FUNCTIONAL PROPERTIES OF ELECTRICALLY CONDUCTIVE ADHESIVES AS INTERCONNECT MATERIALS

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DECLARATION

I declare that this project entitled "The Functional Properties of Electrically Conductive Adhesive as Interconnect Material" is the result of my own work except as cited in the references.

Signature : ……………………………………..

Name : ……………………….……………

Date : ……………………….……………

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons).

Signature : ....

Name of supervisor : ....

Date : ....

DEDICATION

This project work is dedicated to my beloved family for always been there to support and inspire me throughout my life.

ABSTRACT

The use of electrically conductive adhesive (ECA) been expanded widely in microelectronics industry. ECA is to replace solder with beneficial advantages in fastening and brazing, sealing, interconnection, electrical shielding and eco-friendly with elimination of lead usage and reduce flux cleaner, due to increasing awareness to the environment increased as the traditional solder no longer fulfil the increase of miniaturization of electronic device or product and contain toxic lead, harmful to human and hazardous material. This research is focused on the functional properties of electrically conductive adhesives as interconnect materials. In this research, hybrid electrically conductive adhesive was formulated by adding 5 wt.% silver flakes (Ag) and multi walled carbon nano-tubes (MWCNT) with filler loading 5 wt.%, 6 wt.% and 7 wt.% to the epoxy matrix in a centrifugal mixer, Thinky mixer ARE-310 machine. One of the objectives of this research is to establish a lower percolation threshold for electrically conductive adhesive with varying filler loading. The second objective is to investigate the effect of hybridizing the fillers on the mechanical performance of hybrid electrically conductive adhesives. With reference to ASTM F390 standard guideline, JANDEL model RM3000+, a 4-point probe was used to measure the resistivity of printed hybrid ECA, in which each sample was tested for 3 times to get reliable set of data. The mechanical performance is evaluated in term of the lap shear strength of the hybrid ECA as ASTM D1002. The experiment results from electrical characterization suggest that the sheet resistivity gradually reduced (an indication of increasing electric conductivity) from 5 wt.% up to 7 wt.% of the MWCNT which then plateaued, a possible indication of percolation threshold, that is associated with better conductive path between the Ag-MWCNT hybrids fillers in the hybrid ECA. Here, the sheet resistivity is stabilized at 0.45kW/sqr. However, in term of the lap shear strength there is a decrease in the value with increasing MWCNT filler loading, from 8.61 MPa down to 7.03 MPa. At 5 wt.% the hybrid ECA exhibit a combination of cohesive-adhesive failure, in which the hybrid ECA is retained at both sides. However, at 7wt% MWCNT, the hybrid ECA experience an adhesive failure since the hybrid ECA is retained only on one side.

