Faculty of Mechanical Engineering

THE STUDY OF TEMPERATURE ANALYSIS ON FUSIBLE METAL BONDING APPLICATION

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THE STUDY OF TEMPERATURE ANALYSIS ON FUSIBLE METAL BONDING APPLICATION

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DECLARATION

I declare that this thesis entitled "The Study of Temperature Analysis on Fusible Metal Bonding Application" 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 : Yogeswaran a/l Gnanasegaran

Date : 11/11/2020

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature : 

Supervisor Name : ASSOCIATE PROFESSOR DR.AHMAD ANAS BIN YUSOF

Date : 11.11.2020

DEDICATION

I would like to express and dedicate this thesis to my whole family. A big glad thank you for your continuous spirit and long lasting support during my crucial educational years. Without their patience, forgiving and most of all love that been given to me, the completion of this thesis research would been possible.

Beloved Father and Mother and Wife

V.S.Gnanasegaran, N.Susee Dewi, Lavanya

ABSTRACT

High frequency packages become very important due to the rapid growth of wireless communication system. They require compactness, low cost and high performances even at frequency up to 60 GHz. Flip-chip device assembly using organic substrates at very high frequency has become a cost competitive packaging method in semiconductor industries. This thesis discusses the influence of temperature on copper pillar solder joints contact to the surface of the substrate after reflow respect to staging time by using flip chip device. Samples of the flip chip devices will be bonded under selected temperature and then will undergo cross section of sample to determine the failure analysis of flip chip bonded after reflow process. Therefore, different temperature and staging time in bonding process can cause the bonding mechanism of flip chip copper pillar to have less adhesion and copper pillar crack at the neck of the pillar. Besides that, the nature of solder contributes to poor solder wetting and low thermal conductivity. For an example, the behavior of Sn-based solder are similar to current high Pb-solder in term of thermal conductivity and solder wetting characteristic. The test results shows that, the copper pillar solder can be productively sustain the solder joint of the thermal fatigue life cycle and the formation of intermetallic compound (IMC). The basic requirements of the joining material and the process will be discuss in this study. In future, experimental research on the performance of solder joint with different type of temperature is required.In summary, improvement towards the flip chip die bonding process which by controlling the optimum temperature and staging time would overall be a driving force towards the development of similar packages with more demanding requirements towards the existing flip chip packages.

KAJIAN ANALISIS SUHU TERHADAP APLIKASI IKATAN LOGAM

ABSTRAK

Pakej elektrik arus tinggi menjadi sangat penting disebabkan oleh pertumbuhan yang pesat dalam alat sistem komunikasi. Alat elektrik ini memerlukan kuantiti pembuatan yang tinggi, kos yang rendah dan prestasi yang tinggi walaupun pada frekuensi sehingga 60 GHz. Pemasaran peranti cip-balikan dengan menggunakan bahan organik pada frekuensi yang sangat tinggi telah menjadikan kaedah pembuatan yang berdaya saing dari segi kos dalam sektor industri semikonduktor. Oleh itu, tesis ini membincangkan pengaruh suhu dan bahan pelekatan yang digunakan seperti bahan SnAgCu di atas permukaan alat elektrik. Sambungan ini dipengaruhi oleh proses pemanasan dan masa untuk proses cip balikan. Sampel cip-balikan akan dipanaskan di bawah suhu yang terpilih dan seterusnya akan menjalani proses pemotongan cip-balikan untuk menganalisis tahap kegagalan cip-balikan selepas process pemanasan. Oleh itu, suhu dan masa pelekatan cip balikan yang berbeza boleh menyebabkan permukaan mekanisme ikatan tiang tembaga cip-balikan mempunyai pelekatan yang kurang dan retakan pada leher tiang tembaga cip-balikan. Selain itu, pembentukan sifat logam pateri boleh menyebabkan kelembapan logam pateri dan kekonduksian terma yang rendah. Sebagai contoh, sifat logam pateri Sn adalah sama dengan situasi semasa logam pateri Pb dalam keadaan kekonduksian dan kelembapan logam pateri. Hasil daripada ujian ini menunjukkan bahawa logam pateri ini boleh berkesan dengan lebih efektif dan meningkatkan tahap ketahanan haba logam pateri dalam pembentukan sebatian intermetalik (IMC). Keperluan asas bahan pelekatan logam pateri dan proses pelekatan logam pateri akan dibincangkan dalam kajian ini. Pada masa akan datang, penyelidikan eksperimen mengenai prestasi logam pateri dengan suhu yang berbeza serta masa proses yang tepat diperlukan. Secara ringkasnya, peningkatan ke arah proses pelekatan cip-balikan dengan mengawal suhu yang tepat dan masa pelekatan cip-balikan secara keseluruhan menjadi daya penggerak ke arah pembangunan pakej cip-balikan.

