

**DEVELOPMENT OF Sn-Cu FILLED ACTIVATED
CARBON COMPOSITE SOLDER VIA POWDER
METALLURGY TECHNIQUE**

SAYYIDAH AMNAH BINTI MUSA

UNIVERSITY MALAYSIA PERLIS

2015



**Development of Sn-Cu Filled Activated Carbon Composite
Solder Via Powder Metallurgy Technique**

by

**Sayyidah Amnah Binti Musa
(1330410982)**

A Thesis Submitted in Fulfillment of the requirements for the degree of
Master of Science in Materials Engineering

**School of Materials Engineering
UNIVERSITY MALAYSIA PERLIS
2015**

ACKNOWLEDGEMENT

Alhamdulillah, I am grateful for the blessings of Allah swt throughout this research project. I would like to express my best and sincerest gratitude to my supervisor Dr. Norainiza Binti Saud, for giving me this great opportunity to work under her guidance throughout the whole process until complete this research. Her methods in conducting the research and ways of tackling problems were enlightening and inspirational for me. I am also sincerely thankful to her for such valuable suggestions and constructive criticism which has helped me to complete this project successfully. I am greatly indebted for her endless encouragement and extremely understanding at all the times. I believe that, my accomplishment was directly connected to her guidance.

Special thanks to the lecturers and technicians of School of Materials Engineering, UniMAP, for their support and guidance also providing me necessary facility for my research work. I would like to thank the School of Microelectronics Engineering, UniMAP, lab staff for their help and assistance. I am also grateful for the help provided by the staff and technician in the Cluster of Sustainable Engineering, UniMAP.

I also extend my sincere thanks to all my colleagues in the Electronic Packaging Group for their continuous support and helpful in every possible way. I would like to thank all my friends that always understanding and supporting. I am also thankful to those who have helped directly or indirectly for being cooperative and helpful.

I owe my sincere appreciation to my family and relatives for their support, encouragement and understanding me over the years. Their infinite support and unconditional love has driven me to accomplish my study until the end of the research.

TABLE OF CONTENTS

	.PAGES
THESIS DECLARATION	i
ACKNOWLEDGEMENT	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	xi
LIST OF SYMBOLS	xiii
ABSTRAK	xiv
ABSTRACT	xv
CHAPTER 1: INTRODUCTION	
1.1 Background of Studies	1
1.2 Problems Statement	4
1.3 Objectives of Study	5
1.4 Scope of Study	6
CHAPTER 2: LITERATURE REVIEW	
2.1 Introduction	7
2.2 Lead-Free Solders	8
2.2.1 Sn-Cu Alloy	9
2.2.2 Sn-Ag Alloy	11

2.2.3	Sn-Ag-Cu Alloy	12
2.3	Requirements of Lead-Free Solder	13
2.3.1	Melting Temperature	14
2.3.2	Electrical Resistivity	15
2.3.3	Wettability	17
2.3.4	Mechanical Properties	19
2.4	Composite Solder	21
2.5	Effects of Reinforcement in the Composite Solder	22
2.6	Powder Metallurgy (PM) Techniques	24
2.6.1	Mixing Process	25
2.6.2	Compacting Process	27
2.6.3	Sintering Process	28
2.7	Microwave Sintering	32
2.8	Soldering Process	34
2.9	Ostwald Ripening Phenomenon	34
CHAPTER 3: METHODOLOGY		
3.1	Experimental Work Overview	37
3.2	Raw Materials and Sample Preparation	39
3.3	Optimization of Powder Metallurgy Techniques	39
3.3.1	Mixing Process and Optimization	39
3.3.2	Compacting Process and Optimization	40
3.3.3	Sintering Process and Optimization	40
3.4	Standard Metallographic Procedure	44

3.5	Characterization of Bulk Composite Solder	45
3.5.1	Differential Scanning Calorimetry (DSC)	45
3.5.2	X-ray Diffraction (XRD)	46
3.5.3	4-Point Probe	46
3.5.4	Vickers Microhardness	48
3.6	Characterization of Composite Solder Joint	48
3.6.1	Reflow Soldering Process	49
3.6.2	Wettability	52
3.6.3	Intermetallic Compounds (IMC) Thickness Measurements	53
3.6.4	Single-Lap Shear Solder Joint	55