ABSTRAK

Penggunaan "electrically conductive adhesive" (ECA) telah berkembang secara meluas dalam industri mikroelektronik. ECA adalah untuk menggantikan pateri berasaskan plumbum dengan kelebihan dalam pengikat pateri, penyegal, interkoneksi, perisai elektrik dan mesra alam dengan penghapusan kegunaan plumbum dan mengurangkan kegunaan plumbum dan mengurangkan pembersih fluks, kerana peningkatan kesedaran kepada pateri plumbum tidak lagi memenuhi peningkatan daripada pengecilan peranti electronik atau produk dan mengandungi bahan plumbum toksik, boleh membahayakan kesihatan manusia. Penyelidikan ini memberi tumpuan kepada sifat-sifat fungsional "electrically conductive adhesive" sebagai bahan sambung. Dalam penyelidikan ini, hibrid ECA telah diformulasikan dengan menambah 5 wt.% serpihan perak (Ag) dan "multi-walled carbon nano-tube" (MWCNT) dengan kandungan 5 wt.%, 6 wt.% and 7 wt.% matriks epoksi dalam pembancuh sentrifugal, mesin "Thinky ARE-310". Salah satu objektif penyelidikan ini adalah untuk mewujudkan "percolation threshold" yang rendah untuk hibrid ECA. Tujuan kedua adalah untuk mengkaji kesan hibridsasi pengisi prestasi mekanikal pada hibrid ECA. Dengan merujuk kepada garis panduan standard ASTM F390, model JANDEL RM3000+, "4-point probe digunakan untuk mengukur sesitiviti hibrid ECA, setiap sampel diuji selama 3 kali untuk mendapatkan set data yang lebih tepat. Prestasi mekanikal dinilai dari segi "lap shear strength" untuk hibrid ECA sebagi ASTM D1002. Eksperimen yang dihasilkan dari pencirian elektrik menunjukkan bahawa "sheet resistance" berkurang secara beransur-ansur (indikasi peningkatkan kekonduksian elektrik) dari 5 wt.% sehingga 7 wt.% kemudian mendatar, menunjukkan kemungkinan "percolation threshold", ia mengaitkan laluan konduktif yang lebih baik antara kandungan Ag-MWCNT hibrid. Di sini, "sheet resistivity" stabil pada 0.45 KW/sqr. Walau bagaimanapun, dari segi "lap shear strength" terdapat penurunan nilai dengan peningkatan kandungan MWCNT, dari 8.61 MPa hingga 7.03 MPa. Pada 5 wt.%, hibrid ECA mempamerkan gabungan "cohesive-adheisve", di mana hibrid ECA mengalami dikekalkan di kedua-dua belah permukaan. Walau bagaimanapun, pada 7 wt.% hibrid MWCNT mengalami kegagalan "adhesive" kerana kebanyakannya melekat di belah permukaan.

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LIST OF ABBREVIATIONS

Ag	Silver
ASTM	American Society For Testing Material
CB	Carbon Black
CNT	Carbon Nano-Tube
DWCNT	Double-Walled Carbon Nano-Tube
ECA	Electrically Conductive Adhesive
FED	Flat Emission Display
ICA	Isotropic Conductive Adhesive
LCD	Liquid Crystal Display
MWCNT	Multi-Walled Carbon Nano-Tube
SWCNT	Single-Walled Nano-Tube

LIST OF SYMBOL

ω-cm	electrical resistivity
cm	Centimetre
°c	Degree Celsius
G/cm3	Density
GPa	Giga Pascal
Mpa	Mega Pascal
Pa	Pascal
G	correction factor
k	Kelvin
Ω	Ohm
sq	Square
wm−1k−1	Thermal conductivity
sm−1	conductivity
λ	Lambda
L	Length
meq/g	milliequivalents
mm Hg/oC	Vapor pressure
pt-co	Platinum-Cobalt Scale
nm	Nanometer
µm	Micrometer
V	Voltage
I	Current
$Ω/sq$	sheet resistance
t	thickness
UTM	Universal Testing Machine
rpm	Revolutions per minute

CHAPTER 1

INTRODUCTION

1.1 Background

The use of electrically conductive adhesive (ECA) been expanded widely in microelectronics industry. The main application for the electrically conductive adhesive (ECA) is die attachment, surface mounted assembly of package component on wiring printed board, liquid crystal display (LCD). The use of electrically conductive adhesive (ECA) is to replace solder with beneficial advantages in fastening and brazing, sealing, interconnection, and electrical shielding do come with friendliness advance as elimination of lead usage and reduce flux cleaner (Drive, 2010). Compared to other types of adhesives, electrically conductive adhesive (ECA) function as electrical interconnection between two bonded surface and join with sufficient strength on bonded surface. The electrically conductive adhesive (ECA) composed of composites in the form of dispersion of particle in an insulating adhesive matrix. Carbon black, micron or Nano-sized particle silver, gold, and aluminium, and graphite flakes are the common filler used as conductive filler and as for the polymer matrices, epoxy, silicone, polyurethane, and polyamide are the common materials employed. These adhesives have high and stable electrical conductivity, and normally the electrical resistivity of 10^4 Ω-cm, which is higher than metallic conductors. From the literature, past study have investigated a mixture of metal filler into epoxy resin to improve its functional properties such as thermal conductivity, strength and the composite coefficient of thermal expansion (CTE), shrinkage, and heat resistance (Sancaktar and Bai, 2011).