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LIST OF ABBREVIATIONS

ASM	-	Advanced Semiconductor Materials
BGA	-	Ball Grid Array
IMC	-	Intermetallic Compound
IPC	-	Electronic Packaging Circuits
JEDEC	-	Joint Electronics Device Engineering Council
K	-	Dissolution rate
L/V	-	Length of grain and the volume of solder wetting ratio
NCMS	-	National Centre for Manufacturing Science
PPM	-	Parts per Million
PWB	-	Printed Circuit Substrate Materials
RTS	-	Ramp-to-Spike
SEM	-	Scanning Electron Microscope
TSM	-	Top Surface Metallurgy
UBM	-	Under Bump Metallization
UPH	-	Unit Per Hour

LIST OF SYMBOLS

A	-	Area
Ag	-	Silver
Al	-	Aluminium
Au	-	Gold
As	-	Arsenic
Bi	-	Indium
Cd	-	Cadmium
Cu	-	Copper
H	-	Height
In	-	Indium
L	-	Length
N_2	-	Nitrogen
N_2H_2	-	Forming Gas (Nitrogen and Hydrogen)
Ni	-	Nickel
Pb	-	Lead
θ	-	Contact Angle
S	-	Surface of Droplet
Sb	-	Antimony
Se	-	Selenium
Sn	-	Tin
Ti	-	Titanium
V	-	Volume
Zn	-	Zin

LIST OF PUBLICATIONS

Gnanasegaran, Y., Yusof, A.A., and Shukri, M.F., 2018. Study of Thermal-Fluid Analysis on Fusible Metal Bonding Application. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences,* 62 (1), pp.88-102.

CHAPTER 1

INTRODUCTION

This study concerns the bonding temperature on fusible metal bonding application. This work aimed towards copper pillar solder bonding for electronic devices used in automotive electronics industry. Studies on copper pillar solder joint and intermetallic layer formation in leaded alloys system are scarce. Temperature plays an important role in forming a strong adhesion between the fusible metal bonding. The presence of intermetallic growth indicates a good metallurgical formation and generally intermetallic compound (IMC) is brittle and its presence can lead to low shear strength of the joint.

1.1 Fusible metal bonding

Fusible metal bonding or so-called die bonding is a metal alloy that can be easily fused and melted at relatively low temperatures. It is used for soldering with a melting point below 183°C. Melted fusible metals can be used as coolants for their durability under heating and high thermal conductivity such as indium and sodium. In semiconductor, fusible metal alloy is to make electrical devices as interconnection application. It comprises flip chip devices. Flip chip devices are also known as controlled collapse chip connection which refers to a process of interconnecting semiconductor devices such as IC chip and microelectromechanical devices. Flip chip consists of copper metal layer and copper pillar leg. Copper pillar solder leg is connected to the surface of the pad under hot, selected temperature. In most cases, flip chip devices act as electrically-insulating adhesives or so called under fill to provide a strong mechanical connection and heat bridge, and ensure the

solder joints are not stressed due to different heating temperatures of the chip. The under fill potential is to distribute thermal fluid expansion between the chip and the surface of the pad in the solder joints which would lead to a premature failure (Wiese, 2001). Moreover, fusible metal alloys have great durability and can be grouped as flip chip devices or eutectic devices with different types of top layers such as aluminum, copper and silver. Flip chip metal alloys have the highest melting point where the temperature at which the substrate is in solid state is equal to that in the liquid state. Figure 1.1 shows the flip chip units on the wafer table after sawing process whereas Figure 1.2 shows die view after die bonding and molding completion (Tseng et al., 2010).

