Hot Air Solder Levelling (HASL) Process Parameter Optimization for SN100CL

By

Fatin Afeeqa Mohd Sobri

(1430411393)

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DECLARATION OF THESIS

Author's full name : Fatin Afeeqa Binti Mohd Sobri

Date of birth : 15 May 1990

Title : "Hot Air Solder Levelling (HASL)" Process Parameters Optimization for SN100CL

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…………………………………….

(**ASSOCIATE PROFESSOR DR. CHE MOHD RUZAIDI GHAZALI)**

Project Supervisor

School of Materials Engineering

University Malaysia Perlis

(Date: …………………..)

School of Materials Engineering

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LIST OF ABBREVIATION

Cu	Copper
ENIG	Electroless Nickel Immersion Gold
Ge	Germanium
HASL	Hot Air Solder Levelling
ImmAg	Immersion Silver
ImmTin	Immersion Tin
IPA	2-Propanol / Isopropyl Alcohol
JIS	Japanese Industrial Standard
Ni	Nickel
OM	Optical Microscope
OSP	Organic Solderability Preservative
OPS	Oxide Polishing Suspension
PCB	Printed Circuit Board
PLCC	Plastic Leaded Chip Carrier
QFP	Quad Flat Package
ROHS	Reduction of Hazardous Substrate
SEM	Scanning Electron Microscope
SMT	Surface Mount Technology
SOIC	Small Outline Integrated Circuit
Sn	Tin
UBM	Underbump Metallurgy
XPS	X-ray Photooelecron spectroscopy

LIST OF SYMBOLS

t	Time
Q	Activation Energy
Pb	Lead

Proses Mengoptimum Parameter "Hot Air Solder Levelling" (HASL) untuk SN100CL

ABSTRAK

Pembungkusan elektronik yang boleh dipercayai kini menjadi faktor paling kritikal dalam industri elektronik. Ramalan kegagalan pateri dan jangka hayatnya menjadi lebih mencabar kerana permintaan yang semakin tinggi untuk prestasi yang lebih bagus dalam peranti elektronik. Dalam pembungkusan elektronik, kemasan permukaan memainkan peranan penting untuk proses pematerian dan pemasangan. Kajian ini dilakukan untuk menentukan kebolehbasahan oleh permukaan penyalutan SN100CL dan proses mengoptimumkan parameter mesin Hot Air Solder Levelling (HASL). Kajian ini dibahagikan kepada dua fasa. Fasa pertama adalah untuk mengkaji hubungan diantara kebolehbasahan terhadap jumlah ketebalan lapisan, ketebalan pateri yang tidak bertindakbalas dan sebatian antara logam (IMC). Fasa kedua pula adalah kajian komposisi yang berbeza pada elemen Germanium (Ge) dalam pateri SN100CL. Lima komposisi Ge berbeza yang digunakan adalah 0 wt%, 0.002 wt%, 0.006 wt%, 0.010 wt% and 0.020 wt% dalam pateri Sn-0.7Cu-0.05Ni. Kajian ini menunjukkan kesan kebolehbasahan salutan SN100CL dengan perbezaan komposisi Ge. Kaedah ujian imbangan kebolehbasahan oleh Gen3 digunakan untuk menilai tahap kebolehbasahan. Kualiti kebolehbasahan dinilai dengan perbandingan relatif dengan masa pembasahan dan daya kebolehbasahan maksimum terhadap permukaan salutan. Didapati bahawa masa membasahkan adalah lebih lama dan daya maksimum pembasahan adalah lebih rendah dengan mengurangkan ketebalan pateri yang tidak bertindakbalas yang disebabkan oleh pertumbuhan lapisan IMC yang telah menghasilkan permukaan yang tidak boleh dibasahkan. Selain daripada itu, komposisi 0.006 wt% Ge merupakan komposisi terbaik dalam solder SN100CL. Keputusan ini ditentukan dengan salutan SN100CL yang telah didedahkan kepada proses pateri balikan dan penuaan. Ketebalan IMC dan ketebalan pateri yang tidak bertindak balas oleh 0 wt% dan 0.006 wt% dikaji menggunakan Mikroskop Imbasan Elektron (SEM) dan keputusan menunjukkan bahawa IMC daripada 0 wt% adalah lebih tinggi berbanding 0.006 wt% Ge. Seterusnya, pateri aloi Sn-0.7Cu-0.05Ni-0.006Ge telah digunakan dalam proses HASL. Proses mengoptimumkan parameter telah dijalankan dan salutan HASL yang terbaik diperhatikan menggunakan SEM. Secara keseluruhannya, kebolehbasahan telah dipengaruhi oleh lapisan pateri yang tidak bertindakbalas dan 0.006 wt% Ge merupakan komposisi terbaik dalam proses HASL dengan parameter 2 saat untuk masa statik dan 5 saat masa celupan.

