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Faculty of Manufacturing Engineering

DESIGN AND ANALYSIS OF ELECTRICAL TESTING PROBE FOR SEMICONDUCTOR INTERGRATED CIRCUIT

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To my beloved mother and father.

ABSTRACT

In the field of Test and Measurement in Semiconductor industry, where measuring small resistances are necessary on Semiconductor IC (Integrated Circuit). Nowadays given the fact that electronics gadgets are evaluated become more advanced, the size of the gadgets is getting smaller and smaller, and getting cheaper in terms of price, this is a result of human kind is evaluating to advancement of electronics world. In this project, testing robe for Semiconductor IC was design to equip with self-sustaining scrubbing function, sustainable contact force and higher life span by Computer Aided Design (CAD). Then the most appropriate Testing Probe was selected by Analytical Hierarchy Process (AHP), which the pair-wise comparison matrix is constructed with the goal of Scrubbing function (SF), Contact force (CF), Low resistivity (LR), High current (HC), and Life span (LS). To analyze the designed Testing Probe for Semiconductor IC which fulfill the criteria, the test probe was undergo Finite Element Analysis (FEA) to determine the optimum Fatigue stress, Yield strength, maximum stress and displacement. Then the test probe was simulated under testing condition, data such as contact resistance C_{RES} and displacement of test probe was collected until it reach its maximum life spend of 1.3 million touchdown. As result the most appropriate test probe was selected, which fulfilled all of the requirements.

ABSTRAK

Dalam bidang Ujian dan Pengukuran dalam industri Semiconductor, di mana mengukur rintangan kecil diperlukan Semiconductor IC (Integrated Circuit). Pada masa kini memandangkan hakikat bahawa alat elektronik dinilai menjadi semakin maju, saiz alat menjadi semakin kecil dan lebih kecil, dan lebih murah dari segi harga, ini adalah hasil daripada tindakan manusia dalam menilai kemajuan dunia elektronik. Dalam projek ini, testing robe untuk Semiconductor IC telah direkabentuk bersama dengan fungsi self-sustaining scrubbing, *daya kenalan mampan dan jangka hayat yang lebih tinggi oleh Computer Aided Design (CAD). Kemudian Testing Probe paling sesuai dipilih oleh Analytical Hierarchy Process (AHP), dimana perbandingan matriks pasangan-bijak dibina dengan matlamat untuk Fungsi Menyental (SF), Daya Hubungi (CF), Rintangan Rendah (LR), Arus electric yang tinggi (HC), dan Jangka Hayat (LS). Untuk menganalisis rekaan* Testing Probe *untuk Semiconductor IC dimana memenuhi kriteria, probe ujian menjalani Finite Element Analysis (FEA) untuk menentukan tekanan Keletihan yang optimum. Hasil kekuatan, tekanan maksimum dan anjakan. Kemudian probe ujian itu simulasi di bawah keadaan ujian, data seperti* C_{RES} *rintangan kenalan dan anjakan ujian siasatan dikumpulkan sehingga ia mencapai perbelanjaan hidup maksimum sebanyak 1.3 juta pendaratan. Akhirnya Testing Probe yang paling sesuai dipilih mengikuti permintaan yang ditetapkan.*

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LIST OF ABBREVIATIONS

JEDEC	Joint Electron Device Engineering Council
IC	Integrated Circuit
SMED	Single-Minute Exchange of Die
DUT	Device Under Test
CPD	Contact Potential Difference
PCB	Printed Circuit Board
FEA	Finite Element Analysis
AHP	Analytical Hierarchy Process
CAD	Computer Aided Design

Chapter 1

INTRODUCTION

1.1 Introduction

In the field of Test and Measurement in Semiconductor industry, where measuring small resistances are necessary on Semiconductor IC (Integrated Circuit), there is a special measurement technique called the Kelvin contact method (also called as four-wire measurement, Four-terminal sensing (4T sensing), 4-wire sensing, or 4-point probes method).

The Kelvin description comes from Lord Kelvin, the honorary title given William Thomson in the late 1800's. William Thomson was a physicist, inventor, engineer, and professor for more than 50 years at the University of Glasgow in Scotland. One of his main projects was the design and implementation of the first transatlantic telegraph cable. As part of that project, he developed the Kelvin Bridge in 1861, which enabled the accurate measurement of very low resistances. The Kelvin Bridge uses four terminal connections at the high current resistors, thereby giving the name Kelvin connection to the means of providing separate force and sense connections to components (Anonymous, 2014).

A Kelvin probe (KP) is a tool for measuring contact potential difference (CPD, designated Vc), and thus both the spatial and temporal variation of surface potential. It has a vibrating capacitance plate (tip) that is placed near a conducting surface of interest. When an electrical connection is made between the two electrodes, their Fermi levels equalize producing a potential difference between the opposing plates. The vibration, which causes a changing capacitance, results in a current that can be measured. If a backing (bias) potential (Vb) is added between the tip and the surface, the current is proportional to Vb-Vc. From the relationship between the measured current and the (adjustable) backing potential, one can determine the CPD between the tip and the surface under study. The magnitude of the measured current depends on the mean spacing between the tip and the surface, among other things. Therefore, this distance needs to be measured independently. Any change found can be fed back to stabilize the distance (Robert et al.,2013).

The advantage of the four-wire measurement lies in the fact that the result is not influenced by the electrical resistance of the wires and contact points. Besides that, they allow accurate measurement of very low resistance values, accurate voltage measurement, assurance of test, and improved heat dissipation.

