EFFECT OF TEMPERATURE ON FLEXIBLE PRINTED CIRCUIT BOARD DURING REFLOW SOLDERING PROCESS

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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This thesis is the result of my own investigation, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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LIST OF ABBREVIATIONS

SMT	Surface Mounted Technology
SMD	Surface Mounted Device
PCB	Printed Circuit Board
RPCB	Rigid Printed Circuit Board
FPCB	Flexible Printed Circuit Board
FR	Flame Retardant
TPS	Transient Plane Source
BGA	Ball Grid Array
DSC	Differential Scanning Calorimeter
C_p	Specific heat capacity
D_s	Heat flow different
H_r	Heating rate
W_s	Weight of the sample
E	Ratio of the heat capacity of standard sapphire and measured heat capacity

ABSTRAK

Permintaan yang tinggi dari segi fleksibiliti, berat yang lebih ringan, saiz yang nipis dan produk electronik berkos rendah telah meningkatkan penggunaan Papan Litar Bercetak Elektronik Fleksibel (FPCB) mengatasi Papan Litar Bercetak Elektronik Tegar (RPCB). Tetapi, faktor haba memberi kesan yang ketara kepada FPCB semasa proses pematerian balik. Suhu proses pematerian balik menyebabkan FPCB mengalami ubah bentuk yang ketara dan tekanan haba yang tinggi berbanding dengan RPCB. Oleh itu, eksperimen ini bertujuan untuk mengkaji kesan suhu pada FPCB semasa proses pematerian balik. Ubah bentuk RPCB dan FPCB diukur dengan menggunakan Sensor Laser KEYENCE LK-G152 yang diletakkan di pintu masuk dan di keluar ketuhar pematerian balik. Dua profil suhu telah digunakan sebagai pemboleh ubah untuk eksperimen iaitu profil suhu secara rendam dan profil suhu secara meningkat. Hasilnya menunjukkan FPCB mempunyai ubah bentuk rendah dengan profil suhu jalan secara meningkat dan RPCB mempunyai ubah bentuk rendah dengan profil suhu secara merendam. Walau bagaimanapun, ubah bentuk FPCB lebih tinggi berbanding dengan RPCB untuk kedua-dua profil suhu. Perbezaan komposisi bahan FPCB dan RPCB menyebabkan FPCB and RPCB sesuai dengan profil suhu yang berbeza dengan ubah bentuk yang minima. Posisi komponen mempengaruhi ubah bentuk FPCB dan RPCB. Bagi kedua-dua FPCB dan RPCB, posisi komponen mengurangkan ubah bentuk disebabkan sudut pembasahan yang rendah dan berat komponen. Untuk sambungan logam pateri, FPCB mempunyai sudut pembasahan yang baik iaitu menunjukkan logam pateri melekat ke atas FPCB dengan baik. Walau bagaimanapun, beberapa sambungan logam pateri pada FPCB berbentuk tidak seragam kerana bentuk ubah bentuk yang tinggi. Oleh itu, adalah penting untuk mengkaji kesan suhu keatas FPCB semasa proses pematerian balik sebagai garis panduan kepada industri untuk pengeluaran besar-besaran produk FPCB.

ABSTRACT

High demands on flexibility, lighter weight, thinner size and low cost electronic product had increases the application of Flexible Printed Circuit Board (FPCB) over Rigid Printed Circuit Board (RPCB). However, thermal factor affects significantly on FPCB during reflow soldering process. Temperature of reflow soldering process cause FPCB to encounter significant deflection and thermal stress compared to the RPCB. Therefore, the present experiment aims to investigate the effect of temperature on FPCB during reflow soldering process. The deformation of RPCB and FPCB were measured by using KEYENCE LK-G152 laser sensor placed at the entrance and outlet of reflow oven. Two temperature profile were used as variable for the experiment which is soaking temperature profile and ramp temperature profile. The result shows FPCB had low deformation with ramp temperature profile while RPCB had low deformation with soaking temperature profile. However, the deformation of FPCB is higher compared to RPCB for both temperature profile. Different in material composition of FPCB and RPCB cause the RPCB and FPCB have different preferable temperature profile. The experiment also shows that component placements pattern influences the deformation of FPCB and RPCB. For both FPCB and RPCB, component placements reduce deformation due to low wetting angle and component weight. For solder joint, FPCB solder joint has good wetting angle (<90°) which is indicate good solder paste deposited on the FPCB. However, several solder joints on FPCB are irregular in shape due to high deformation. Therefore, it is important to study the effect of temperature on FPCB during reflow soldering process for industries guideline for mass production of FPCB products.

CHAPTER I

1. INTRODUCTION

1.1 Overview

The Flexible Printed Circuit Board (FPCB) has unique capabilities including reduced board thickness, added “twist” of flexibility and low cost electronic product has encourage people to research and development of FPCB to replace Rigid Printed Circuit Board (RPCB). FPCB has gain interest due it mechanical flexibility that can bend to certain extend and light weight because FPCB thickness is lower compared to RPCB [4], [9]. FPCB have been used in several applications such as mounted flow sensor on the FPCB for heat and flow detection and flexible wet sensor sheet to detect urination in diaper. FPCB exhibits higher sensitivity compared to sensor fabricated on RPCB [10], [11]. Samsung Electronics chose FPCB antennas to be used for the Galaxy S6. FPCB antennas performance is better compared to Laser Direct Structuring (LDS) antennas. LDS antennas have problems with electromagnetic interference in a metal and case space design. FPCB antennas is preferable due to do Shaped like a sticker, not adhere to ferrite sheets for electromagnetic shielding, smaller and cheaper to produce without any problem in product performance [1]. Researcher also has applied FPCB as personal computer motherboard to measure the durability and long term performance are primary concerns in the use of FPCB as motherboard [12]. Over the years, FPCB have been widely being study and to fulfil people demands. Figure 1.1 shown Flexible Printed Circuit Board (FPCB) antenna used in SAMSUNG Galaxy S6.

Figure 1.1: FPCB antenna used in SAMSUNG Galaxy S6 [1]

Reflow soldering process is ones of the production line processes of Surface mount technology (SMT). SMT is the main technology used to attach and connect surface mount devices permanently onto the Printed Circuit Board (PCB). There are 3 types of surface mounted component (SMC) attachment process on PCB which are wave soldering, reflow soldering and conductive adhesive curing. Reflow soldering is preferred due to higher yield and reliability. Surface mounted production line can be divided into several processes. Its consist of solder paste printing, component placement and soldering reflow process as shown in Figure 1.2. Solder paste printer will apply solder paste on the PCB using a stencil and squeegees. This is the most widely used method for applying solder paste. Most solder paste printing machines have the option of including automatic inspection, but it depends on the size of the PCB. This process can be time consuming and so a separate machine can often be preferred. Once the printed PCB has been confirmed to have the correct amount of solder paste applied, it moves into the next part of the manufacturing process which is component placement. Each component is picked from its packaging using either a vacuum or gripper nozzle. It checked by the vision system and programmed component placed in system at high speed. Once all component placements have been checked the PCB assembly moves into the reflow soldering machine where all the electrical solder connections are formed between the components and PCB by heating the assembly to a sufficient temperature. This would appear to be one of the less complicated parts of the assembly processes but the correct reflow profile is key to ensure acceptable solder joints without damaging the parts or assembly due to excessive heat.