“Hot Air Solder Levelling (HASL)” Process Parameters Optimization for SN100CL

ABSTRACT

Reliability of electronic packaging has now become the most critical factor in electronic industries. The prediction of solder joint failure and its shelf life becomes more challenging as the increasing demand for superior performance of electronic devices. In electronic packaging, surface finish plays an important role for soldering and assemblies process. This study was made to determine the solderability of SN100CL coating surface and optimized the Hot Air Solder Levelling (HASL) process parameters. This research work was divided into two phases. The first phase is to study the relationship between solderability and the total coating thickness, free solder thickness and interfacial intermetallic compound (IMC). The second phase was the investigation of different composition of Germanium (Ge) in SN100CL solder. Five different composition of Ge used are 0 wt%, 0.002 wt%, 0.006 wt%, 0.010 wt% and 0.020 wt% in Sn-0.7Cu-0.05Ni solder alloy. This research reveals the effect on solderability of SN100CL coating with different Ge compositions. Gen3 wetting balance test method was used to evaluate the solderability. The quality of wetting was evaluated by relative comparison on the wetting time and maximum wetting force exerted on the coated copper surface. It was found that the wetting time was longer and the maximum wetting force was lower with decreasing of free solder thickness layer due to growth of interfacial IMC layer and produced less wettable surface of solder coating. Apart from that, 0.006 wt% of Ge was observed to have the best composition of Ge in SN100CL solder. The results was determined with SN100CL coated surface when introduced to reflowed and aged conditions**.** The IMC and free solder thickness of 0w wt% and 0.006 wt% was observed under Scanning Electron Microscope (SEM) and the results shows that IMC of 0 wt% Ge growth higher compared to 0.006 wt% of Ge. Sn-0.7Cu-0.05Ni+0.006Ge solder alloy was then deployed in HASL process. The parameter optimization was performed and the good HASL coating was observed under SEM. Overall, the solderability are found to be affected by free solder thickness and 0.006 wt% of Ge shows the best composition in HASL process with 2 seconds and 5 seconds of dwell time and level time respectively.

CHAPTER 1

INTRODUCTION

1.1 Background

Solder plays a crucial role in assembly and interconnection of electronic products. As an interconnection, solders provide electrical, thermal and mechanical functions. Environmentally conscious manufacturing is becoming a very important objective for the electronics industry. It is highly desirable to minimize the environmental impact of electronic manufacturing processes. The electronics industry is being forced to eliminate lead from products, due to the undeniable evidence of lead toxicity (Sun et al., 2007).

Lead-free soldering has become one of the most important trends in recent years in the electronics industry due to worldwide environmental and health concerns. All soldering materials must be lead-free, including the solders as well as the surface finishes that are used on the pads of printed circuit boards (PCB) and underbump metallurgy (UBM) on the chip side. Copper is commonly used as the base metal of the soldering pads on PCBs because of its good wetting property with solder. Today, more lead-free surface finishes have been investigated and applied on the Cu base metal of the soldering pads, such as organic solderability preservative (OSP) and electroless nickel immersion gold (ENIG) (Zhang et al., 2009).

