Faculty of Mechanical and Manufacturing Engineering Technology

INVESTIGATION OF COVERLAY ADHESION BY ACRYLIC-BASED ADHESIVE ON COPPER-POLYIMIDE LAMINATE FOR FLEXIBLE PRINTED CIRCUIT

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INVESTIGATION OF COVERLAY ADHESION BY ACRYLIC-BASED ADHESIVE ON COPPER-POLYIMIDE LAMINATE FOR FLEXIBLE PRINTED CIRCUIT

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DECLARATION

I declared that this thesis entitled “Investigation of Coverlay Adhesion by Acrylic-Based Adhesive on Copper-Polyimide Laminate for Flexible Printed Circuit” is the results of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	…………………………………………….
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Date	:	……………………………………………

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Manufacturing Engineering Technology (Process & Technology) with Honours.

Signature : ………………………………………….

Supervisor Name : Hairul Effendy Bin Ab Maulod

Date : …………………………………………

DEDICATION

To my beloved family, lecturers and friends.

ABSTRACT

This study is to investigate the coverlay adhesion by using acrylic-based adhesive on copper-polyimide laminate for Flexible Printed Circuit (FPC). Nowadays, the functionality of electronic devices continues to increase at higher rate. FPC is one of the higher requests in various industries. In FPC, lamination process is required to join the coverlay with copper clad laminate (CCL) using acrylic-based adhesive under heat, pressure and interval time. This process is to improve the bonding strength between the materials after curing. One issue that may occur after curing process is delamination of FPC. Thus, the overall thickness of FPC and the correlation of pressure and temperature distribution of lamination press machine towards delamination issue on coverlay adhesion by acrylic-based adhesive on copper polyimide laminate is investigate in this study. Testing and analysis included cross-section test and thermogravimetric analysis (TGA) to characterize the adhesive bonding correlated with acrylic-based adhesive with copper polyimide after curing process in FPC. From the analysis of the layer thickness, the highest and lowest thickness of adhesive is determined using 3D Laser Microscope where the highest thickness is on middle book while the lowest thickness is on top book of FPC. There are no delaminations occurred but the result of the adhesive thickness obtained showing the tendency of delamination to occur. The TGA curve analyzes the weight loss of each material in the FPC where the FPC starts to degrade at temperature 400^{o}C. From the analysis of TGA, the more weight loss in the thermal analysis shows the less bonding strength of adhesive.

ABSTRAK

Kajian ini adalah untuk mengkaji lapisan penutup pelekat menggunakan pelekat berasaskan akrilik pada lamina *copper polyimide* dalam litar bercetak fleksibel. Pada masa kini, fungsi komponen elektronik terus meningkat pada kadar yang tinggi. Litar bercetak fleksibel mempunyai permintaan yang tinggi dalam pelbagai industri. Dalam litar bercetak fleksibel, proses laminasi digunakan untuk mengabungkan lapisan penutup dengan *copper clad laminate (CCL)* menggunakan pelekat berasaskan akrilik di bawah haba, tekanan dan jangka masa. Proses ini adalah untuk meningkatkan tahap kekuatan ikatan antara bahan selepas proses pengawetan. Salah satu isu yang mungkin berlaku selepas proses pengawetan adalah delaminasi. Oleh itu, keseluruhan tebal dalam setiap lapisan litar bercetak fleksibel dan hubungkait tekanan dan pembahagian suhu dalam mesin laminasi terhadap isu delaminasi pada lapisan penutup pelekat oleh pelekat berasaskan akrilik pada *copper clad laminate* akan dikaji. Uji kaji dan analisis termasuk kajian keratan rentas dan analisa *thermogravimetric* yang akan dijalankan untuk menggambarkan ciri-ciri kekuatan pelekat yang dikaitkan dengan pelekat berasaskan akrilik dengan *copper polyimide* selepas proses pengawetan dalam litar bercetak fleksibel. Daripada analisa ketebalan lapisan litar, ketebalan pelekat yang paling tinggi dan yang paling rendah telah ditentukan di mana tebal yang paling tinggi terletak pada bahagian tengah buku dan tebal yang paling rendah terletak pada bahagian atas buku. Tiada isu delaminasi berlaku tetapi selepas mengkaji setiap lapisan, isu delaminasi mungkin berlaku. Analisis *thermogravimetric* telah mengurangkan berat daripada setiap bahan dalam litar bercetak fleksibel di mana degradasi bermula pada suhu 400^{o}C. Daripada analisa TGA, lagi banyak berat berkurang, lagi sikit kekuatan ikatan antara pelekat tersebut.