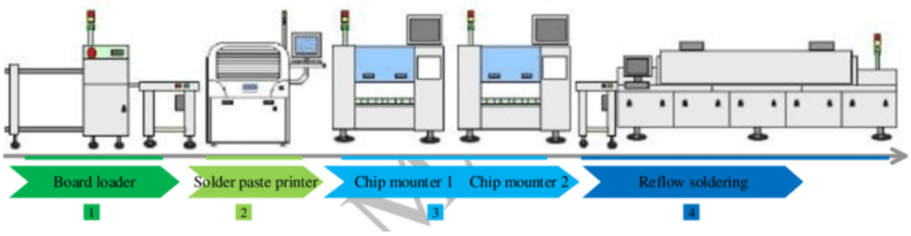
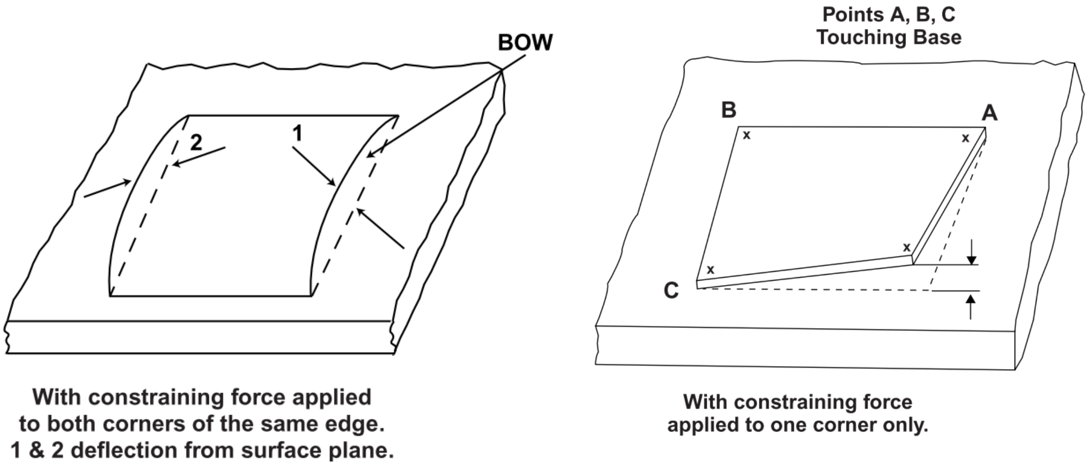


Figure 1.2: Surface mount technology production line [2]

Effect of temperature during reflow soldering process give a significant outcome on FPCB compared to RPCB due to different material composition and thickness [13]. The main concern reflow soldering process is the quality of solder joint. Proper control of temperature profile can minimize defect on FPCB or RPCB and improve solder joint quality. Sufficient heat must be provided during reflow soldering process to ensure the solder paste fully melt. When excessive heat was given, the RPCB and FPCB start to deform which is known as PCB warpage. Figure 1.3 shows common type of RPCB warpage [3]. Hence, study on thermal-mechanical characteristic of FPCB is the main concern. Various material testing had been carried out to study mechanical and thermal-mechanical properties of FPCB such as Hot Disk Thermal Analyzer test and Tensile Test [9] to measure the material properties of FPCB. The characteristic of FPCB when undergoing reflow soldering process also being inspected and studied based on certain factors.



a) Bow b) Twist

Figure 1.3: Type of RPCB warpage [3]

There are many factors that can affect the behaviour of FPCB. Flow of fluid and thermal distribution on FPCB during reflow soldering cause it to deform. The deformation occurred due to non-uniform heating and flow distribution cause thermal stress on FPCB. Lau et al. [9] had studied thermal effect and fluid flow on FPCB. The experiment were conducted in wind tunnel with BGA package on FPCB [9]. They were successfully conducted the experiment under control environment.

Material compositions of FPCB are different from RPCB. FPCB consist of single copper and single polyimide layer with thickness of 0.053mm [9]. Polyimide characteristic are lightweight, flexible, resistance to heat and chemical. Therefore, it was used as flexible cable in the laptop that connect the motherboard to the display. The main composition of RPCB are copper and FR-4 substrate. FR-4 is a grade for glassreinforced epoxy laminated material. It is a composite material that composed of woven fiberglass cloth with the epoxy resin binder that is flame resistant. FR-4 is a common material for printed circuit board (PCB). It popular due to versatile high pressure thermoset plastic laminate grade with good strength to weight ratio. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions [14], [15].

Reflow oven used in reflow soldering process is performed by using BTU Paragon 150 Convection Reflow Oven as shown in Figure 1.4. It designed to have 5842mm total length system, 1524mm total system width and 1524mm total system height. Each heating zone has 317.5mm in length for heating and 584mm for cooling zone. Each heating zone temperature is controllable and being as temperature profile [6]. Typical temperature profile can be divide into 4 stages which is preheating, soaking, reflow and cooling as shown in Figure 1.4. BTU Paragon 150 Convection Reflow Oven consists of ten heating zones and two cooling zones at the exit. Each zone consists of two heaters on both top and bottom equip with blower.

Figure 1.4: BTU Paragon 150 Convection Reflow Oven at PPKT MEKANIK, USM

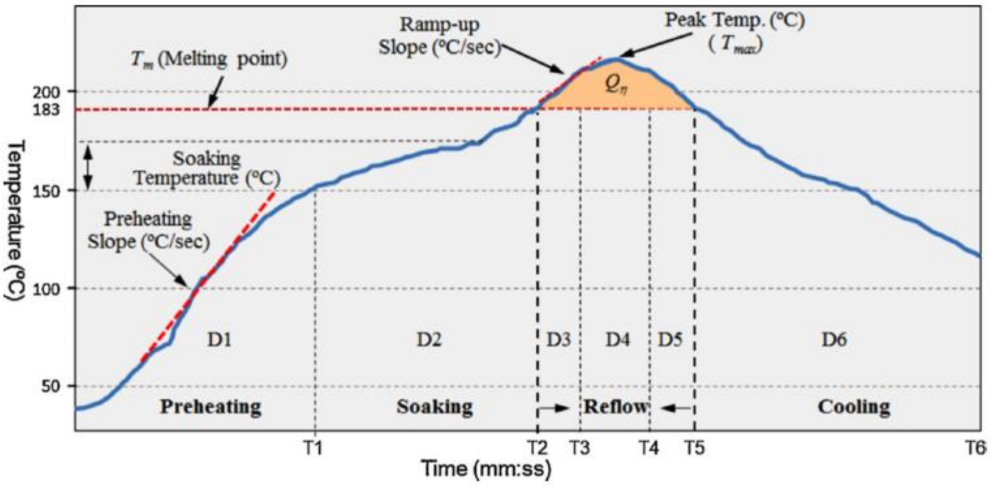


Figure 1.5: Typical reflow thermal profile Source: Tsai[4]

1.2 Problem Statement

The characteristic of RPCB have become limitation for modern electronic device. Hence, FPCB become as an alternative to RPCB that has better flexibility to absorb more stress and impact. Thermal stress in RPCB is very significant due to various materials used as a substrate. It caused the expansion of RPCB in different rate and lead to high stress between materials. Thermal stress in RPCB is dangerous especially at interconnection joints. Therefore, a lot of studies have been carried out on heat transfer on RPCB for electronic cooling. There are other issues regarding RPCB which is bending stress, mechanical shock impact and joint connection [16]. Therefore, FPCB becomes more popular nowadays as an alternative to RPCB [17].

