UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CIRCUIT DEFECTS DETECTION OF FLEXIBLE PRINTED CIRCUIT BY ELECTROPHORETIC DEPOSITION OF ORGANIC DYE

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

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DECLARATION

I hereby, declared this report entitled “Circuit Defects Detection of Flexible Printed Circuit by Electrophoretic Deposition of Organic Dye” is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The members of the supervisory committee are as follow:

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(Official Stamp of Principal Supervisor) (Official Stamp of Principal Supervisor)

ABSTRACT

This project cover the Investigation of circuit defects of Flexible Printed Circuits (FPC) based on Electrophoretic Deposition method (EPD). EPD was purpose as a new method replacing Optical Microscopy and visual inspection to improve the defects detection of FPC due to difficulties in differentiate conductive material and non- conductive material. The objective of this project is to determine suitable parameters for Electrophoretic Deposition (EPD) method on conductive material, to investigate circuit defects on FPC using EPD and to validate circuit defects on FPC using Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD) and Optical Microscopy (OM). Methylene blue suspension and Carmoisine dye suspension have been used in this project to determine a suitable solution for EPD on FPC. Optimum EPD parameters for Methylene Blue suspension are 1.5 mM concentration of MB with 0.3 mM concentration of $AlCl_3$ with total volume of solution is 50 ml. The optimum EPD parameters for Methylene Blue suspension are 50V voltage applied in 10 minutes deposition time. While for second solution, Carmoisine dye suspension, optimum parameters used for EPD are 5 g of Carmoisine powder with 45ml of distilled water to produce 50 ml total volume of solution. The EPD process for Carmoisine dye suspension involve 5 V of voltage applied in 5 minutes deposition time. However, Carmoisine dye suspension have been used for EPD on FPC because the yield of deposited dye from Carmoisine dye suspension are better than Methylene Blue suspension even at low voltage applied. It is recommended for further research on dye that can be dispersed in distilled water and can be repeatedly use for economical purpose.

ABSTRAK

Projek ini meliputi siasatan kecacatan litar pada Litar Fleksibel Bercetak (FPC) berdasarkan kaedah Electrophoretic Deposition (EPD). Kaedah EPD adalah bertujuan sebagai kaedah baru menggantikan Mikroskop Optik dan pemeriksaan visual untuk meningkatkan pengesanan kecacatan pada FPC disebabkan kesukaran membezakan bahan konduktif dan bahan bukan konduktif. Objektif projek ini adalah untuk menentukan parameter yang sesuai untuk kaedah Electrophoretic Deposition (EPD) pada bahan konduktif, untuk menyiasat kecacatan litar pada FPC menggunakan EPD dan untuk mengesahkan kecacatan litar pada FPC menggunakan Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spektroskopi (FTIR), X-ray Diffraction (XRD) dan Optical Microscopy (OM). Methylene Blue dan Carmoisine telah digunakan dalam projek ini untuk menentukan bahan yang sesuai untuk EPD pada FPC. Parameter terlibat dalam Methylene Blue ialah1.5 mM kepekatan MB dengan 0.3 mM kepekatan $AlCl_3$ dengan jumlah isipadu larutan ialah 50 ml. Proses EPD untuk Methylene Blue melibatkan 50V voltan digunakan dalam 10 minit masa pemendapan. Manakala bagi bahan kedua, parameter digunakan bagi Carmoisine untuk EPD ialah 5 g serbuk Carmoisine dengan 45ml air suling untuk menghasilkan 50 ml jumlah larutan. Proses EPD untuk Carmoisine melibatkan 5 V voltan digunakan dalam 5 minit masa pemendapan. Walau bagaimanapun, Carmoisine telah digunakan untuk EPD pada FPC kerana hasil pewarna daripada Carmoisine adalah lebih baik dari Methylene Blue walaupun pada voltan rendah. Ia adalah disyorkan untuk penyelidikan lanjut mengenai pewarna yang boleh larut di dalam air suling dan boleh berulang kali digunakan untuk tujuan menjimatkan kos.

DEDICATION

This thesis is dedicated to my beloved parents, for without their early inspiration and spirit, none of this would have happened. For family members who never stop support and always stand by my side throughout this research.

ACKNOWLADGEMENT

I wish to express my sincere thanks to Assoc. Prof. Dr. Mohd Rizal Bin Salleh, Dean of the Faculty, for providing me with all the necessary facilities for the research and continuous encouragement.

I am also grateful to my supervisor DR. LAU KOK TEE and PM DR. MOHD ASYADI 'AZAM BIN MOHD ABID , lecturer in the Department of engineering material. I am extremely thankful and indebted to him for sharing expertise, and sincere and valuable guidance and encouragement extended to me.