The development and minimizing trends of microelectronic packaging technology triggers the component to be smaller and the density of the integrated circuit grows higher. It is now a trend of having smaller gadgets as an urban lifestyles. Continuing the miniaturization the microelectronic components have make the solder joint and its performance becomes the primary focus while choosing the solder and soldering techniques. The processability and manufacturing of the components should be considered regardless of its commercial perspective. With the development of microelectronic packaging technology, components are getting ever smaller and the density of integrated circuits grows higher. It is necessary to understand the mechanical behaviour of the solder alloy for a high reliability of the electronic devices (Kumar et al., 2013; Plumbridge et al., 2004).

Apart from miniaturizing the components and devices, the solder components itself are critical factors that determining the solder joint reliability. Properties such as non-toxicity and non-harmful to the environment are now being resolute by the researchers. A product will be considered lead-free when any of the individual materials used to construct it, contains less than 0.1 percent lead. PCB is the foundation of all kinds of electronic devices ranging from cell phone, personal computer to military products. The surface finish of PCB is one of the key factors which has a significant influence on its reliability performance (Yan et al., 2013).

The significant of solder deploy in assemblies are as important as the surface finish of the PCB. The insufficient of PCB with surface finish coating are correspond to the demands of electronic products as it is being produced more and more every day. These demands are increasing and pressuring the performance of surface finish to continue to operate under extremely harsh environmental conditions. As a results, the precision in choosing the surface finish is important. The criteria of choosing the best PCB surface finish should be considered on its shelf life and the cleanliness on the surface (Toscano & Long, 2014). According to Wayne and Sweatman (2012), Hot Air Solder Levelling (HASL) finish was one of the popular finishing due to its long shelf life and low cost compared to other finishes such as electroless nickel immersion gold (ENIG), immersion silver (Ag) and immersion tin (Sn). Figure 1.1 shows the HASL surface finish coating layer on PCB. The HASL coating layer is on top of the copper substrate. An interfacial IMC layer are formed between the surface finish layer and copper substrate.

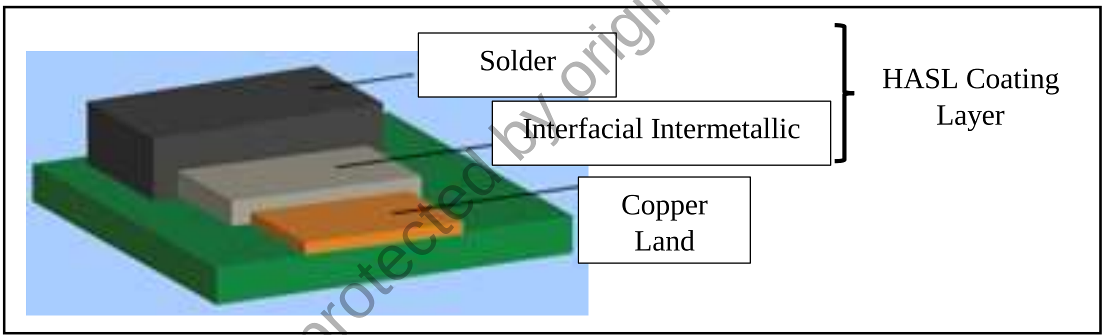

Figure 1.1: HASL surface finishes coating layer illustration, International Circuit Inc. (2012).

1.2 Problem statement

Despite the wide use of HASL finish in coating of PCB, the coating thickness that are required to ensure good solderability are not well studied. HASL finish provide excellent shelf life, shorter solder wetting times in assembly and the formation of an intermetallic bond prior to the assembly process. However, the issues arise in HASL finish including solderability, oxidation, surface planarity and shelf life is still not fully solved and other surface finish becomes competitive in the electronic area. With a very thin solder coating, HASL finish may face a high risk in dewetting which then lead to electric circuit failure. Thus, SN100CL is a new solder in market and yet the properties of HASL process have not been fully explored. It is important to understand the properties of SN100CL HASL coating relating to its solderability performance. This includes in understanding the effect of interfacial IMC growth and free solder thickness to its solderability performance and determining the best Ge content levels in the compositions. The ability of molten solder to react with the substrate at the interface of solder and substrate to form a certain amount of interfacial IMC are referred as wetting.