Some researchers have studied on the effect of fluid flow on FPCB and thermal effect on FPCB with BGA packaging [18]. But is does not enough since the components also can limit the flexibility of FPCB. Furthermore, the components also can dislocate from the solder paste during reflow soldering. The study of fluid flow and thermal effect on FPCB is not enough to since its only being conducted in control environment. There are many factors that need to be considered when performing reflow soldering process by using reflow oven. Therefore, some experiments were planned to study the effect of temperature on FPCB in reflow oven which is a real condition environment when performing reflow soldering process.

1.3 Objectives

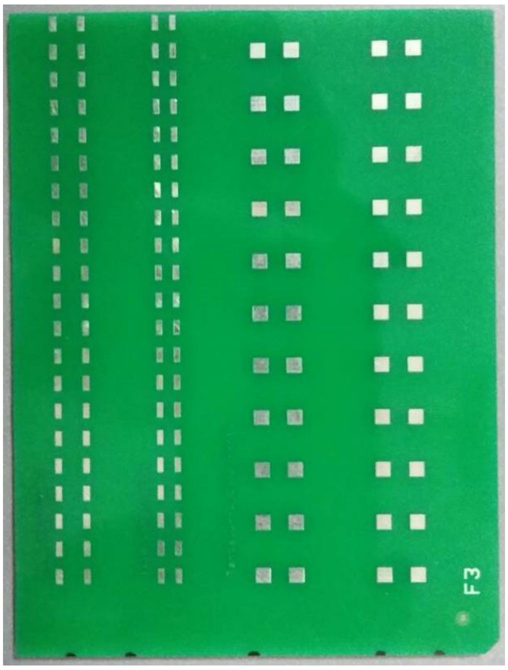
The objectives for the experiment are:

I. To study the effect of temperature on Flexible Printed Circuit Board Assembly.
II. To investigate the deflection of FPCB during reflow soldering process.
III. To analyse solder joint characteristic after reflow soldering process.

1.4 Scope of Project

The experiment will be performed using FPCB and RPCB to investigate the effect of temperature during reflow soldering process. The temperature profile characteristic is important because it affect the behaviour of FPCB and RPCB. Figure 1.6 shows sample of RPCB and FPCB with same width and length (83mm x 113mm) but different in thickness. The main priority for the temperature profile is to ensure the solder paste fully melt and solidify after reflow soldering process. Excessive heat can cause to warpage phenomenon in which the RPCB and FPCB had a deformation. Non-sufficient heat also can cause the solder joint defects. Non-uniform heat on FPCB and RPCB lead to thermal stress and deflection occur. Material composition also can affect the deformation of RPCB and FPCB. RPCB consists of copper layer and FR-4 material. Deflection occurred due to different heat coefficient between the material. FPCB consist of single copper and single polyimide layers with thickness of 0.053mm. Polyimide as lower glass transition temperature compared to copper. Hence, it affects the behaviour of FPCB since the polyimide start to become soft and rubbery structure once it passes glass transition temperature.

The deflection of FPCB and RPCB were measured by KEYENCE LK-G152 laser sensor that connected to a controller with an accuracy of 0.0001mm. The lasers were placed on inlet and outlet of BTU Paragon 150 Convection Reflow Oven. It measured deflection of RPCB and FPCB before and after reflow soldering process. This experiment also was conducted to study the best temperature profile for FPCB for industries uses. Develop suitable method to operate FPCB using reflow soldering process for the mass production in the future.



a) RPCB b) FPCB

Figure 1.6: RPCB and FPCB samples with same width and length (83mm x 113mm) but different in material composition and thickness.

CHAPTER II

2. LITERATURE REVIEW

2.1 RPCB and FPCB Dimension

FPCB used consist of single layer copper and single layer polyimide. Lim et al. [1] used 120mm x 120 mm x 0.053mm (Lx H x W) for his experiment to measure the effect of airflow on FPCB. On the FPCB, he mounts ball grid array (BGA) package at the centre of FPCB and run it in wind tunnel. For the simulation, he defined the fluid domain with dimensions of 213.5mm x 213.5mm x 610mm (L x H x W) which is imitate the wind tunnel test section in ANSYS with control boundary and limit condition [9], [13]. They found that well control on air flow and thermal effect can reduce major deflection and stress on FPCB. Leong et al. used FPCB with dimension 190mm x 204mm x 0.053 (L x H x W) as a motherboard. They also attach motherboard components such as CPU fan, heat sink, memory, PCI connector and USB connector. The FPCB motherboard was test in wind tunnel with adjustable fan speed. They found that the deformation of FPCB depends on components configuration and air flow direction [12].

2.2 FPCB Thermal and Material Properties Testing

Lim et al. [1] had conducted several materials testing on FPCB. They perform hot disk thermal analyser to find thermal conductivity and specific heat of FPCB. Hot Disk Thermal Analyser TPS 2500 had been used by using Transient Plane Source technique (TPS) [7]–[9]. During the measurement, the TPS sensor was placed in between of FPCB layers. The density of FPCB was obtained using weighing scale AUW220D with an accuracy of 0.1mg to measure the mass of FPCB. The FPCB mass obtained was divided by its own volume to obtain density. Young’s Modulus and yield strength of FPCB were obtained by using INSTRON 3367 Universal Testing Machine. Result was obtained with 95% confident level [9].

2.3 Reflow Oven Temperature Profile

Temperature profile is a temperature-time graph which is used to control the thermal mass and heat distribution on PCB to form robust solder joints between the RPCB and electronics components during reflow soldering. An inhomogeneous temperature distribution for a reflow thermal profile can cause various soldering defects, which can lead to significant productivity loss and lower product reliability. Briggs et al. [5] studied two typical temperature profile which is ramp temperature profile (Figure 2.1) and soaking temperature profile (Figure 2.2). Both temperature profile exhibit different behaviour on RPCB. However, both temperature profile must follow melting temperature of solder paste. They find that soaking temperature profile cause higher deformation into RPCB due to thermal stress compared to ramp temperature profile [5].