Isotropic conductive adhesive (ICA) and anisotropic conductive adhesive (ACA) are two main classification of electrically conductive adhesive (ECA) (Yi Li Daniel Lu C.P. Wong, 2010). Isotropic conductive adhesive (ICAs) can be either thermoset or thermoplastic. Thermoplastic has long curing time but rework-able. Meanwhile, thermoset form chemical cross link between polymer chains when undergoes chemical reaction and has poor rework ability and limited shelf life. Anisotropic electrical conductivity (ACAs) normally purpose for substitution of lead-free solder when undergo assembly expose with high heat sensitive component, which will cause damaged under temperature applied soldering process. The ICAs commonly used for fine-pitch assembly, it advance in low frequency and no bridging in adhesive compared to lead solder (Republic, 2011). Carbon Nanotube (CNT) features unique characteristic; it has good chemical stability, conduct electricity, and exhibit strong mechanical properties. Carbon Nanotube (CNT) are divided into two types; single walled carbon Nanotube (SWCNT) and multi walled carbon Nano-tube (MWCNT). Single walled carbon Nanotube (SWCNT) has one dimensional structure and relatively more expensive to produce. Multi-walled carbon Nano-tube (MWCNT) consists of multi-layer of graphite roll in one tubes, and unique in mechanical and electrical properties will be new application in material and devices(Mantena, 2009).

1.2 Problem Statement

With an increasing concern and better awareness to protect the environment, therefore, it is no more favourable to consider traditional solder which contain toxic lead, since it is harmful and hazardous material to human health (luo *et al.*, 2016). Due to lead-solder low resolution, it has no longer fulfil the demand for increase in miniaturization of electronic device or product (Zhang *et al.*, 2011). To replace the lead-based solder, lead free electrically conductive adhesive (ECA) is develop, which comes along with many advantages such as low temperature processing, simple processing and finer pitch. However, some of the major drawbacks of the electrically conductive adhesive (ECA) in comparison to the lead-based solder include low mechanical strength, limited impact resistance, and high or increase in contact resistance increased, hence inferior electrical conductivity (Mantena, 2009).

Carbon Nano-tubes (CNT) is introduced to replace the lead based solder. It exhibits unique characteristics in terms of mechanical, electrical, structure, and thermal properties. With the advantages in easy preparation, less amount of limitation in size, it is used to fabricate CNT firm (Pan, Zhu and Gao, 2008). CNT is the stiffest and strongest fibre among others with unique characteristics; stable in chemical, strong and conductive electricity (Mantena, 2009).

In this research project, epoxy is mixed with two conductive fillers: these being Multi-Walled Carbon Nano-tube (MWCNT) which is hybridize with silver flakes to formulate with varying filler loading of the MWCNT.

1.3 Objective

The objectives of this research project are:

I. To determine the percolation level for the electrically conductive adhesive with varying filler loading and two types of filler

II. To investigate the effect of varying the filler loading and types on the lap shear strength of the electrically conductive adhesives.

1.4 Scope of Project

The scope of this research projects is listed as below:

I. Formulation and fabrication of electrically conductive adhesives.

II. ECA sheet resistance measurement by conducting a four-point probe test on printed ECA.

III. ECA mechanical testing via lap shear test.

IV. Morphological study on substrate surface and fractured surface of the ECA.

1.5 Planning and Execution

The research activities for PSM I and II are shown in Table 1.1 and 1.2 respectively. The research activities include project tittle selection, literature review, experimental design, formulation and fabrication of ECA, ECA sheet resistance measurement and lap shear test on ECA as well as the failure analysis of the hybrid ECA using visual observation. For both semester, the completion of all research activities is followed by data analysis, report writing, report submission and the presentation during the seminar for each semester.

Table 1.1: Gantt chart for PSM 1.

WEEK / ACTIVITIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Research title selection	■	■	■													
Literature review				■	■	■	■	■	■	■	■	■	■	■	■	
Experimental design									■	■	■					
Formulation and fabrication of ECA										■	■	■				
ECA electrical conductivity test											■	■	■			
Preliminary data analysis												■	■			
Report writing												■	■	■		
Report submission														■		
PSM 1 seminar																■

Table 1.2: Gantt chart for PSM II.