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LIST OF ABBREVIATION, SYMBOLS AND NOMENCLATURE

μ	-	Microns
oz	-	Fluid Ounce
mil	-	Milliliter
mV	-	Millivolts
^{o}C	-	Degree Celsius
mm	-	Millimeter
min	-	Minute
m	-	Mass
ρ	-	Density
SiO2	-	Silicon Dioxide
ANSI	-	American National Standard Institute
AOI	-	Automated Optical Inspection
CCL	-	Copper Clad Laminate
CFRP	-	Carbon fiber reinforced plastic
CO_2	-	Carbon dioxide
ECM	-	Electrochemical migration
EVA	-	Ethylene-vinyl acetate
FEP	-	Fluorinated ethylene propylene
FPC	-	Flexible Printed Circuit

FPCB	-	Flexible Printed Circuit Board
IEC	-	International Electro-technical Commission
IPC	-	Institute for Interconnecting Packaging Electronic Circuits
NEMA	-	National Electrical Manufacturers Association
MIL	-	Military Standard
PCB	-	Printed Circuit Board
PI	-	Polyimide
PTH	-	Plate Through Hole
PET	-	Polyethylene terephthalate
PEN	-	Polyethylene naphthalate
PTFE	-	Polytetrafluoro ethylene
PBA	-	Printed Board Assembly
SMD	-	Surface Mount Device
SMT	-	Surface Mount Technology
TGA	-	Thermogravimetric Analysis
V	-	Volume

CHAPTER 1

INTRODUCTION

This chapter will explain the overview of the study and the purpose of this study. The chapter includes the background of the study, problem statement, objectives that is expected to be achieved and the scope of the study that is going to be conducted.

1.1 Background of Study

Nowadays, flexible printed circuit (FPC) has many requests in industry due to their thin, lightweight and flexible properties. They are evolves and high-growth technology in electrical interconnectivity and improved performance by making electronic devices more compact, lighter and thinner for applications spanning automobiles, cellular phones, smart watches and portable laptops (Kim, S. Lee, Yu, & Han, 2017). FPC is a perfect solution for the electronic packaging need. A flexible printed circuit board (FPCB) is a polymer-based substrate with metal interconnects for the wiring of integrated circuits. The raw materials of FPCBs include a flexible copper clad laminate (FCCL) and epoxy or acrylic coverlay, in which the copper foil and epoxy or acrylic resin were both bonded with the polyimide (PI) film. The bonding methods of copper foil in FCCLs are both physical and chemical. Generally, the bond of the FCCL and coverlay is by adhesive using lamination press process.

Lamination is a method of manufacturing that widely used in industry where the joining or stacking of the two or more layers of material together permanently. Lamination are also used in wide range of applications such as for the manufacture of technical laminates for the solar energy and insulation panel sectors as well as in the food and non-food packaging industries. This technique is to ensure the strength, stability, appearance and properties of the materials are improved by using two or more materials stacked in multiple layers in flexible circuit board. In general terms, a laminate is permanently assembled by heat, pressure or adhesive.