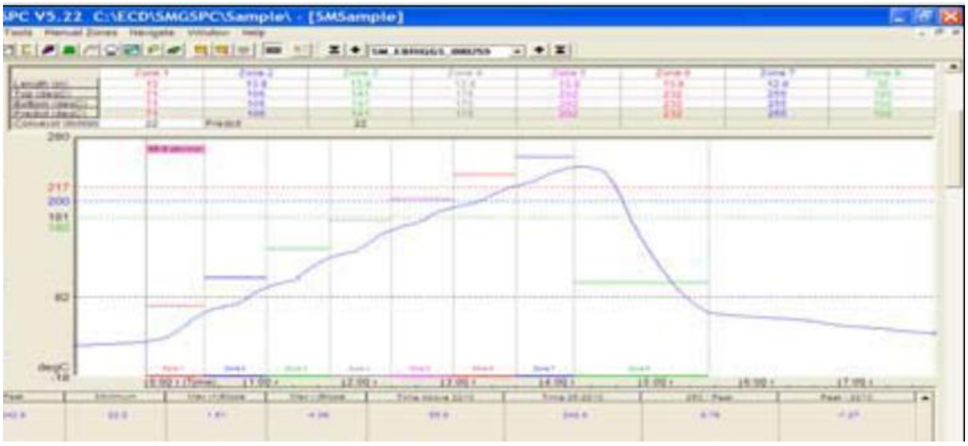


Figure 2.1: Ramp temperature profile [5]

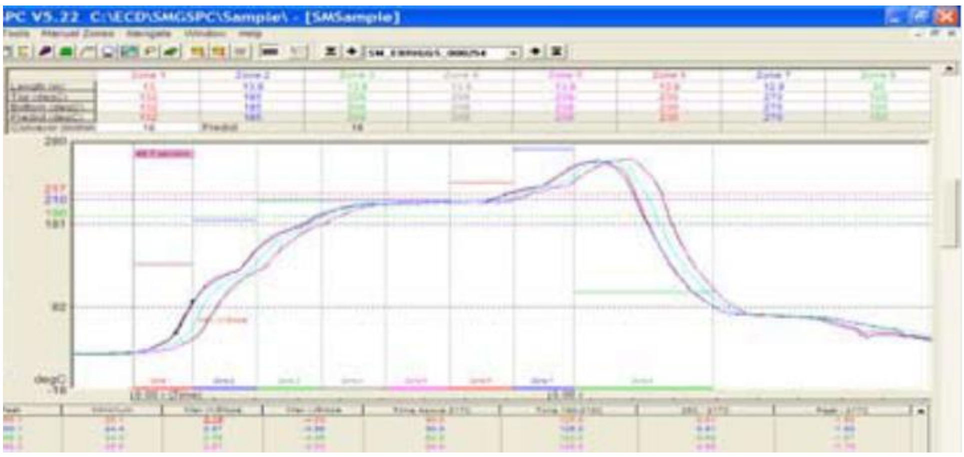


Figure 2.2: Soaking temperature profile [5]

2.4 BTU Paragon 150 Convection Reflow Oven

Figure 2.3 shows schematic diagram of BTU Paragon 150 Convection Reflow Oven used consist 10 heating zones and 2 cooling zones with maximum temperature of 350°C. It designed to have 5842mm total length system, 1524mm total system width and 1524mm total system height. Each zone has 317.5mm in length for heating and 584mm for cooling zone. Heating is performed by forced impingement convection with side to side gas recirculation. Forced convection is provided by a blower system. Each zone used BTU's Porcupine II heating element due to high reliability, high surface area open coil wire arrangement for fast response time and low mass. The temperature, conveyor speed and blower speed are adjustable using computer interface. Proper control of these parameter can produce good solder joint and minimum warpage on RPCB and FPCB. Figure 2.4 shows blower system configuration in BTU Paragon 150 Convection Reflow Oven. Cooling zones is accomplished by forced convection cooled by water heat exchangers. Figure 2.5 and Figure 2.6 shows heat exchanger and cooling zones of BTU Paragon 150 Convection Reflow Oven [6].

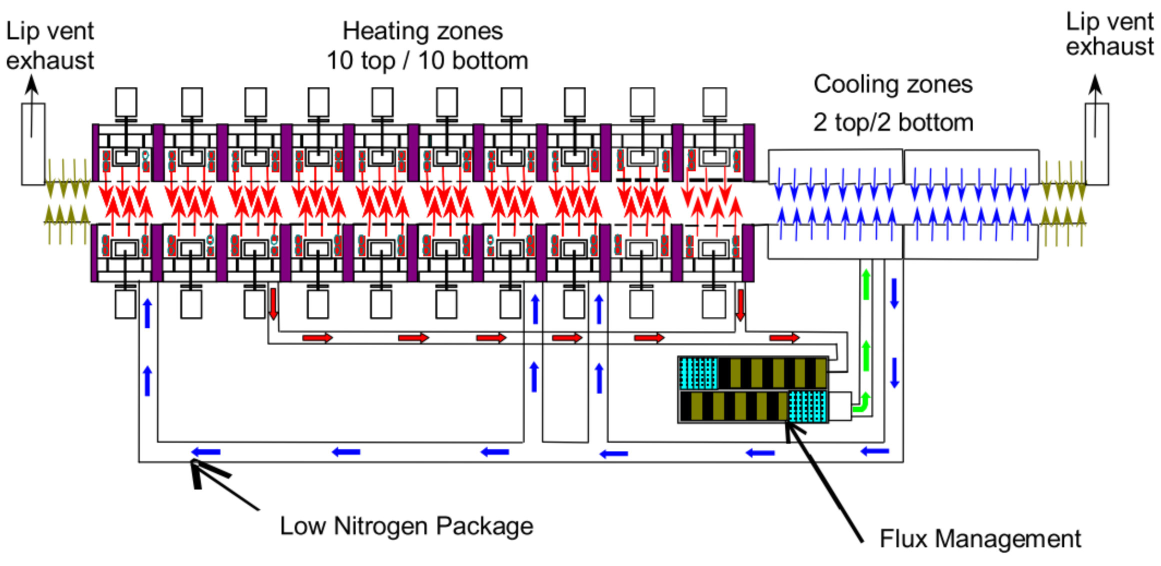


Figure 2.3: Schematic diagram of BTU Paragon 150 Convection Reflow Oven [6]

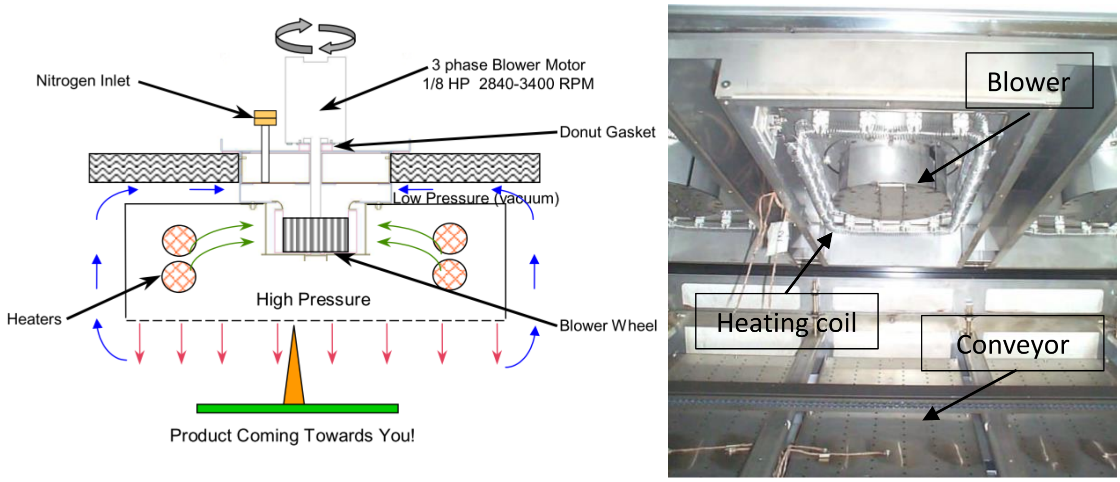


Figure 2.4: Blower system in BTU Paragon 150 Convection Reflow Oven [6]

