EFFECT OF Zn ADDITION ON MICROSTRUCTURE, INTERMETALLIC COMPOUND FORMATION AND MECHANICAL PROPERTIES OF Sn-0.7Cu SOLDER ON Cu SUBSTRATE

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by

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LIST OF ABBREVIATIONS

Ag	Argentum (silver)
ASTM	American Society for Testing and Materials
Al	Aluminium
Au	Gold
BGA	Ball Grid Array
Bi	Bismuth
BSE	Backscattered Electron
Cd	Cadmium
cm	Centimeter
Cu	Copper
Cu-Sn	Copper-Tin
DSC	Differential Scanning Calorimetry
EDX	Electron Dispersive X-Ray Spectroscopy
FCP	Few Chip Package
g	gram (weight)
IMC	Intermetallic Compound
In	Indium
kN	kilo Newton
mg	milligram
min	minute (time)
mm	milimeter (length)

Ni	Nickel
µm	micrometer
Pb	Plumbum
Pd	Palladium
Pt	Platinum
PCB	Printed Circuit Board
SAL	Sebatian Antara Logam
Sb	Antimony
SEM	Scanning Electron Microscopy
SMT	Surface Mount Technology
Sn	Stanum (Tin)
SnPb	Lead-tin
SnCu	Tin-Copper
Zn	Zinc

LIST OF SYMBOLS

A	Area
β-Sn	Sn-rich phase
d	IMC thickness after aging
d_o	Initial IMC thickness
D	Diffusion coefficient
D_o	Intrinsic Diffusivity
F	Wetting force
F_b	Buoyancy force
F_e	End force
F_{max}	Maximum wetting force
F_w	Withdrawal force
m	meter
µ	micron
N	Newton
Q	Activation energy
R	Gas constant
S_b	Ratio of wetting force just before withdrawal to the wetting force during complete wetting
t	Aging time
t_1	Wetting time

T	Temperature
T_c	Crystallization temperature
T_m	Melting temperature
Θ	Wetting angle
γ	Surface tension of solder
γsg	Surface tension between solid and gas
γsl	Surface tension between solid and liquid
γlg	Surface tension between liquid and gas
^oC	Degree celcius
%	Percentage
wt %	Weight percent

KESAN PENAMBAHAN Zn KE ATAS MIKROSTRUKTUR, PEMBENTUKAN SEBATIAN ANTARA LOGAM DAN SIFAT-SIFAT MEKANIKAL PATERI Sn-0.7Cu PADA SUBSTRAT KUPRUM

ABSTRAK

Sambungan pateri berfungsi sebagai sambungan elektronik dan mekanikal diantara komponen-komponen serta substrat dalam peranti elektronik. Kebimbangan terhadap keracunan plumbum menjadi fokus yang sangat penting dalam mencari pateri plumbum alternatif untuk menggantikan pateri tradisional Sn-Pb. Aloi Sn-Cu cenderung untuk dipilih kerana ia lebih murah daripada pateri yang mengandungi Ag. Walau bagaimanapun, Sn-0.7Cu telah dilaporkan mempunyai kekuatan yang lebih rendah daripada pateri bebas plumbum yang lain. Terdapat potensi untuk meningkatkan lagi prestasi Sn-0.7Cu dan meningkatkan kebolehharapan sambungan pateri terutamanya untuk sambungan pateri berkuasa tinggi. Dalam kajian ini aloi Sn-0.7Cu, Sn-0.7Cu -0.5Zn dan Sn-0.7Cu -1.0Zn telah dibangunkan. Penambahan Zn berpotensi untuk menghaluskan mikrostruktur pateri dan menyebabkan zarah sekunder yang boleh mengukuhkan pateri. Pengaloian Zn juga telah dilaporkan untuk mengurangkan ketebalan lapisan Cu-Sn Sebatian Antara Logam (SAL) bagi aloi pateri berasaskan Sn. Pencirian aloi pateri tertumpu kepada mikrostruktur pukal pateri dan penilaian terhadap SAL. Takat lebur pateri telah ditentukan dengan menggunakan Kalorimeter Imbasan Pembezaan (KIP) manakala komposisi unsur aloi dianalisis dengan menggunakan pendarfluor Sinar X (PSX). Penuaan telah dilakukan selama 100, 200 dan 500 jam pada suhu 150 ° C dan 180 ° C. Mikrostruktur pukal pateri dan SAL terbentuk pada antara muka pateri dan substrat Cu diperhatikan menggunakan SEM dilengkapi dengan EDX. Penambahan Zn menyebabkan penurunan sedikit