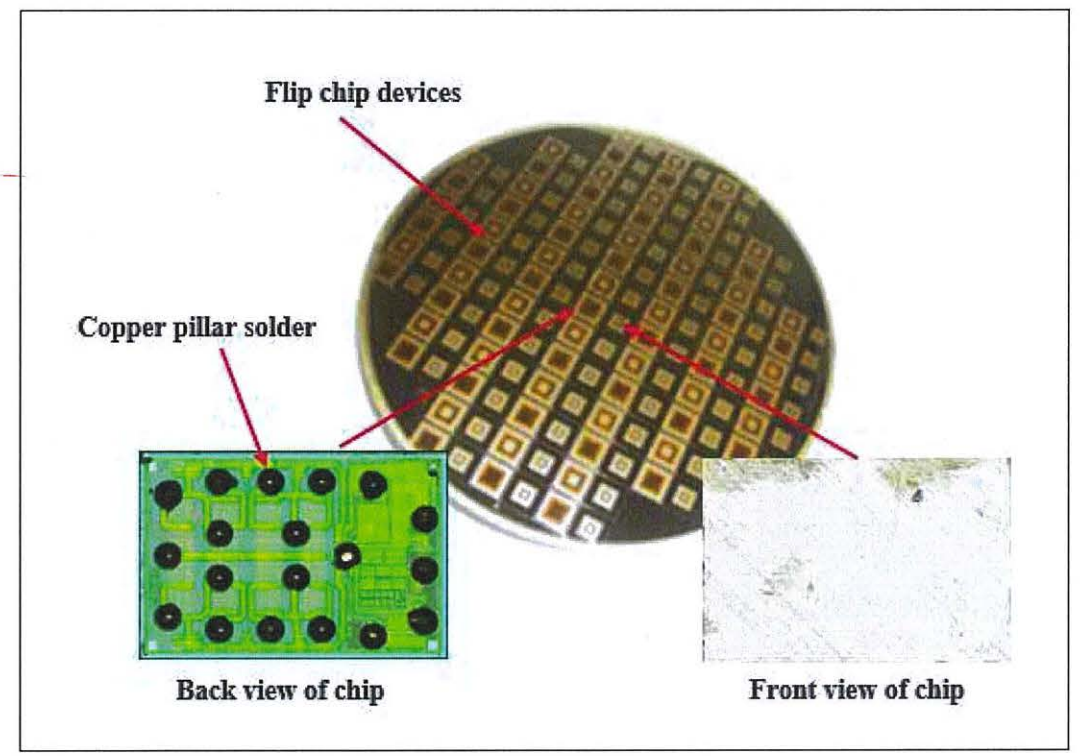

Figure 1.1: Flip chip unit on wafer

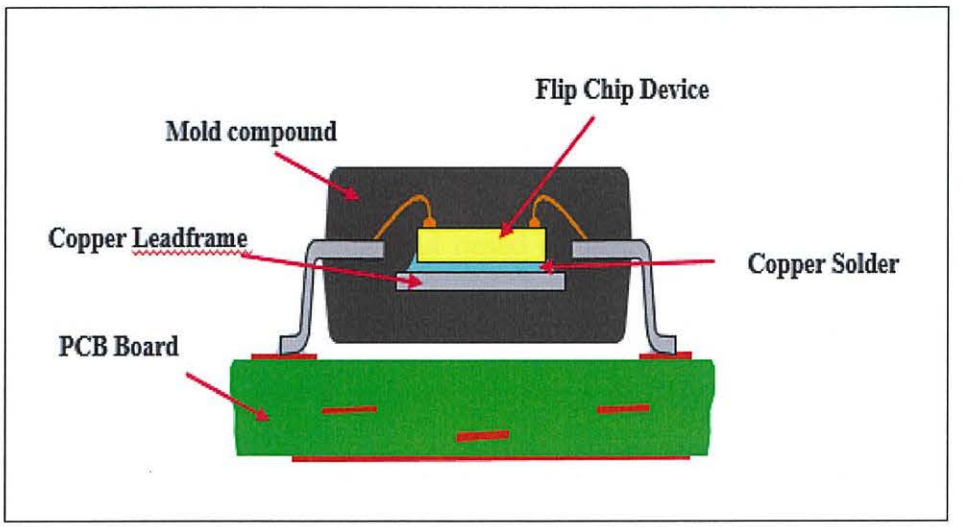

Figure 1.2: Flip chip view after molding

1.2 Sn-Ag-Cu solder alloy

The primary characteristics of copper pillar solder and solder paste for electronic devices are the capability of metal bonding with joining materials, presence of oxygen during bonding, and soldering and properties of alloys reaction between elements. In an analysis of approximately 12,000 pair and ternary phase diagrams conducted by The National Centre for Manufacturing Science (NCMS) (2001), the researchers discovered that the charge amount of competent elements can be formed with the presence of Sn namely Ag, As, Au, Bi, Zn, Cu, In, Sb, Se and Cd. Besides, an overall view of the periodic table indicates that such metallic elements are the nearest to Sn within the same group in the table. Thus, the elements effectiveness with Sn can be studied and compared in the periodic table (Sriyarunya et al., 2010).

Besides, SnPb have been acknowledged as the most prominent materials used in soldering for electronic components and devices because of the material properties connection and minor costs. Because of environmental concerns worldwide, most organizations in Japan and Europe tend to disqualify Pb usage in electronic devices due to the constitutional toxicity of Pb. A large number of Pb-free solder alloys have been replaced

by SnPb solders in electronic devices because of the increasing awareness of the harmful contamination of alloy based lead on environment and human health. In short, SnAgCu solders family are considered to be the most favorable alloys. They have been recommended as the primary candidates for replacing lead based solders because of their low melting temperature, good mechanical property and good wettability. Thus, SnAgCu solders are broadly used in the electronic industry as solder materials. Lately, trace rare earth elements (RE) are combined with lead solder alloys to form excellent solder alloys properties. The addition of RE behaviors such as mechanical, microstructure and wetting behavior are enhanced. However, several issues need to be corrected and resolved for SnAgCu solders which are related to the best composition, high soldering temperature properties, huge undercooling and formation of large