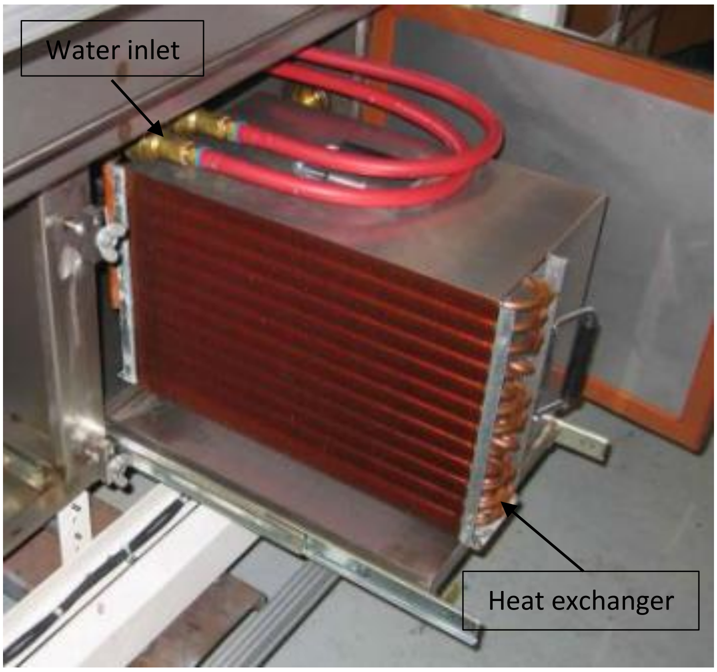


Figure 2.5: Water heat exchanger of BTU Paragon 150 Convection Reflow Oven [6]

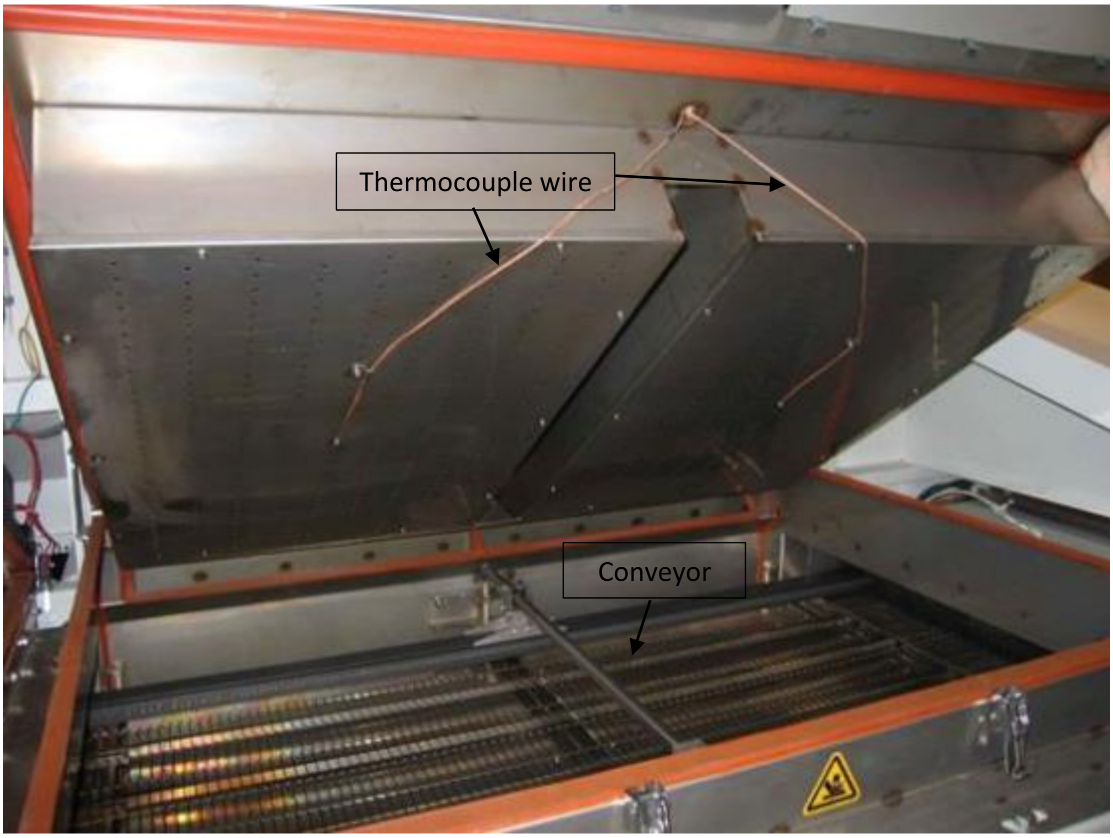


Figure 2.6: Cooling zone of BTU Paragon 150 Convection Reflow Oven [6]

2.5 Solder Joint Behaviours and Defects

Gao et al. [18] had optimized the reflow profiles to achieved high reliability of solder joints based on the heating factor by defect mechanism analysis. However, these methods involve many experiments which are costly. Study on solder paste behaviour during reflow soldering process will help manufacturing industry significantly. Many researcher, had worked on thermal analysis of component assemblies during reflow soldering process using numerical analysis and computer simulation. Tavarez and Gonzalez [18] studied of the thermal behaviour of a solder deposition pad on top of a multi-layer printed circuit board (PCB). The solder deposition pad was modelled using a multi-mode heat transfer numerical formulation and solved by finite different method (FDM) [18]. Khader et al. [19] study the amount of solder paste during stencil printing process. To prevent solder joint failures, it is very important to control the amount of solder paste and the solder paste must perfectly deposit to targeted location. Short and excessive deposition lead to various printing defects such as shifting, slumping, bridges and incompleteness. Solder paste failures also affected by squeegee speed and pressure, solder paste composition and stencil design [19]. Defects also cause due to thermal stress on solder paste. Thermal stress developed due to abrupt temperature change [20]. For typical reflow oven temperature profile, the temperature change is drastic from room temperature up to 250°C and cooling process right after solder paste melting phase.