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1	Optimization parameters for Powder Metallurgy (PM) Technique (in Phase 1)	57
4.1.1	Optimization Study of Mixing Time	57
4.1.2	Optimization Study of Compacting Loads	63
4.1.3	Optimization Study of Sintering Parameter	65
4.2	Microstructural Analysis (in Phase 2)	73
4.2.1	Microstructure of Monolithic and Composite Solder	74
4.2.2	Phase Analysis of Monolithic and Composite Solder	77
4.2.3	Microstructure of Monolithic and Composite Solder After Sintering process	78
4.2.4	IMC Formation at the Bulk Solder Area	79
4.2.5	IMC Formation at Solder/Substrate Interface	82

4.2.6	Quantitative Analysis of IMC Layer at Solder/Substrate Interface	86
4.3	Melting Temperature	91
4.4	Electrical Resistivity	92
4.5	Microhardness	94
4.6	Wettability Measurement	96
4.7	Single-Lap Shear Testing	98
4.7.1	Shear Strength	98
4.7.2	Fracture Surface Analysis	100
4.8	Optimization	103
CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS		
5.1	Conclusions	104
5.2	Recommendations	105
REFERENCES		106
APPENDICES		123
LIST OF PUBLICATIONS		131

LIST OF TABLES

NO.		PAGE
3.1	Table of time exposure needed to reach the desired microwave sintering temperature.	42
3.2	Function description of the design features for microwave sintering setup.	43
4.1	Table of all testing compiles for monolithic and composite solder.	103

©This item is protected by original copyright

LIST OF FIGURES

NO.		PAGE
2.1	Microstructure of eutectic Sn-Cu lead-free solder (Tsao et al., 2012).	11
2.2	Microstructure of eutectic Sn-Ag lead-free solder (Huang & Wang, 2002).	12
2.3	Microstructure of eutectic Sn-Ag-Cu lead-free Solder (Chuang et al., 2011).	13
2.4	Schematic drawing of molten solder wetting on the Cu substrate (Zhang & Tu, 2014).	18
2.5	The sintering model of the two spheres (German, 1994).	30
2.6	The steps of leading to pore isolation and spheroidization in the sintering process (German, 1994).	31
2.7	The pore-grain boundary configuration during sintering (German, 1994).	32
3.1	The complete flow chart of the project.	38
3.2	Schematic diagram of the microwave sintering setup.	42
3.3	Photograph of the actual plan view for microwave sintering setup.	43
3.4	Schematic diagram of four point probe configuration used for the electrical resistivity measurements.	48
3.5	Reflow profile used for reflow soldering process.	52
3.6	Schematic of the contact angle measurement.	53
3.7	Sample preparation illustration for contact angle.	53
3.8	The illustration of the area and the length of IMC layer measurement.	55
3.9	Shear testing illustrations specimens.	56
4.1	Optical microscope of Sn-0.7Cu based solder matrix grain structures at 50x magnifications.	58
4.2	Optical microscope of Sn-0.7Cu+0.1AC grain structures at 50x magnifications for different mixing time which is (a) 1 hour, (b) 2 hours, (c) 3 hours, (d) 4 hours and (e) 5 hours.	61

4.3	SEM elemental mapping of (a) Sn-0.7Cu+AC, (b) C, (c) Cu, (d) Sn and (e) graph of element atomic percentages.	62
4.4	Graph of relative density with different compacting loads for Sn-0.7Cu+0.1AC.	65
4.5	Graph of densification for composite solders at different sintering temperature before and after sintering processes.	68
4.6	Graph of sintered density at difference sintering temperature for Sn-0.7Cu composite solder.	68
4.7	Graph of total fractional porosity with respect to various sintering temperature.	69
4.8	Optical microscope of grain structures at 50x magnifications before sintering process, (a) Sn-0.7Cu based solder, and (b) Sn-0.7Cu+0.1AC composite solder.	70
4.9	Optical microscope of grain structures at 50x magnifications for post-sintering process of Sn-0.7Cu+0.1AC composite solder at different sintering temperature, (a) 160 ⁰ C, (b) 170 ⁰ C, (c) 180 ⁰ C, (d) 190 ⁰ C, and (e) 200 ⁰ C.	72
4.10	XRD patterns of Sn-0.7Cu+0.1AC sintered at the different temperature.	73
4.11	SEM micrograph powder of (a) Sn-0.7Cu based solder and (b) AC particles.	74
4.12	Optical microscope images of (a)Sn-0.7Cu and (b) Sn-0.7Cu+AC at 20x magnification.	76
4.13	SEM micrograph of Sn-0.7Cu+0.1AC (a), and the corresponding EDX results of the spotted (b) β-Sn phase and (c) Cu ₆ Sn ₅ phase and AC particles region, respectively.	76
4.14	XRD spectra of Sn-0.7Cu based solder addition with (a) 0 wt%, (b) 0.05 wt%, (c) 0.1 wt%, (d) 0.15 wt% and (e) 0.2 wt% of AC particles.	77
4.15	Optical micrographs of microstructure at 50x magnifications: (a) Sn-0.7Cu, (b) Sn-0.7Cu+0.05AC, (c) Sn-0.7Cu+0.1AC, (d) Sn-0.7Cu+0.15AC, and (e) Sn-0.7Cu+0.2AC.	79
4.16	Morphology of the constituent phase distribution of the Sn-0.7Cu composite solder; (a) 0 wt%, (b) 0.05 wt%, (c) 0.1 wt%, (d) 0.15 wt%, (e) 0.2 wt% of AC particles.	82
4.17	SEM micrograph of intermetallic compounds formation at the interfaces of	