intermetallic compound (IMC) as dominant speed up which may cause serious issues under stressed condition in real printed boards in electronic industry. The uses and function of Cd, Sb and Hg can be eliminated immediately due to their inherent toxicity that is harmful to the environment and human health. Moreover, elements such as Mg and Ga are commonly extraordinary and sensitive which are depreciated for further consideration and purposes. Au's costliness is the main reason it is not a choice for further investigation on the reactive characteristic. Bi is also not being considered because it is a byproduct of the Pb mining process. Hence, when Pb manufacturing decreases, the outputs of Bi elements significantly decrease where it may advance with the increase of Bi manufacturing cost. Moreover, certain elements could be thought-through, most alloy compounds that merge with Sn elements have been widely used to substitute the Sn-Pb solder elements in manufacturing electronic products (Sriyarunya et al., 2010).

1.3 Reflow temperature

In order to avoid failure of flip chip after bonding, reflow temperature control process is proposed to acquire a stable thermal mechanical stress during a reflow to eliminate solder joint crack and failure during electrical testing process. The temperature is controlled by the zone where the substrate will flow from the heating to cooling zone. Flip chip alloys begin to melt at a certain temperature and then enter a slushy state before they fully melt at a higher temperature. In order to attach the chip to the surface of the pad, it is flipped over so that its top side faces down, and is aligned so that its pads are aligned with matching pads on the surface pad, and then the solder is reflowed to complete the interconnection. Low or high melting alloys are available in a variety of forms such as cake, ingot, bar, shot, wire, stick, strip and custom shapes. In addition, low manufacturing cost is possible through lead frame density and speed optimization on flip chip. Lead frames are the metal structures inside the flip chip package that carry signals from the die to the outside. Figure 1.3 shows an example of a heater block covered with heater zone cover and Figure 1.4 shows the temperature control and parameter of the heater in a conventional die bonding machine (Lee, 2002).