2.6 Experiment Setup

Lim et al. [9] used KEYENCE LK-G152 laser sensor were used to measure the deformation of FPCB in wind tunnel. The laser sensor was connected to controller with 1μm accuracy to study the effect of fluid flow on FPCB deflection. Their finding was the higher the flow velocity, the higher the deflection of FPCB [9]. Temperature on the FPCB during the reflow process will be measured by SlimKIC thermal profiler. The profiler will move with the FPCB on conveyor. Thermocouple wire will be attached to specific location of FPCB to measure heat distribution. Reflow oven used consist of 10 sections of 2 section for cooling for BTU Paragon 150 convection flow oven[18], [21]. Leong et al. [22] used motherboard electronic components position as variable to their research to study fluid-structure interaction. CPU fan, heat sink and input/output connector were mounted on FPCB with different configuration to study the deformation of FPCB. The configuration of electronic component significantly affects the deformation of FPCB due to fluid movement [22]. Chien et al. [23] measured the warpage effect on PCB by applying strain gauge on the PCB to study the different level of thermal expansion of PCB composite structures consisting of FR-4, solder mask and copper. From their finding, this method yields inaccurate warpage data because strain gauges can only be used to measure relatively small strain ranges. Strain gauge to generate accurate curvatures when used over large strain ranges or for PCB samples with heterogeneous materials. Strain gauges also were easily affected by disturbances resulting from temperature changes or vibrations. As a result, inaccurate curvatures when used for measuring bare PCB warpage during reflow at a high temperature. The proposed strain gauge technique can be applied to measure the thermal deformation of PCB only in non-vibrating and stationary environments [23], [24], [25].

CHAPTER III

3. METHODOLOGY

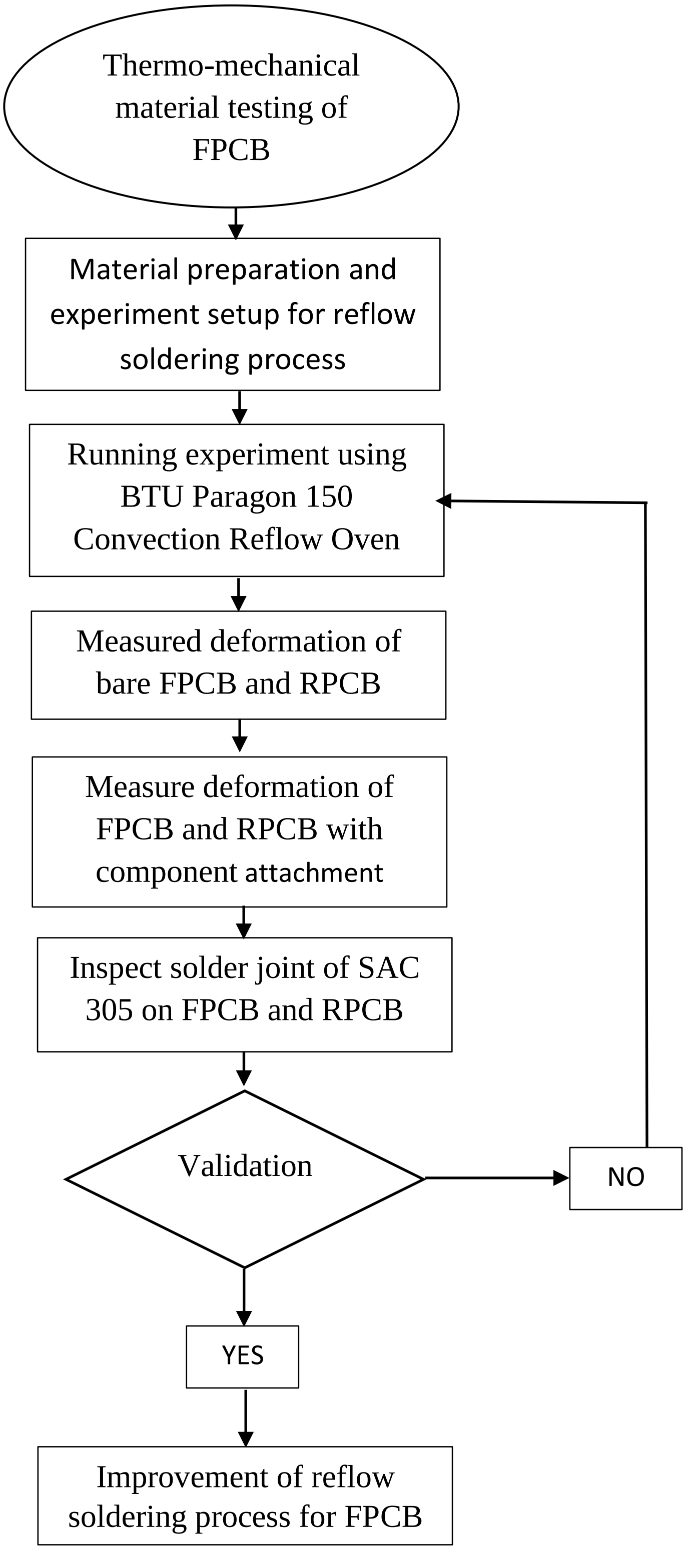


Figure 3.1: Experimental flow chart

3.1 FPCB Mechanical and Thermal Material Test

For this experiment, single side FPCB is used that consist of single copper and single polyimide layers in total and it overall thickness is 0.053mm. The density of FPCB was obtained by using Shimadzu Weighing Scale AUW220D with an accuracy of 0.1mg. the mass of FPCB is measured and divided by its own volume.

Tensile test was conducted by using INSTRON 3367 Universal Testing Machine to obtain Young's Modulus and yield strength. The FPCB was tested at speed 0.25 mm/min based on ISO 527-3. Three sample had been tested with three sample were cuts from FPCB.