	the solder joint after reflow soldering process; (a) Sn-0.7Cu, (b) Sn-0.7Cu +0.05AC, (c) Sn-0.7Cu+0.1AC, (d) Sn-0.7Cu+0.15AC, (e) Sn-0.7Cu +0.2AC and (f) SEM-EDS of Cu ₆ Sn ₅ represent, respectively.	85
4.18	Schematic diagram of the diffusion paths for growth process of the IMC layer.	86
4.19	The thickness of Cu ₆ Sn ₅ IMC layer at the interfaces of solder/Cu-substrate of the Sn-0.7Cu based solder and composite solder.	88
4.20	IMC layer analysis of Sn-0.7Cu+AC composite solder for (a) SEM micrograph, line mapping analysis result for line marked of (b) 001, (c) 002, (d) 003 and (e) 004.	90
4.21	Melting temperature of monolithic and composite solder.	92
4.22	Results of the electrical resistivity for monolithic and composite solder.	93
4.23	Graph of microhardness results of monolithic and composite solder.	95
4.24	Representative image of the measurement of contact angle for Sn-0.7Cu/0.10AC composite solder.	97
4.25	Graphical relationship between weight percentages of AC addition in Sn-0.7Cu solder matrix and contact angle.	97
4.26	Shear strength results for monolithic and composite solder.	100
4.27	SEM fracture surfaces of (a) Sn-0.7Cu based solder, (b) Sn-0.7Cu+0.05AC, (c) Sn-0.7Cu+0.1AC, (d) Sn-0.7Cu+0.15AC and Sn-0.7Cu+0.2AC, respectively.	102

LIST OF ABBREVIATIONS

Sn	Tin
Pb	Lead
Ag	Silver
RoHS	Restriction of Hazardous Substance
WEEE	Waste Electrical and Electronic Equipment Directive
Hg	Mercury
Cd	Cadmium
Cr ⁶⁺	Hexavalent Chromium
PBB	Polybrominated Biphenyls
PBDE	Polybrominated Diphenyl Ether
Zn	Zink
Bi	Bismuth
Sb	Antimony
TiO ₂	Titanium Dioxide
Si ₃ N ₄	Silicon Nitride
Al ₂ O ₃	Aluminum Oxide
AC	Activated Carbon
PM	Powder Metallurgy
DOE	Design of Experiment
DSC	Differential Scanning Calorimetry
XRD	X-ray Diffraction
OM	Optical Microscope

SEM	Scanning Electron Microscope
EDX	Energy Dispersive X-ray
IMCs	Intermetallic Compounds
α -Sn	Gray Tin
β -Sn	White Tin
In	Indium
Cu	Copper
NEMI	National Electronics Manufacturing Initiative
PCB	Printed Circuit Board
ISO	International Standard Organization
Fe_2O_3	Iron (III) Oxide
ZrO_2	Zirconium Oxide
SiC	Silicon Carbide
CNTs	Carbon Nanotubes
NC	No Clean
M	Malaysia
OPS	Oxide Polishing Suspension
HNO_3	Nitric Acid
HCl	Hydrochloric Acid
Ni	Nitrogen
SMT	Surface Mount Technology
FR-4	Flame Resist-4
C	Carbon