I take this opportunity to express gratitude to all of the Department faculty members for their help and support. I also thank my parents for the unceasing encouragement, support and attention. I am also grateful to my friends who supported me through this venture.

I also place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

FPC - Flexible Printed Circuit.

PDA - Personal Digital Assistants.

PCB - Printed Circuit Board.

OM - Optical Microscopy.

EPD - Electrophoretic Deposition.

SEM - Scanning Electron Microscopy.

XRD - X-Ray Diffraction.

FTIR. - Fourier Transform Infrared Spectroscopy

CCL - Process Of The Copper – Clad Laminated.

IPC - Interconnecting Packaging Electronic Circuits

NEMA - National Electrical Manufacturers Association

MIL - Military Standard

IEC - International Electrotechnical Commission

ANSI - American National Standard Institute.

ECM - Electrochemical Migration.

PBA - Printed Board Assembly.

ZNO - Zinc Oxide

$AlCl_3$ - Aluminum Chloride.

CRT - Cathode Ray Tube

SE - Secondary Electrons

BSE. - Backscattered Electrons

HCl - Hydrochloric Acid.

PI - Polyimide.

CHAPTER 1

INTRODUCTION

1.1 Background

Flexible printed circuit (FPC) boards interconnect rigid boards, showcases, connectors and different parts in a three-dimensional electronics packages. They can be twisted or shaped to interconnect numerous planes or adjust to particular package sizes and having capacity to unite moving segments, a prime requirement in disk drives, printer heads. Plus, their capacities in reduced package size and weight, brought down gathering cost and time, and increased in system reliabilities had generally utilized as a part of portable PCs, mobile phones, personal digital assistants (PDAs) and others. Figure 1.1 show example of Flexible printed circuit (Khandpur, 2005)

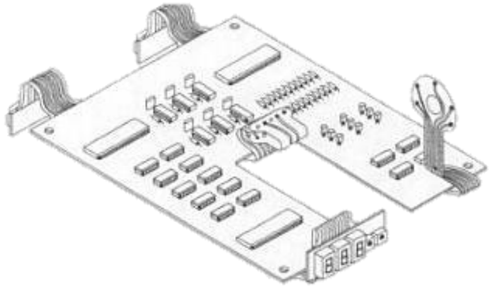

Figure 1.1: Example of flexible printed circuits (Khandpur, 2005)

FPC is an alternative to conventional wiring. They enhance connection reliability, part appearance and simplify the gathering of segment. For the most part, FPC fit one and only way and subsequently, cause fewer errors during installation and servicing, thereby reducing re-work and troubleshooting time. Since a FPC is more resistance to shock and vibration than a rigid printed circuit board (PCB), repair and replacement costs in case of the former are clearly considerably less. FPCs are thin and light in weight make them suitable for redundant circuitry for satellites and aeronautical instruments, progressed experimental sensors, flexible heating components, medical equipment, robots, and security devices (Khandpur, 2005). There has been an increment in the interest for quality control in FPC making industry with FPC being broadly utilized. However, there are a few issues on the defects found in the FPC. Three common defects in the Flexible Printed Circuits are, short circuits, contaminations and delamination will be discussed in chapter 2 (Khandpur, 2005).

1.3 Problem statement

For many years, circuit defect detection of Flexible Printed Circuits (FPC) have been done by using visual inspection or optical microscopy (OM). However, both OM and visual inspection contributes to low accuracy of detection data. It been purposed to replace both method with automatic image detection system that consists of computer image processing and pattern recognition to increase the efficiency and accuracy of FPC defect detection (Ren and Hong, 2014). However, their effectiveness in detection of circuit defect are subjected to argument due to their indirect evaluation approach which are based on optical images gathered during the inspection process. Research found that circuit defects mostly occur due to the presence of excess conductive materials between the conductive copper circuit traces and these excess conductive materials are particularly low in contrast as compared to other circuit microstructure thus are not noticeable through optical images. Besides, it is difficult to distinguish the conductive defects with the nonconductive defect structure caused by etching and cover-lay's adhesive resins even by using a high resolution microscopy. In fact, defect tracking of the circuit defects is a tedious process because of the complex and miniature of the printed circuit. Although inspection through pattern recognition technology increases the tracking speed, new algorithms are required for new FPCs which in turns increase the inspection cost.