WEEK / ACTIVITIES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Literature Review	■	■	■	■	■	■	■	■	■	■	■	■	■				
Methodology				■	■	■	■	■	■	■	■	■	■				
Conduct Experiment: Electrical Conductivity		■	■	■													
Conduct Experiment: Lap Shear Test					■	■	■										
Data Analysis				■	■	■	■										
Progress Report Submission								■									
Report Writing	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Draft Submission														■			
PSM II Seminar														■			
Report Submission																	■

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review on the electrically conductive adhesive (ECA) which include the type of polymer matrix, type of filler, type of carbon nanotube, and functional properties ECA which is reported in the literature.

2.2 Electrically Conductive Adhesive (ECA)

The production of the solar cell is now doe by the leaded soldering. Electrically conductive adhesive to replace the standard soldering, as lead free and provides a gentle interconnection (Eitner *et al.*, 2012). The electrically conductive adhesive is found out have more application owing to numerous advantage such as the ability to bond two irregularly shaped surface, corrosion resistance, and proficient mechanical load transfer, stress and mechanical vibration resistance. These adhesive can be applied onto the film, adhesive joint and coating. Electrically conductive adhesive is a type of composite adhesive that comprised of two materials, the polymer binder resin (form of thermoset like: epoxy), conductive filler material (silver, gold, aluminium). This composite materials is an alternative electronic packaging material to the lead based solder, have advantage in high shear strength, environment friendly, save time(reduce in process step compared to solder), low temperature process, and accurate pitch capabilities (Trinidad *et al.*, 2017).

The used of electrically conductive adhesive (ECA) is shown to be an effort in replacing the soldering interconnection with an alternative substitute material such as the ECA.

Electrically conductive adhesive is a polymer composite system containing conductive particles and engineered to produce chemical and electrical bonds upon treatment and application. The treatment is normally heated up about in range of 120 °C to 180 °C. The electrically conductive adhesive can be used as a paste by dispensing or screen printing, conductive firm/tacky material, and pre-cured. The bonding process used in conductive adhesive and film does in principle not required larger areas as soldering(Beaucarne *et al.*, 2015). A schematic diagram of an electrically conductive adhesive bonded to an electrical component and connecting pad (Trinidad, 2016) is shown in Figure 2.1.

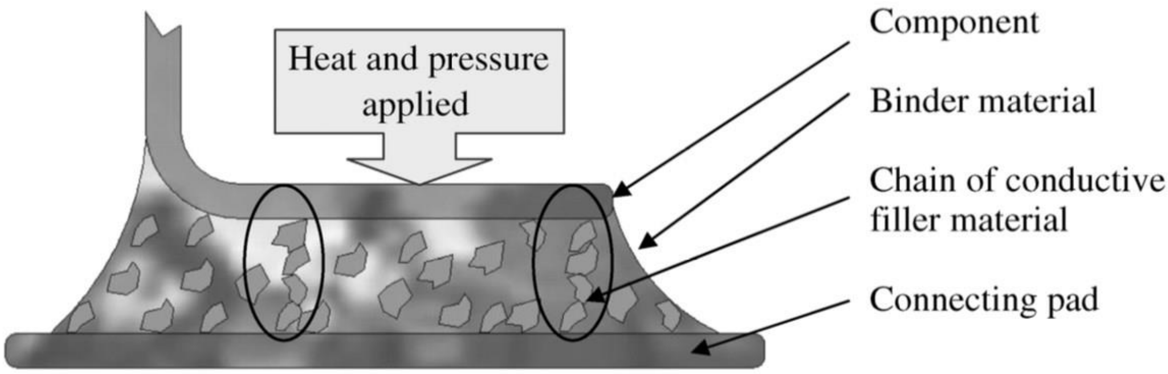

Figure 2.1: Schematic example of an electrically conductive adhesive bonded to an electrical component and connecting pad (Trinidad, 2016).