. In the past, ground bond with gold wire did not posed much problem. With the introduction of copper wire and pre-plated frame, wire bond reject become more significant. From manufacturing data, for copper wire bonding on ground, 3% of yield loss was observed because of non-sticking on ground ring (NSOG). Consequently, this will affect the margin of cost saving for the copper wire introduction. Factors affecting the high yield loss need to be studied with systematic method in order to reduce the NSOG reject to acceptable level (0.5%) for manufacturing. Fundamental knowledge of copper wire bonding and DMAIC methodology were reviewed. Two methods of optimization (DOE and DMAIC) are regularly employed by researcher to solve specific problem. There exists a gap in the understanding of copper wire bonding on pre-plated ground ring which is overhang. This gap will be covered in this project. Overall, DMAIC methodology is used in this project. The first objective of this project is to determine factor that influence NSOG defect. This is accomplished with hypothesis testing on identified factors from C&E matrix. P-value of 0.05 or less serves as guideline to determine the significance of each factor. The second objective is to develop mathematical model to describe NSOG defect. This is possible with the DOE and ANOVA analysis. Final objective is to improve NSOG defect to acceptable level (0.5%) for manufacturing purpose with DMAIC approach. At the end of Analyse phase, ground bond parameters; copper wire FAB hardness; and clamp and paddle are determined as significant factors. Mathematical model for NSOG defect was proposed which is a linear model with interaction terms of ultrasonic power, bond force and bond time. From the multi responses DOE optimization, process window was derived to minimize NSOG defect; and to maximize ball pull and ball shear value. Small scale study with different machines was carried out in the Improve phase. In Control phase, performance of NSOG was monitored. With DMAIC approach, NSOG defect was confirmed to meet objective of 0.5% and below for manufacturing condition. Stable and sustainable performance improvement is proven with various tools in DMAIC.

ABSTRAK

Industri semikonduktor dalam proses menukarkan gold wire bonding dengan copper wire bonding kerana penjimatan dari harga emas. Penukaran kepada copper wire bonding menimbulkan pelbagai cabaran kerana sifat tembaga. Copper wire bonding adalah sangat sensitif kepada gabungan jenis wire, mesin, kapilari, pretreatment, teknologi bond pad, lead frame plating, dan lain-lain bahan-bahan atau proses yang secara langsung atau tidak langsung dalam hubungan dengan interconnect tersebut. Biasanya dalam semikonduktor, wire bond menyambung dari bond pad ke lead finger. Dalam beberapa aplikasi, ground bond diperlukan untuk menyambung ground ring ke lead finger. Dahulu, ground bond dengan gold wire tidak menimbulkan banyak masalah. Dengan pengenalan copper wire dan pre-plated frame, wire bond reject menjadi lebih ketara. Daripada data pengeluaran, 3% reject adalah non-sticking on ground ring (NSOG). Oleh yang demikian, kos pembuatan akan meningkat. Untuk mengurangkan kadar tersebut ke tahap yang boleh diterima untuk pembuatan (0.5%), faktor-faktor yang berkaitan perlu dikaji dengan kaedah yang sistematik. Pengetahuan asas copper wire bonding dan metodologi DMAIC dikaji berdasarkan sumber yang ada. Dua kaedah pengoptimuman (DOE dan DMAIC) kerap digunakan oleh penyelidik untuk menyelesaikan masalah tertentu. Wujud jurang dalam pemahaman copper wire bonding pada pre-plated ground ring yang tergantung. Jurang ini dibincangkan dalam projek ini. Secara keseluruhan, metodologi DMAIC digunakan dalam projek ini. Objektif pertama projek ini adalah untuk menentukan faktor yang mempengaruhi kecacatan NSOG. Ini dapat dicapai dengan pengujian hipotesis yang dikenal pasti daripada matriks C&E. P-value 0.05 atau kurang berfungsi sebagai garis panduan untuk menentukan kepentingan faktor. Objektif kedua adalah untuk membangunkan model matematik untuk NSOG. Ini boleh dilakukan dengan DOE dan ANOVA analisis. Objektif terakhir adalah untuk memperbaikan NSOG kepada tahap yang boleh diterima (0.5%) untuk tujuan pembuatan dengan pendekatan DMAIC. Pada akhir fasa Analyse, parameter ground bond; kekerasan copper wire FAB; dan clamp and paddle ditentukan sebagai faktor-faktor yang penting. Model matematik bagi NSOG telah dicadangkan adalah model linear dengan interaksi oleh ultrasonic power, bond force dan bond time. Daripada DOE pengoptimuman untuk pelbagai respon, tetingkap proses diperoleh untuk mengurangkan NSOG; dan untuk memaksimumkan ball pull dan ball shear. Kajian berskala kecil dengan mesin yang berbeza dijalankan dalam fasa Improve. Dalam fasa Control, prestasi NSOG telah dipantau. Dengan pendekatan DMAIC, NSOG disahkan memenuhi objektif 0.5% atau kurang untuk pembuatan. Peningkatan prestasi yang stabil dan mampan terbukti dengan pelbagai kaedah dalam DMAIC.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Associate Professor Ir. Dr. Puvanasvaran A/L A. Perumal from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis.

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3 Steps bond mode	-	Wire bond parameters setting with three segments
AHP	-	Analytic hierarchy process
Al	-	Aluminium
Au	-	Gold
ANOVA	-	Analysis of variance
BBD	-	Bonded ball diameter
BBH	-	Bonded ball height
C&E Matrix	-	Cause and effect matrix
C/V	-	Contact velocity
Cu	-	Copper
DMAIC	-	Define, measure, analyse, improve and control
DOE	-	Design of experiments
EFO	-	Electronic flame off
FAB	-	Free air ball
FMEA	-	Failure mode and effects analysis
H2	-	Hydrogen gas
HAZ	-	Heat affected zone
IC	-	Integrated circuit
IMC	-	Intermetallic compound
JEDEC	-	Joint Electron Device Engineering Council
K&S	-	Kulicke and Soffa
KPIV	-	Key process input variable
KPOV	-	Key process output variable
MTBA	-	Mean time between assist
N2	-	Nitrogen gas
NiPdAu	-	Nickel palladium gold
NSOG	-	Non-stick on ground

NSOL	-	Non-stick on lead
NSOP	-	Non-stick on pad
PDCA	-	Plan, do, check and act
PdCu	-	Palladium coated copper wire
RSM	-	Response surface methodology
SIPOC	-	Suppliers, inputs, process boundaries, outputs, customers
Std	-	Standard
Std Bond Mode	-	Wire bond parameters setting with one standard segment
UPH	-	Unit per hour
USG	-	Ultrasonic power of transducer

CHAPTER 1

INTRODUCTION

This chapter depicts overall review of the project. Problem statement, purpose, and scope of the project are presented in this chapter. The project significance and outline of this report are presented in this chapter.

1.1 Background of the Project

In the past gold wire bonding was the most common wire bond technology with high and stable yield in semiconductor industries. Gold wire bonding was slowly converted to copper wire bonding because of the cost saving benefit. In general, based on World Gold Council (2015), gold price increased significantly from 2005 to 2013. Even with price dropped in 2014 (USD41 per gram), gold price is 2.7 times compared with gold price in 2005. Figure 1.1 shows the gold price trend for 10 years (from 2005 till 2015). On the other hands, copper material price is relatively cheap, which is USD7 per kg (Infomine, 2014). However, the conversion from gold to copper also gives rise to many challenges due to the copper wire properties. Non-stick on ground (NSOG) is one of the challenges that will be explained in this chapter.