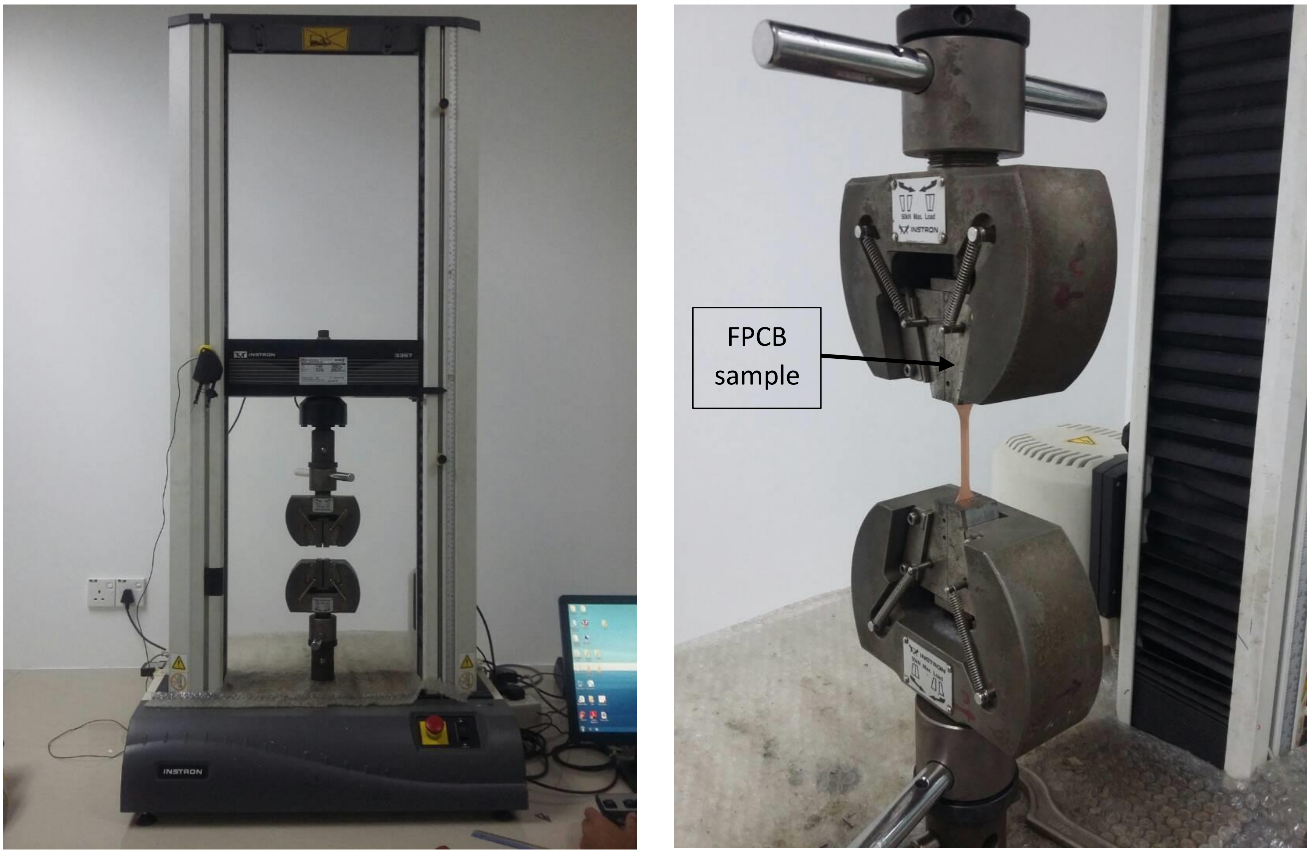


Figure 3.2: INSTRON 3367 Universal Testing

Figure 3.3: Die cutter of specimen

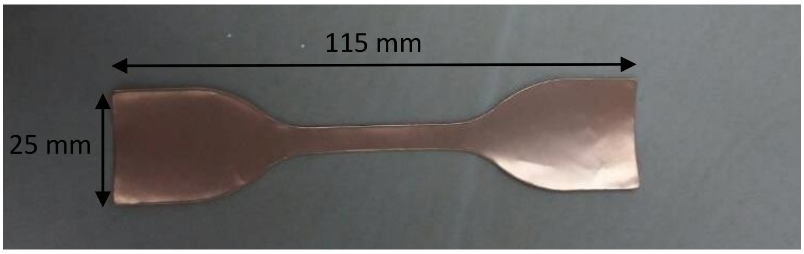


Figure 3.4: FPCB sample for testing

The thermal conductivity and specific heat of FPCB were obtained by using Hot Disk Thermal Constant Analyser TPS 2500 S. ISO 222007-2 was used which is employed Transient Plane Source Technique that applicable to thin film testing. The hot disk sensor was placed in between of two FPCB as shown . The thermal conductivity was measured at 23℃. The sample were cut in square shape with dimension of 5cm x 5cm. It sufficient since the diameter of the hot disk is about 3cm for thin film testing.

Figure 3.5: Thermal Constant Analyzer TPS 2500 S

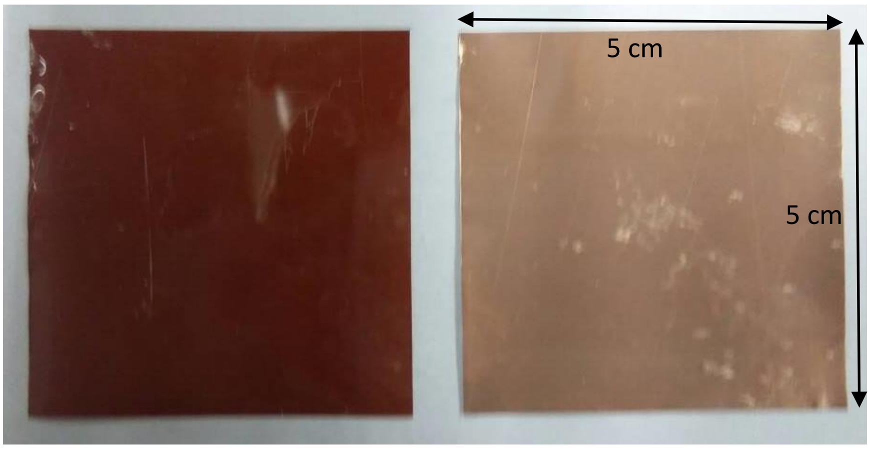


Figure 3.6: FPCB sample (5cm x 5cm)

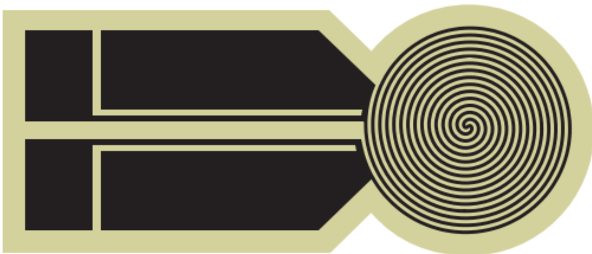


Figure 3.7: TPS sensor used in Hot Disk Thermal Analyser TPS 2500 [7]

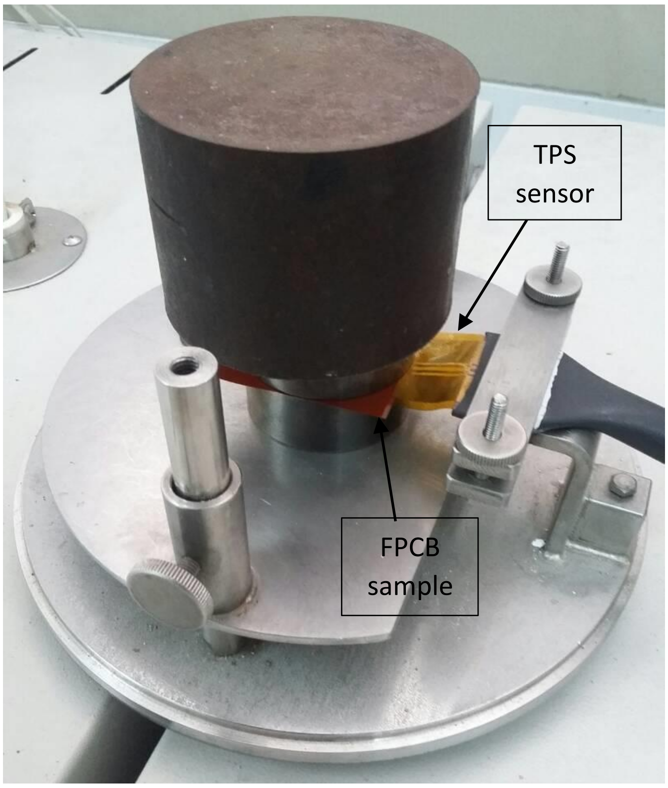


Figure 3.8: Experimental setup of FPCB sample using Hot Disk Thermal Constant Analyser TPS 2500 S

