UNIVERSITI TEKNOLOGI MARA

STUDIES ON INTERMETALLICS AND PHYSICAL PROPERTIES OF Sn-3.5Ag-1.0Cu LEAD FREE SOLDER WITH Zn ADDITIVE

IZIANA BINTI YAHYA

Thesis submitted in fulfilment of the requirements for the degree of Master of Science

Faculty of Applied Sciences

May 2016

ABSTRACT

The need for replacing lead based solder has received great attention among researchers because of their toxicity. The Sn-Ag-Cu family is the most promising candidate. However, these solder systems need better improvement in terms of controlling their intermetallic formation, growth rate and also their mechanical properties. In this study, the Sn-3.5Ag-1.0Cu solder was studied and three different amounts of Zn were added into the solder system. The solder was prepared using powder metallurgy method. It was characterized for their melting temperature, hardness and density. For intermetallic study, the solder was melted at 250°C on a Cu substrate and placed in an oven at 150°C until 1000 h. After the aging process, the solder joint was cross-sectioned and analysed under a Scanning Electron Microscope and Energy Dispersive X-ray. The thickness of Cu_6Sn_5 and Cu_3Sn intermetallics were measured using image J software and their growths kinetic were calculated. The shear joint specimen was aged until 1000 h and the joint strength test was performed using an Instron machine. The addition of Zn has no significant effect on their melting temperature. Density and hardness results show that the optimum condition in preparation of solder disc was 2 h is mixing time and 14 MPa pressure. The addition of Zn retarded the growth of the intermetallic with 0.4 wt.% Zn gives the most significant values compared to 0.1 and 0.7 wt.% Zn addition. The growth of intermetallic compounds followed a parabolic law, implying that the growth of the intermetallic layer was diffusion control. The addition of 0.4 wt.% Zn gives the smallest growth constant (k) which are 0.16 x 10^{-14} , 2.56 x 10^{-14} and 4.00 x 10^{-14} cm²/s for Cu_6Sn_5 , Cu_3Sn and total intermetallic, respectively. Smaller k value indicates that the growth of intermetallic was slower and thus Zn retards the intermetallic growth. The decreasing of solder joint strength as aging time increases can be correlated to the growth of the intermetallic. Solder composition with the addition of 0.7 wt.% Zn has the highest stress values which is 20.14 MPa for as-soldered and 15.30 MPa for 1000 h aging time.

ACKNOWLEDGEMENT

Alhamdulillah, I wish to express my sincere gratitude with the honour from Allah S.W.T. and his power of giving strength and good health during completing my master study.

It is satisfactory to recognize the help of many people who assisted me throughout the course of this study and in preparing this thesis. I would like to express my gratitude to my supervisor Dr. Ramani Mayappan and Associate Professor Dr. Hamidi Abd Hamid as my co-supervisor for their supervision, guidance and comments through the learning process of this master thesis. Without their supervision and constant help this dissertation would not have been possible.

I acknowledged the help from Noor Asikin Ab Ghani as my colleague in set up and conducting an experiment. Not forgotten, a lot of thank you to Mr. Murizam Darus and Mr. Ahmad Hadzrul Iqwan Jalaludin staff of University Malaysia Perlis (UNIMAP) for their help during sample analysis.

I would like to thank Universiti Teknologi MARA, Malaysia and Universiti Teknologi MARA Perlis, Malaysia for giving me an opportunity to further my study and financial support.

A special thanks to my beloved parent, Mr Yahya Yaakob and Mrs Zaini Mohd Nor and other family members. Words cannot express how grateful I am for all of their sacrifices and support. I would also like to thank all of my friends who always by my side when I need them.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR'S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF PLATES	xiv
LIST OF SYMBOLS	xv
LIST OF ABBREVIATIONS	xvi

1
1
2
3
4
4
.5
5
6
6
7
8
10
11
14

2.4.2 Sn-0.7Cu	15
2.4.3 Sn-9Zn	16
2.5 Sn-Ag-Cu Solder Family	17
2.6 Alloying Element Additive	19
2.6.1 Zinc as Additive	20
2.7 Melting Temperature	21
2.7.1 Lead-free Solder Melting Temperature	22
2.8 Solder Density	23
2.9 Solder Hardness	24
2.9.1 Vickers Hardness Test	24
2.10 Aging	24
2.10.1 Liquid State Aging	25
2.10.2 Solid State Aging	25
2.11 Copper as Interconnect Material	26
2.12 Intermetallic Formation	26
2.12.1 Intermetallic Formation of Cu/Sn System	27
2.12.2 Phase Diagram and Intermetallic of Cu/Zn system	27
2.13 Growth Rate of Solder System	28
2.14 Mechanical Properties	30
2.14.1 Shear Strain Loading of Cu/Solder/Cu Joint	31
2.14.2 Cyclic Loading	32
2.14.3 Tensile Loading of Cu/Solder/Cu Joint	32
2.14.4 Joint Strength	33
2.15 Performance of Structural Material	33
2.15.1 Tensile Deformation of Ductile Metal	34
2.15.2 Ductile and Brittle Behaviour	35
2.16 Powder Metallurgy (P/M)	36
2.16.1 Blending and Mixing	37
2.16.2 Compacting	37
2.16.3 Sintering	38