In this research, an *in situ* FPCs' circuit defect detection technique based on dye deposition using Electrophoretic deposition (EPD) technique is purposed. EPD technique, a colloidal-based electrodeposition technique, has emerged as one of the most promising technique for coating application due to its versatility, simplicity, and low cost. With manufacturing industry moving toward implementing sustainable manufacturing practice, EPD presents the possibility of using environmentally friendly natural dye as deposit materials and water as solvents for the detection process. Furthermore, it can be used to selectively deposit the dye coating materials on particular conductive surface. Thus, it will provide more details information on the circuit defects in terms of their electrical properties.

1.4 Objective

1. To determine parameters for electrophoretic deposition of dye suspension on conductive materials.
2. To investigate circuit defect microstructure on Flexible Printed Circuits (FPC) using electrophoretic deposition technique.
3. To validate circuit defects on FPC using Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and Optical Microscopy (OM).

1.5 Scope

Throughout this research, 12 samples of stainless steel sheet and 4 type of flexible printed circuit (FPC) were used. Determination of suitable parameters used in the EPD method was performed by tuning all the parameters involve in the process. Next, all the sample undergoes investigation of defects area and defects validation. The investigation of defects is focus on the microstructure form by the dye deposition which was conducted using EPD method with fix parameters and the validation of defects is carried out using OM, SEM, XRD and FTIR.

CHAPTER 2

LITERATURE REVIEW

In this chapter, basics of Copper electroplating and the manufacturing of Flexible Printed Circuit board will be discuss together with the basic of Electrophoretic deposition method and parameters used in the experiment. Fundamentals of Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD) and Optical Microscopy (OM) also discussed in this chapter.

2.1 Copper Electroplating

Copper reported as one of the most common metal plate. Copper electroplating is widely used on plastics, zinc die casting, electro refining, automotive bumpers, printed wiring boards, electroforming and rotogravure rolls (Di Bari and George, 2000). Due to its ability to covers minor imperfection in the base metal, copper is the best decision for an underplate. Copper plating is well known with its high plating effectiveness that subsequent in excellent coverage even on hard to plate parts. Its profoundly conductive and mechanical properties making it an excellent coating for printed circuit boards or coating on steel wire which is utilized to conduct electricity. In any case, it is recorded as an inert electroplating metal in many solutions of other normal metals. Copper electrodeposition include three basic used system which are the acid sulfate, fluoborate simple ion systems, and the alkaline cyanide and pyrophosphate complex ion system. There are a couple of other sort of solution yet researched found that they are unstable and poor in deposit characteristics over sufficiently wide current density ranges.

However, for deposition of relatively thick deposition, copper deposit using cyanide solutions are not a good choice and little by little, cyanide solution have been replace by noncyanide solutions due to its toxicity and waste treatment problems. Same case with cyanide solution, pyrophosphate solution have been widely used for printed circuit boards before being replace with high-throw acid sulfate solutions and fluoborate have been replace with sulfate ions. The replacement of sulfate ions occur as it can give same quality with less susceptible to impurities and it is easier to control compared to fluoborate. In addition, the fundamental purpose behind this case is that acid fluoborate electrolyte chemical cost is roughly twice that of acid sulfate per gallon. Electrodeposition of copper with acid solution have been used for electroplating, electrorefining, and electroforming. An exceptionally normal utilized of acid copper sulfate solutions in printed circuit boards and for semiconductor interconnect technology (Di Bari and George, 2000).

2.1.1 Factor Effecting Copper Plating

Formation of a copper deposit at the first stage relies on upon the substrate surface nature deposition technique, deposition rate, concentration of copper salts, additives, free acid, temperature, cathode current density, and degree of agitation strongly effect the characteristic of copper deposits. The growth of bulk copper continues in cycles of nucleation, agglomeration, and crystallization at the potential between - 60 and - 30 mV (Di Bari and George, 2000).

2.2 Fabrication of Flexible Printed Circuits

FPC assembly is very like the rigid 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.

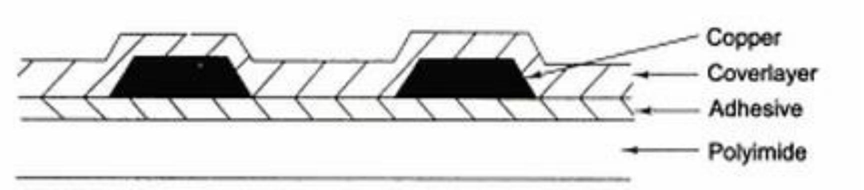

Figure 2.1: Constructional part of FPC (schematic view) (Khandpur, 2005).

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.