Technological advancement in the field of lamination has led to different ways in which sheet can be laminated. Hot-roll lamination, extrusion lamination, flame lamination and adhesive lamination are a few example of processing approaches. In this study, a detailed discussion on the fundamentals of lamination is provided. Thermal lamination is the approach of bonding two substrates with an adhesive. The adhesive, which is in the form of polyolefin such as EVA (ethylene-vinyl acetate) is first applied to and cooled and dried on one of the substrates. The substrates are pressed together in the nip of the two rollers under constant heat, providing an adequate amount of force to establish the intimate contact required for the bond. Extrusion lamination is another approach to bonding two substrates. The hot extruded film is trapped between two substrates and cooled to bond two substrates. Wet bond lamination uses solvent-based adhesives, which are only to be used with substrates with high permeability to water or other solvents. Wet bond is not generally successful with plastic films, even when laminating them to paper. Dry bond lamination is considered as a process of choice when laminating two materials using either an aqueous or solvent-based adhesive. In a solvent-less lamination, two substrates are bonded together by curing without the presence of a solvent. The adhesive layer formed by curing systems does not release solvents, but small traces of carbon dioxide (CO2) have been found (Ashter, 2014).

For this study, lamination process is used to combine the coverlay and the copper clad laminate (CCL) with adhesives using hot press laminate machine. The conductor of the finished flexible circuit is protected and enhances the flexibility by the coverlay. CCL in flexible printed circuit consist of two type of thermoset that is polyimide and polyester. The adhesives used in lamination are acrylic-based adhesive and epoxy-based adhesive. Typically, a laminate is done by bonding together a base material, an adhesive and a metal foil. The stack is then exposed under heat and pressure in a hot press laminate machine to create a permanently bonded metal polymer laminate.

1.2 Problem Statement

A flexible printed circuit (FPC) is widely used in industry in area of electrical interconnectivity. The production of FPC is very high due to many requests of the customers. Many process in FPC that has been developed to improve the quality and properties of the board. In FPC, one of the processes used to manufacture the board is lamination process. The layer of the laminates consists of copper clad laminate (CCL) and coverlay with adhesive are bond together under heat and pressure with interval time. The coverlays are etched to form the required pattern of conducting traces, and the adhesive of the layers fills the spaces where the copper was removed. When an adhesive is used to fill the gap between the undersides of a component, it will result the other issues of delamination. The bonds of „„underfill" adhesives act to reinforce the connection with the FPC. Delamination is one of the main failure modes that occurred in FPC. During the soldering process, delamination may occur particularly with lead-free solders which require higher reflow temperatures than leaded solders. Bending of steel plate during installation, service and repair can also can cause FPC delamination.

Therefore, it is very important to understand the delamination process in FPC (Akbari, Nourani, & Spelt, 2018).

One enabler for shrinking electronics has been the flexible circuit board that allows the circuit board to fit in a wide variety of shapes. Flexible circuit boards have the capability to be very thin and can have unpackaged components directly attached using surface mount assembly and flip chip on flex technologies. Unfortunately, with this flexibility come other reliability issues. One issue is the tendency of flexible circuit panels absorbing the chemical solvents that are used during the surface mount device (SMD) assembly cleaning process, specifically the process of vapor degreasing. These solvents can remain trapped in the circuit layers and cause blistering and delamination of the circuit boards during subsequent assembly steps (Krzmarzick, Dzarnoski, & Xing, 2013). In FPC, polymer coverlay is applied on the copper-polyimide laminate using acrylic-based adhesive, followed by elevated time, temperature and pressure during process.

1.3 Objectives

The objective of the project is to:-

i. To characterize the thickness of acrylic adhesive of lamination Flexible Printed Circuit (FPC) from different areal and layer positions.
ii. To assess thermal degradation behavior of the laminated Flexible Printed Circuit (FPC) by TGA-DTG analysis.

1.4 Scope

The study on this topic can be benefit for certain circumstances. This project is "Investigation of coverlay adhesion by acrylic-based adhesive on copper-polyimide laminate for Flexible Printed Circuit" through lamination process and test the effect after curing. The scopes of this study are focusing more on curing of coverlay adhesive by acrylic-based adhesive on copper polyimide laminate correlation with temperature and pressure profiles. Next, the study also looks on the relationship of delamination with the evenness distribution of temperature and pressure at specific interval time. The findings will be further supported by the analysis of Thermogravimetric analysis (TGA) and cross section test using 3D laser microscope.