LIST OF SYMBOLS

γ	Surface Tension of wettability
θ	Contact Angle
V	Volume
r	Radius
h	Height
ρ	Density
m	Weight
t	Thickness
A	Area
L	Length
C	Solubility
T	Temperature
Γ	Surface tension of intermetallics compound
γ	Fractional porosity of sintered sample
x	Mass fraction
R	Resistance
ρ	Resistivity
s	Probe tips spacing
I	Electric current

Penghasilan Pateri Komposit Sn-Cu terisi Karbon Teraktif Melalui Teknik Kaji

Logam Serbuk

ABSTRAK

Revolusi dalam perkakasan elektronik di mana bahagian komponen digunakan semakin kecil telah membuatkan teknologi pateri menjadi sebahagian penting di dunia. Aloi bertakat lebur yang rendah harus mempunyai beberapa sifat unik untuk memastikan keboleharapan dalam pemasangan elektronik yang membolehkan sambungan untuk berfungsi lebih baik. Pateri komposit berasaskan Sn-0.7Cu telah berjaya dihasilkan melalui teknik kaji logam serbuk (PM) yang terdiri daripada proses pencampuran, pemadatan dan pensinteran. Komposisi karbon teraktif (AC) telah dipelbagaikan kepada 0, 0.05, 0.1, 0.15 and 0.2 wt% digunakan sebagai pengisi dalam pateri bebas plumbum. Parameter teknik PM seperti masa pencampuran, beban pemadatan dan masa pensinteran telah dipelbagai dan pengoptimuman telah dilakukan sebelum proses penghasilan pateri komposit. Seterusnya, pateri bebas plumbum kemudiannya diperhadapkan kepada ujian mekanikal, fizikal dan elektrik. Dalam kajian ini, masa pencampuran, beban pemadatan dan masa pensinteran optimum yang terpilih adalah 1 jam, 390 MPa dan 141 saat, masing-masing. Mikrostruktur pateri pukal selepas pemanasan mendedahkan penambahbaikan yang ketara melalui penambahan zarah AC dalam kuantiti sedikit terhadap Sn-0.7Cu. Zarah AC telah tersebar secara seragam sepanjang sempadan fasa β -Sn. Hasil kajian telah menunjukkan bahawa suhu takat lebur telah menurun sedikit dengan penambahan zarah AC, namun begitu, ianya masih didalam julat yang boleh diterima. Penambahan zarah AC telah menaikkan keberintangan elektrik pateri Sn-0.7Cu. Kebolehasahan pateri komposit telah dipertingkatkan dimana sudut sentuh terbaik merupakan 24.6° bagi penambahan 0.2 wt% zarah AC. Semantara itu, sifat mekanikal khususnya mikrokekeraan dan kekuatan ricih telah mengalami penambahbaikan dimana dengan penambahan 0.1 wt% zarah AC telah menghasilkan keputusan terbaik iaitu 12.14 Hv dan 13.19 MPa masing-masing. Tambahan lagi, kekasaran pada permukaan patah telah menaik dengan penambahan zarah AC sehingga 0.15 wt%. Ketebalan lapisan sebatian antara logam Cu_6Sn_5 pada permukaan penyambungan pateri telah menaik kepada $2.16 \mu m$ dengan penambahan 0.1 wt% zarah AC. Keseluruhannya, penambahan zarah AC sebagai pengisi menguat terhadap pateri bebas plumbum Sn-0.7Cu menghasilkan penambahbaikan dari segi mekanikal dan fizikal pateri komposit tersebut.