1.2 Background of study

Nowadays given the fact that electronics gadgets are evaluate become more advanced, the size of the gadgets is getting smaller and smaller, and getting cheaper in term of price, this is a result of human kind is evaluating to advancement of electronics world. In the trends of electronic gadgets is becoming smaller, better and affordable to be owned by all ranges of user in society, the manufacturers cracking their head to reduce the manufacturing cost for their electronic products.

Hence, semiconductor companies have become 'fabless' or 'fablite', which majority of the semiconductors IC are outsourcing for fabrication of the devices to a specialized manufacturer called a semiconductor foundry. This is where Kelvin contactors take place in this competitively markets, it allow testing of devices with measurements sensitive to contact resistance (R_C), power management devices, precision op amps, and high BIT count ADCs or DACs.

Because of Kelvin's initial costs, it is used when no other test method accurately can test the devices. The cost of Kelvin's test systems tends to be higher and typically requires a more difficult load board (PCB) layout, this is due to it need at least two Electrical test probes on one tiny leads or pads. The minimum pads or leads on the IC can go beyond 0.2x0.15 mm in size. Besides that, the tolerance of the layout on load board (PCB) need to be very high in tolerance and precision to cater with fine pads and pitch of IC. Hence, it resulted that the process of fabrication becomes critical and expensive, due to small spacing required to separate the force and sense pad.

Besides that, the design of the Electrical test probe need to ensure there is no wear and tear caused on the load board (PCB) side, this is to ensure that the costly customized PCB's based on each IC's contact pad will not wear off, due to movement of the test probe when performing testing in real production. Hence, it can reduce the manufacturing cost for IC.

1.3 Problems statements

When come into maintenances, all of the user would like to have "maintenance free" in their systems, but in reality it would not happen. In real semiconductor IC's production, which the Electrical test probe will be in contact with the IC's pad, which some time the probes will be contaminated by the dust or debris carried together with the IC. The IC's pad normally is coated with Matte-tin (Sn) or Nickel Palladium (NiPdAu), when it's exposed in production it will tend to be oxidize. Hence, a oxide layer will be formed to covered the IC's pad, which this is not beneficial for Electrical test probe. Therefore the Electrical test probe will be needed to have self-sustain feature to be build in when in design stage, the self-sustaining scrubbing function is to break through oxide layers present on many device pads.

On top of that, due to the pad size is getting smaller and smaller, the Electrical test probe which equipped with self-sustaining scrubbing function, need to have tiny scrubbing distance. This is to avoid the test probe will over travel beyond the pad size and having electrical test on IC molded body instead IC's pad which will resulted failed in Kelvin test. Besides that, the electrical test probe has a more pointed contact probe for accurate voltage measurements.

In order to have more economical in terms of price tag, the Electrical test probe need to be sustain in higher life span. This is to ensure a single piece of test probe can sustain more than 1 million (1KK) insertions in production environment. The selection material of the test probe need to be hard enough to sustain high consumption production environment, besides that coating on the surface of test probe can enhance and prolong the life span.

With device pads controlled by JEDEC, the variances in package parameters require that the Electrical test probe to be designed to hit the center of the device pad. This is to assure the contact also will always connect with the device pad or lead, due to the IC's pad is tend to become tiny nowadays. Besides that, the fast conversion or Single-Minute Exchange of Die (SMED) is also critical in IC manufacturing industry, which it provide rapid change over to another type of IC production on machine and quick changing Electrical test probe when its wear off in production. Hence, the design of Electrical test probe must be easy to replace and change over.

Last but not least, the Electrical test probe force when in contact need to be designed and calculated carefully. Too strong in contact force will cause IC resin molded body cracked and the die molded in the IC to be cracked. Weak of contact force will cause on bad contacting on device's pad and it will not having the self-sustaining scrubbing function is to break through oxide layers present on many device pads. Table 1.1 shows the electrical specification of test probe.

Table 1.1: Electrical specification of test probe

Typical contact resistance per pin	50mΩ	Must
Continuous Current	4A	Must
Pulse Current	Up to 10A @ 0.3ms	Must
Max Voltage	500V	Wish
Test Mode	Kelvin / non-Kelvin	Must
Bandwidth	Min loss 2 GHz @ -1 db (S21)	Must

1.4 Objectives

The objectives of the study design and analysis of electrical testing probe for semiconductor integrated circuit as follows,

i. To design Testing Probe for Semiconductor IC, to equipped with self-sustaining scrubbing function, sustainable contact force and higher life span.

ii. To select the most appropriate Testing Probe for Semiconductor IC.

iii. To analyze the designed Testing Probe for Semiconductor IC, which fulfill the criteria to have self-sustaining scrubbing function, sustainable contact force and higher life span.

1.5 Scope of Study

The scope of study cover the design of Probe for Semiconductor IC to equipped with self-sustaining scrubbing function, sustainable contact force and higher life span. testing robe for Semiconductor IC are design to equipped with self-sustaining scrubbing function, sustainable contact force and higher life span by Computer Aided Design (CAD). Then the most appropriate Testing Probe was selected by Analytical Hierarchy Process (AHP). To analyze the designed Testing Probe for Semiconductor IC which fulfill the criteria, the test probe was undergo Finite Element Analysis (FEA) to determine the optimum Fatigue stress, Yield strength, maximum stress and displacement. Then the test probe was simulated under testing condition, data such as contact resistance C_{RES} and displacement of test probe was collected until it reach its maximum life spend of 1.3 million touchdown.