1.5 Organization of Research Study

This project is divided into five chapters that describe the analytical and experimental research performed. This dissertation shows the defect occurred after the lamination press process in flexible printed circuit. The cause regarding the delamination with copper clad laminate has been studied, in search of improvements on their physical and mechanical properties. The organization of this research study is as follows. This dissertation has been organized into five chapters. The first chapter is introduction to the study that brief about objectives, problem statement, significant of study and the project overview.

Chapter two begins on the literature background of this study. It discusses on the history of flexible circuit board, types of material used in flexible circuit board and it processes. The important element that included in this chapter is about the lamination process of coverlay with copper clad laminates (CCL) and the defect occurred after curing process which is delamination of the FPC.

Chapter three provides details explanations on the methodology used for overall research work, raw materials, procedure property analysis that had been done. In this chapter four, instead of investigation of coverlay adhesion by acrylic-based adhesive on copper-polyimide laminate, also want to understand the factors that contribute delamination after curing process in FPC and discuss about the analysis result after done the analysis testing for the FPC. The last chapter (chapter 5) concludes the overall results obtained from this research. In this chapter, it explains either the objectives of this study are achieved or not. The recommendation for future project also has been included in this Chapter 5.

CHAPTER 2

LITERATURE REVIEW

In this chapter, it will explain about the previous research that has been writing from the numerous of the journalist and researcher which come from the internet, journals, article and books about the topic that is related to this final year project study. This chapter also explains about the overview of the acrylic-based adhesive on copper-polyimide laminate for flexible printed circuit. The success of a design and material testing also depends on the creativity of designers and the use of appropriate technology to meet the needs of effective and functional. The design and study is ongoing process that involved creative problem solving is known as a literature.

In the production this project, all theory and information of material substance used, production and testing in relation this project has been described to achieve objective of the project those implemented.

2.1 Assembly of Flexible Printed Circuit (FPC)

Flexible printed circuit (FPC) board interconnect rigid boards, displays, connectors and various other components in a three-dimensional package. They can be bent-folded or shaped to interconnect multiple planes or conform to specific package sizes. Flex circuits also have the ability to connect moving components, a prime requirement in disk drives, printer heads and other continually moving electronic assemblies.

FPC assembly is very like the rigid printed circuit board (PCB) assembly yet the thin substrate of FPC makes it more vulnerable to various types of defects that range from minute twist on the board to the spacing between soldering. Thus, it drags the production yield down. Figure 2.1 shows the constructional part of flexible printed circuits which consist of cover layer, copper foil, adhesive and polyimide.

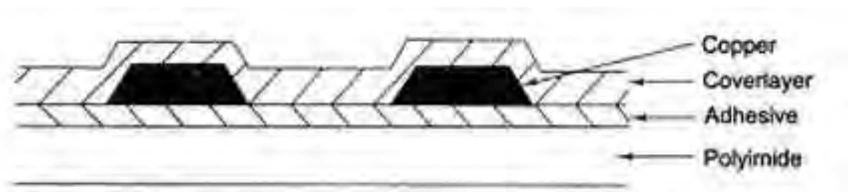

Figure 2.1: Constructional part of FPC (schematic view) (Khandpur, 2005)

Comparing to PCB, cleaning flexible material need more caution and it involve different procedure of cleaning even both type of printed board required same number of cleaning cycles. Cleaning of FPC involves an environmentally safe process which include an alkaline bath, a through rinse, a micro etch and a final rinse. Usually, damage to the thin clad materials often occurs with racking of the panels, agitating the panels in the tank, breaking the surface tension in the cleaning tanks, removing racks from the tanks. Research found that the FPC can be less expensive of mass production compared to rigid PCB. This is due to the manufacturing process of flexible printed circuit boards that enable to be produce on a continuous basis which is start from laminate roll and directly produces the finished boards (Khandpur, 2005).

Figure 2.2 shows the continuous process of manufacturing flexible printed circuit board. This continuous process enable all manufacturing steps can be done in-line by machines that placed sequentially.