Development of Sn-Cu Filled Activated Carbon Composite Solder Via Powder

Metallurgy Technique

ABSTRACT

The revolution of electronic applications which have been assembled in smaller parts, lighter and more functional, causes the solder to become crucial over the worlds. These classes of low melting point alloys must provide a unique set properties to ensure the reliability of the electronic assemblies also allowing the joints to become more functional. A composite Sn-0.7Cu based solder was successfully fabricated via powder metallurgy (PM) technique which consist of mixing, compacting and sintering processes. Varying amount of activated carbon (AC); 0, 0.05, 0.1, 0.15 and 0.2 wt% were used as reinforcement to obtain a new lead-free composite solder. The parameters of PM technique which are mixing time, compacting loads and sintering time were varied and these parameters were optimized prior to composite solder synthesis. Subsequently, the lead-free composite solder were then subjected to physical mechanical and electrical tests. In this study, the best mixing time, compacting load and sintering time selected were 1h, 390 MPa and 141 s, respectively. Microstructure of the bulk solder after reflow process exposed significant improvements through addition of a small amount of AC particles into Sn-0.7Cu which had refined the microstructure of Sn-0.7Cu composite solder. The various percentages of AC particles were uniformly distributed along the β -Sn grain boundaries. The results revealed that melting temperature was slightly decreased with increasing the addition of AC particles; however still in acceptable range. The addition of AC particles slightly increased the electrical resistivity of Sn-0.7Cu solder. The wettability of the composite solder was improved where the best contact angle was 24.6° for 0.2 wt% of AC particles. Meanwhile, the mechanical properties in terms of microhardness and shear strength experienced enhancements with addition of AC particles reinforcement where the 0.1 wt% of AC particles shows the best results among other percentages which was 12.14 Hv and 13.19 MPa, respectively. Furthermore, the roughness of the fracture surface increased with the increasing number of amounts of AC particles up to 0.15 wt%. The thickness of Cu_6Sn_5 IMC layer at the interface of the solder joint decreased to $2.16 \mu\text{m}$ with the addition of 0.1 wt% of AC particles. Overall, the addition of AC particles as reinforcement into Sn-0.7Cu lead-free solder based exhibit the enhancement of physical and mechanical properties compared with the solder matrix.

CHAPTER 1

INTRODUCTION

1.1 Background of Studies

Nowadays, solder remain among the most important joining materials in electronic assembly. A revolution in the electronic devices such as capacitors, transistors, diodes, resistors and integrated circuits was assembled in smaller parts, lighter and more functional, causes the study in solder technology becomes essential worldwide. Therefore, the solder must provide a unique set of properties to ensure cost-effective production of reliable electronic assemblies since solder serves both mechanical and electrical functionality to the connection of electronic components. Nowadays, the most widely used solders for electronic assemblies are low temperature near-eutectic SnPb alloys such as 60Sn40Pb, 63Sn37Pb and Ag-bearing 62Sn36Pb2Ag (Evans, 2007a). These alloys are used in applications ranging from consumer products to space communications systems and have been essential to the worldwide electronics industry.

However, based on legal foundation from Restriction of Hazardous Substance (RoHS) that took effect on 1 July 2006, which also closely linked with the Waste Electrical and Electronic Equipment Directive (WEEE) were approved the directive restriction of use of six hazardous materials in the manufacture of various types of electrical and electronic equipment (Restriction of Hazardous, 2010). The six hazardous materials are Lead (Pb), Mercury (Hg), Cadmium (Cd), Hexavalent Chromium (Cr^{6+}),

Polybrominated biphenyls (PBB), and Polybrominated diphenyl ether (PBDE). Understanding the effects of these materials awoken many countries to take action in banning the usage of lead on all electrical and electronics components. Thus, the developments of lead-free solders have become an urgent affair nowadays.

Recently, lead-free solders had received considerable attention from the field of electrical and electronic applications. There are assortment of candidates in order to replace high-lead solder which are Sn-Cu, Sn-Ag-Cu, Sn-Ag, Sn-Zn, and Bi-Sn. Lead-free solders have been used in particularly step soldering technology, flip-chips connection, solder ball connections and the bonding of semiconductor devices onto substrates. Unfortunately, the deficiency among these lead-free solder in fulfill the high-functional requirement and the miniaturization of electronic components in advance solder technology can no longer guarantee the reliability of the solder joints. Thus, to enhance the reliability of the solder interconnects; new solder materials with combinations of good electrical, mechanical and thermal properties have to be produced (Lee & Lee, 2007; Wu et al., 2004; Han et al., 2012; Han et al., 2010a).

In order to develop the new solder interconnects, a method which is composite solder was developed, where the solder matrix was reinforced by particulate fillers. The existence of reinforcements in the solder matrix provides greater reliability since the reinforcing particles was believed not to only suppress the grain boundaries sliding, intermetallic compound formation or grain growth, but also may perhaps reorganize stress uniformly (Lee & Lee, 2006). Lead-free composite solder have shown better solderability, physical and mechanical properties, also good in electrical and thermal properties too which has been published by previous researchers (Nai et al., 2008; Han et al., 2010b; Tai et al., 2005; Tai et al., 2010).