kebolehbasahan berbanding Sn-Pb, tetapi masih mempunyai nilai kebolehbasahan yang baik kerana semua sudut pembasahan berada di dalam julat 34° hingga 38°. Hasil kajian menunjukkan bahawa kebolehbasahan berkurang dengan jumlah peningkatan Zn tetapi kekerasan telah bertambah. Penambahan Zn juga menunjukkan peningkatan kekuatan ricih sebanyak 40 peratus lebih tinggi daripada aloi pateri Sn-Cu.

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ABSTRACT

Solder joints serve as both electronic and mechanical connections between components as well as substrates in electronic devices. Concern over the toxicity of lead sparked intense focus on finding alternative lead-free solders to replace the traditional Sn-Pb solder. An attractive candidate is Sn-Cu alloy as it is cheaper than Ag-containing solders. However, Sn-0.7Cu has been reported to have lower strength than the other lead-free solders. There is potential to further improve the performance of Sn-0.7Cu and increase solder joint reliability especially for high-powered solder joints. In this study Sn-0.7Cu, Sn-0.7Cu -0.5Zn and Sn-0.7Cu -1.0Zn bulk solder alloys were developed. The addition of Zn potentially refines solder microstructure and results in secondary particles that could strengthen the solder. Alloying of Zn also has been reported to decrease thickness of Cu-Sn IMC layer in Sn-based solder alloys. Characterization of the solder alloys focused on the bulk solder microstructure and IMC evaluation. Melting point of solder was determined using Differential Scanning Calometry (DSC) while elemental composition of solders were analysed using X-ray fluorescence (XRF). Aging was done for 100, 200 and 500 hours at 150 °C and 180 °C. Microstructure of bulk solder and the IMC formed at interface between solder and Cu substrate were observed using SEM equipped with EDX. Addition of Zn slightly decreased the wettability compared to Sn-Pb, but still having good wettability because all the wetting angle are in range of 34°to 38°. Results showed that wettability reduced

with increasing amount of Zn but the hardness was increased. The addition of Zn also showed increased shear strength up to 40% higher than that of the Sn-Cu solder alloys.

CHAPTER ONE

INTRODUCTION

1.1 Research Background

The soldering process has been a fundamental aspect in the realisation of all electronic products since the commencement of the electronic age and has been used extensively in the electronic industry. Currently, the concerns over the toxicity of lead (Pb) in eutectic Sn-Pb solders has prompted the development of lead free solder alloys for electronic packaging (El-daly *et al.*, 2013). Solder alloy is an interconnect material attaching components to a substrate in electronic devices. Following the miniaturization of contemporary solder joints, the fraction of intermetallic compound (IMC) to the total volume of solder is increasing, and hence the elastic properties of IMC formed during soldering reaction become crucial to the reliability of solder joints (El-daly *et al.*, 2011).

There are several promising candidate lead-free solders for improving mechanical and electrical properties including Sn-Ag, Sn-Cu, Sn-Zn and Sn-Ag-Cu systems. However, each of these solder alloys holds certain disadvantages including reliability and cost issues, too high or too low melting temperature and low to moderate wetting. Among these candidates, Sn-Cu binary alloy, has been chosen as a low-cost substitute and most promising lead-free candidate for iron, dip and wave soldering operation (Yu *et al.*, 2010).The presence of Cu in Sn-based materials leads to an improvement in resistance to thermal cycle fatigue and wetting properties due to the formation of Cu_3Sn and Cu_6Sn_5 IMC. It also plays an important role in decreasing the rate of dissolution of Cu from the board. However, its major drawbacks of high melting temperature, insufficient oxidation resistance characteristic and tin whiskers caused by