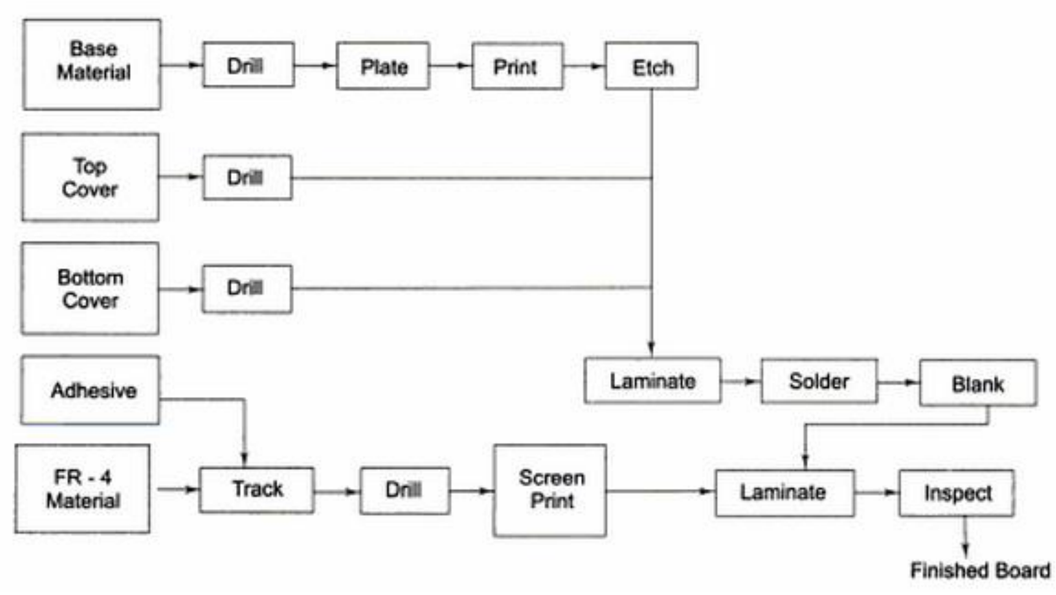

Figure 2.2: Continuous process of manufacturing flexible printed circuit board (Khandpur, 2005).

2.2.1 Films

The flexible printed circuits is consist of flexible laminate. The properties of laminate playing a big role and very important for both manufacturing process and performance of the finish product. There are two part in flexible laminate which is conducting foil part and dielectric substrates. Two categories of dielectric substrates that normally used for flexible printed circuits. First category is thermosetting which consist of polyimide, polyacrylate, etc. Second is thermoplastics which include materials, such as some types of polyester, fluorinated hydrocarbon, polymers, etc., which after curing, will soften by heat input. Copper foil have been commonly used as conducting path (base material) while virtually all flexible circuitry is built on polyimide or polyester film. There are a number of factors that influence the selection of particular film. Due to its excellent performance, polyimide are used in the manufacturing of high performance flexible circuit which is specially manufactured for military applications. For commercial used, a cost-sensitive circuits are manufactured using polyester films in which provide polyimide performance at a lower cost with reduce thermal resistance (Khandpur, 2005).

2.2.1.1 Polyimide

Due to its favorable electrical, thermal and chemical characteristics, polyimide film have been the most common film used in flexible circuits. Studies found that polyimide film can withstand the temperatures encountered in soldering operations and this film was found to be used in wire insulation and as insulation in transformers and motors. Besides, the ability to withstand the heat of manual and automatic soldering, excellent thermal resistance and have continuous use ratings approaching 300 ° C making polyimide film widely used in industry. At around 300 ° C, copper foils and solder joints will quickly destroyed through oxidation and inter-metallic growth. It is crucial to understand the influence of both adhesive and film properties while selecting a laminate, this is because, the behavior of the laminate is depends on the combined properties of adhesive and supporting film. Combination of polyimides which is inherently non-burning with specially compounded fire-retardant adhesives can produce laminates that can withstand high temperature. However, polyimide films are sensitive to moisture, it absorb a great deal of moisture. It must be keep for at least one hour at 100℃ or higher for single layer circuits and longer for multi-layer constructions and the laminate should be stored under dry conditions IF the process cannot be completed within an hour’s time. This is because the moisture is rapidly re-uptake (Khandpur, 2005).

2.2.1.2Adhesive

There are a few type of adhesive, acrylic adhesive, polyimides, epoxies, polyester and phenolics which commonly used in manufacturing of flexible printed circuit board. Acrylic adhesive is widely used in polyimide film substrate and have been used for dynamic flex applications due to its high heat resistance and good electrical properties. Nevertheless, for electronic packaging applications, there are limiting factors when using this type of adhesive which are thickness and high Z-axis expansion. Besides, polyimide substance also can be paired successfully with polyimides adhesive with better heat