Lately, the most typical technique used in fabricating the solder was casting technique, which was the common technique utilized in solder industries (Arenas et al, 2006; El-Daly et al., 2013a; Yu & Wang, 2008). Besides of casting technique, powder metallurgy technique is another alternative to fabricate composite solder. The powder metallurgy technique is now recognized as a competitive technology and an alternative to casting or conventional metal forming. Powder metallurgy has been defined as the art and science of producing fine metal powder and objects finished or semi-finished from individual, mixed or alloyed metal powders with or without the presence of non-metallic constituent (Angelo & Subramanian, 2008). Powder metallurgy was applied to make the metal powder which added with reinforcement form into valuable engineering component. High quality parts with complex shapes can be fabricated using powder metallurgy technique. Powder metallurgy also low in cost because it was produced low scrap with low energy consumption and there is no needs skilled worker. These advantages show the powder metallurgy as one of the best technique used in synthesizing the composite materials (German, 1994). Production of powder metallurgy parts involves in mixing the powder materials, compaction of the mixture powder and finally sintering the compacted billet.

Sn-0.7Cu solder was one of typical lead-free solder that been suggested for replacement the Sn-Pb solder. Sn-0.7Cu solder was low temperatures solder and melts at the temperature of 227⁰C. Compared with other solder alloys such as Sn-5Bi-5Ag, Sn-2Ag, Sn-3.5Ag, Sn-3.2Ag-0.5Cu and Sn-5Sb, the Sn-0.7Cu solder was found to be less in toxicity (Satyanaran & Prabhu, 2011). Besides that, Sn-0.7Cu solder is a low cost and exhibit an excellent physical and mechanical properties. Moreover, Sn-0.7Cu solder reveal significant enhancement in creep and fatigue properties compared with Sn-Pb solder (Satyanaran & Prabhu, 2011).

There are several researchers that have been investigating on Sn-0.7Cu lead-free composite solder, but none of them was studying about Sn-0.7Cu solder matrix reinforced with Carbon particles. Literature studies have shown that addition of some reinforcement to Sn-0.7Cu solder matrix can improve the properties of the solder matrix in solderability, physical, thermal, mechanical and electrical properties. Tsao et al had proven that by the addition of TiO₂ nanoparticles into Sn-0.7Cu solder, the resulted microstructure becomes more uniform and the mechanical properties of the solder was enhanced (Tsao et al., 2012). Salleh et al. investigated and founded that when Sn-0.7Cu solder added with Si₃Ni₄ particles, the composite solder had revealed better mechanical properties compared to Sn-0.7Cu solder (Salleh et al., 2012). Gupta et al. declared that the addition of Al₂O₃ nanoparticles into the Sn-0.7Cu solder where the mechanical properties of the composite solder was better than Sn-0.7Cu Solder (Zhong & Gupta, 2008). Therefore, the improvement of composite solder properties inspired an idea to synthesize a new Sn-0.7Cu-AC lead-free composite solder to enhance the solder properties.

1.2 Problems Statement

Lead-free solder is believed to be an alternative to counter these concerns regarding lead contamination. However, to make them extra functionality, better in performance, miniaturization of electronic appliances and more reliable in electronic applications, an attractive and potentially method had been created by adding the third element into them. The third element acts as reinforcement to the lead-free solder and form as lead-free composite solder.

Powder metallurgy technique parameters are the key factors influencing the properties of lead-free composite solder. Powder metallurgy technique consists of mixing, compacting, and sintering process. The parameters that can be control during powder metallurgy technique were mixing time, compacting loads and sintering temperature. Each parameter could have restraint that could diminish the solder properties. Consideration of solder powder particles from overmixing, reach the maximum compaction loads and the optimum sintering temperature was important in powder metallurgy technique to produce the best bulk composite solder properties.

Currently, Sn-0.7Cu based solder is considered as the most potential base matrix alloy because it is a low cost material and have good potential of metals. However, the properties of Sn-0.7Cu solder is still lacks in terms of wettability and mechanical properties. Therefore, the Sn-0.7Cu solder need to be synthesized into the lead-free composite solder which is an alternative to improve the solder properties. Activated carbon has good mechanical and electrical properties which is suitable to be reinforcement in solder alloy in order to improve physical, electrical and mechanical properties. The Sn-0.7Cu solder is the lowest in cost among the other lead-free solder. It will be a great improvisation if the limitation in the wettability and mechanical properties could be overcome to improve the limitation of Sn-0.7Cu solder and make it into lead-free composite solder.