SN100CL solder is a superior type of surface finish solder on the PCB with composition of Sn-0.7Cu-0.05Ni-0.01Ge. However, there is not much experience or confidence in the use of the SN100CL HASL process and the information on the shelf life is very limited. The composition of SN100CL that having the superior characteristics are not being distinguish as the composition previously in a large range of percentage. The problem occurs is the coating thickness is too thin to provide solder free area for soldering process. Since the interactions determine the shelf life of the PCB, the HASL coating on the copper area are required to be determined.

1.3 Objectives

This study will focus on several objectives listed as below:

i. To investigate the optimum SN100CL HASL coating thickness for excellent solderability. This includes in understanding the effect of the total coating thickness, free solder thickness and interfacial intermetallic layer to the solderability performance.

ii. To determine the effect of accelerated aging to the growth of IMC in SN100CL coating.

iii. To identify the effect of Ge content in Sn-0.7Cu-0.05Ni solder to the coating solderability performance.

iv. To optimize the HASL coating parameters using actual HASL coating machine for SN100CL HASL coating application.

1.4 Work Scope

In this study, the coating thickness that is required for a good solderability will be conducted using Gen3 wetting balance test. In phase I of study, initial coating process optimization of coating dipping time using copper strips with dimension of 10 mm (length) X 3 mm (width) X 0.3 mm (thickness). For determining the relationship between interfacial IMC, free solder thickness and coating thickness, accelerated aging test are conducted and cross section were observed under SEM. The thickness of interfacial IMC, free solder thickness and coating thickness are measured by J-image software. A plotted graph is constructed to observe the relationship of the thickness versus aging time.

In phase II of experiment, the best composition of Ge are determined by using a range of Ge composition which are 0 wt%, 0.002 wt%, 0.006 wt%, 0.010 wt% and 0.020 wt%. The best solder compositions are deploy in HASL machine and the thickness of the solder coating are visually observed and further observe are conducted under SEM observation. To support the results from SEM cross sections, solderability testing by Gen3 wetting balance test machine is performed on the coated PCB.

1.5 Thesis Outline

The chapter of this thesis are outlined as follows:

Chapter 1 is the introduction to the solder, soldering process and surface finish that being utilize in the electronic area. It provides the problem statement, objective, and the work scope of the experimental project descriptions.

Chapter 2 is the literature review on the focused topic of the research. The raw materials, background study and the related solder finish process in electronic packaging industries are being introduced and discussed. The roles and features of solder finish were disclosed further at the end of the chapter.

Chapter 3 presents the experimental procedures which includes the experimental procedures and testing involved. This includes the equipment details which was used throughout the study.

Chapter 4 contains the results and finding with detail discussions and explanation. The root cause and reason behind the results are being studied based on theoretical and experimental results and from previous studies from other research.

Chapter 5 draws the overall conclusion from the experimental studies. Apart from that, some recommendation are being suggested for future works in order to empower and generate more scientific findings.

CHAPTER 2

LITERATURE REVIEW

2.1 Soldering in Electronic Packaging Area

Soldering is a method used to produce permanent electrical and mechanical connections between metallic materials. The four basic components in soldering process are including the base metals, solder, flux and heat. The base metal reacts with the molten solder to form an interfacial IMC. The formation of interfacial IMC establishes a successful solder joint or bond between two or more components. The heat supplied must be sufficient to melt the solder but not enough to cause any melting of the base metals. It also have to prevent from any damage to the board or components. The thickness of an interfacial IMC layer increases with temperature and soldering time and may become embrittled and weak if the IMC layer is too thick. In solder electronics area, the base metal is generally copper. It is usually found on the PCB metallic circuitry and component leads or pins (Efzan & Marini, 2012; Plumbridge et al., 2004).

Solders are metal alloys that having a role that are used to bond or join two or more components and are used extensively in the electronics industry to physically hold assemblies together. They must allow expansion and contraction of the various components, must transmit electrical signals, and also dissipate any heat that is generated. The bonding action is accomplished by melting solder material, allowing it to flow among and make contact with the components to be joined (Efzan & Marini, 2012). Some