1.3 Objectives of Study

- i. To investigate the best parameters for composite solder development via powder metallurgy technique through optimization.

- ii. To study the optimum physical, electrical and mechanical properties for the new bulk Sn-0.7Cu-AC composite solder.
- iii. To investigate the microstructure, wettability and mechanical properties of the Sn-0.7Cu-AC composite solder joint.

1.4 Scope of Study

In this research, Sn-0.7Cu solder will be added with AC particles and fabricated via powder metallurgy techniques which comprise of mixing, compacting and sintering process. The synthesis of lead-free composite solder was prepared via optimization of process parameter for powder metallurgy technique (Phase 1). In the mixing process, the mixing speed will be constant at 200 rpm but the mixing time was varied from 1 to 5 hours. The compaction loads parameter were 217, 260, 303, 347 and 390 MPa, meanwhile the optimization of sintering time is 107, 116, 124, 132 and 141 s. According to the preeminent parameter acquired from the optimization process, the selected parameter for mixing, compacting and sintering was 1 h, 390 MPa and 180 °C. Following the optimization from the Phase 1, the samples were then prepared for the characterization testing but with different percentages composition of AC particles addition into solder matrix (Phase 2). The percentages of AC particles added into Sn-0.7Cu composite solder were approximately about 0, 0.05, 0.10, 0.15 and 0.20 wt. %. The investigation involved for the Phase 2 was including with the bulk composite solder and composite solder joint. The bulk Sn-0.7Cu-AC composite solders was carried out with the melting temperature, phase analysis, resistivity and hardness test. The composite solder were then reflowed to make a joint and the composite solder joint have investigated for the wettability, shear strength and microstructural analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Soldering is a significant process which determines the reliability of electronic assemblies and the interconnection technology in the electronics applications. An endurance and consistency of the solder joints was depending on the functionality and lifetime of an electronic product. The key in upgrading the solder properties are optimized the physical and mechanical properties to generate a strong interconnection. Soldering is a metallurgical joining technique using a filler metal known as solder. Solder joining provides electrical, thermal and mechanical connection in electronics assemblies. Solder heating up on a substrate which applied with the flux to remove the oxides at both substrate and the solder meanwhile, allowed the solder melt during the soldering process. The important things in soldering were wettability and the intermetallic compound formation to create a bonding between the solder and the substrate by applying with the melting temperature less than 315 °C (Manko, 2001). The solder will be melted and wet at the substrate surface after reaching the temperature higher than their melting temperatures, and the dissolution of the substrate and interfacial reaction between the solder and substrate were occurs (Abteu & Selvaduray, 2000; Laurila et al., 2005).

These classes of low melting point alloys must provide a unique set of properties to insure cost-effective production of reliable electronic assemblies also allowing joints

to serve both mechanical and electrical functions. Previously, the most widely used solders for electronic assemblies are low temperature near-eutectic SnPb alloys such as 60Sn40Pb, 63Sn37Pb and Ag-bearing 62Sn36Pb2Ag (Evans, 2007a). These alloys are used in applications ranging from consumer products to space communications systems and have been essential to the worldwide electronics industry. However, recent recognition of toxicity of Pb to the environment and human health has encouraged great efforts to develop lead-free solders (Tong, 2000; Riva, 2012).

Wave soldering operation is a soldering process which has potential source of occupational exposure in electronic method. The inhalation of Pb vapors or Pb bearing dust that produced by dross during the wave soldering process has the potential risk to workers. The surface oxidation at the surface of the molten solder will generate the dross during the wave soldering process. The dross formation can be refined to pure metal for reuse was about 90 %, but the remaining will be as a waste product (Abteew & Selvaduray, 2000). Due to the modern rapid expansions in electronic technology, more assessment needed to create a new robust solder that is convenient with the solderability and reliability of solder joints needed in electronic applications.

2.2 Lead-Free Solders

Since the toxicity of lead, which can cause the negative impacts to both the human health and the environment, new 'green solder' also called as lead-free solder has to be created in consequence of current rapid desired about electronic technology in the worldwide (Ma & Suhling, 2009; Manko, 2001). Sn-Pb solder have been widely used in electronic applications because of their desirable properties which is low cost, good wettability, high ductility, low shear modulus, high corrosion resistance and