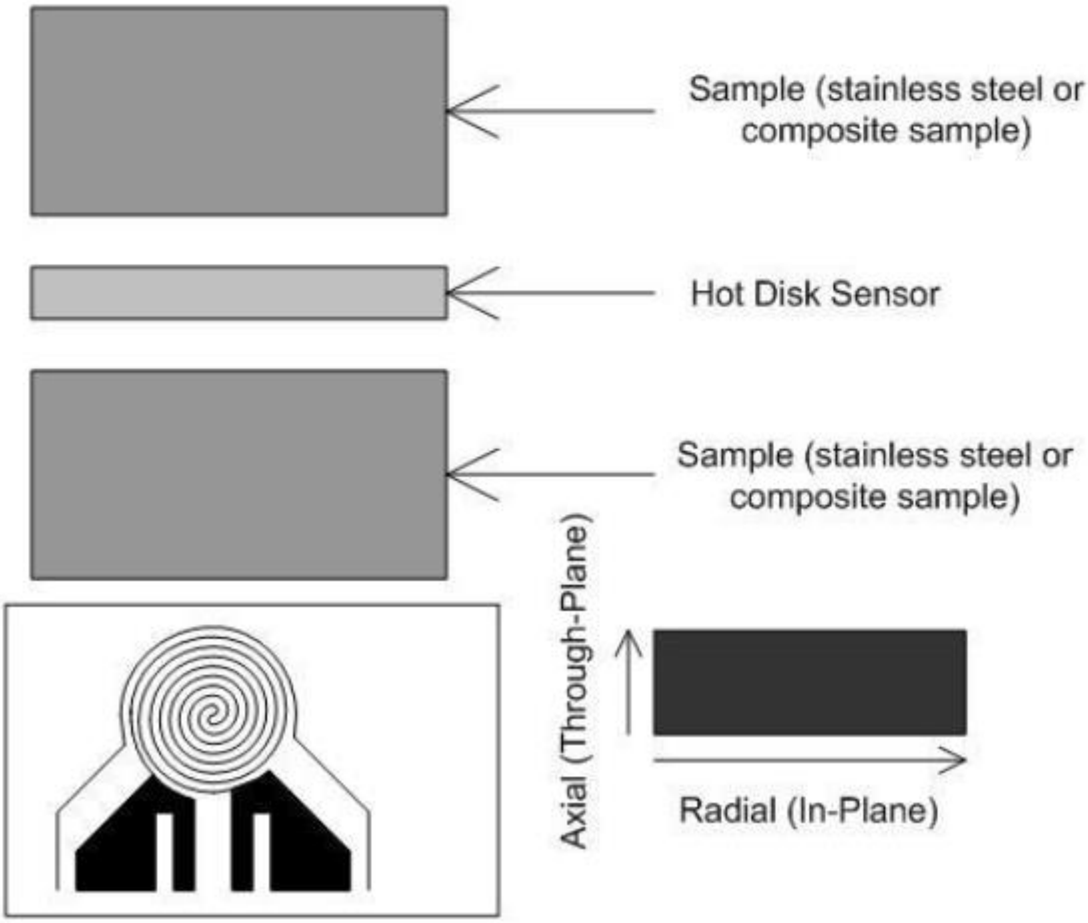


Figure 3.9: Schematic of Samples and Sensor for the Hot Disk The insert at the lower left shows the double spiral heating element [8]

Specific heat capacity was obtained by using Differential Scanning Calorimeter (DSC). FPCB, RPCB and solder paste were prepared about 5-10mg by using Shimadzu analytical balance AUW220D with an accuracy of 0.1mg. Then, the samples were place into an aluminium Tzero pan. The heating rate for the test is 20°C/min and the samples were heated from 30°C to 300°C. The DSC experiment were conducted using argon with mass flow rate setting of 50mL/min.

To determine specific heat capacity, empty aluminium Tzero pan was run and set as baseline. Next, the sapphire crimp pan was conducted as standard. Finally, the sample between 5-10mg was placed into the aluminium Tzero pan. From the heat flow temperature curve of baseline, sapphire and sample are used to calculate specific heat capacity at desire temperature. The specific heat capacity (C_p) of the samples were calculate by using the following equation.

$$C_p = \frac{60.D_s}{H_r.W_s}.E \quad eq.3.1 \quad [26]$$

Where:

C_p = Specific heat capacity

D_s = Heat flow different

H_r = Heating rate

W_s = Weight of the sample

E = Ratio of the heat capacity of standard sapphire and measured heat capacity

Figure 3.10: DSC equipment in USM, TA DSC Q2

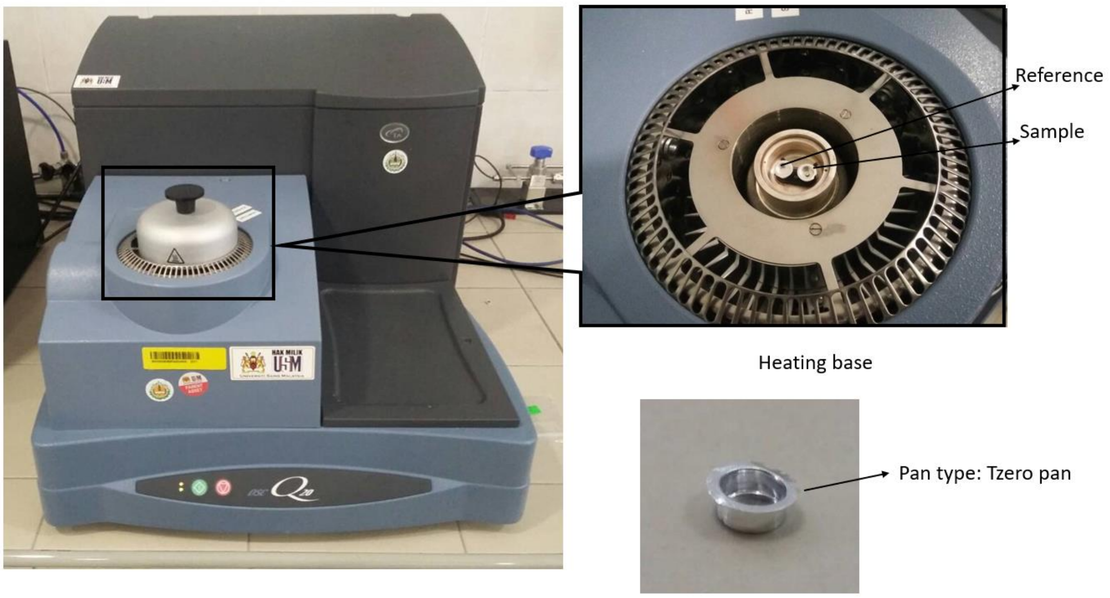


Figure 3.11: DSC experiment setup

3.2 Deformation Measurement of RPCB and FPCB Experimental Setup

This experiment used KEYENCE LK-G152 laser sensor. The sensor was connected to controller with 1μm accuracy with read range of 11-18cm. It was installed at the inlet and outlet of reflow oven to measure the deformation before and after reflow soldering process due to warpage phenomenon. The sensor is hold by magnetic stand and were placed on non-vibrating part to reduce measurement error.

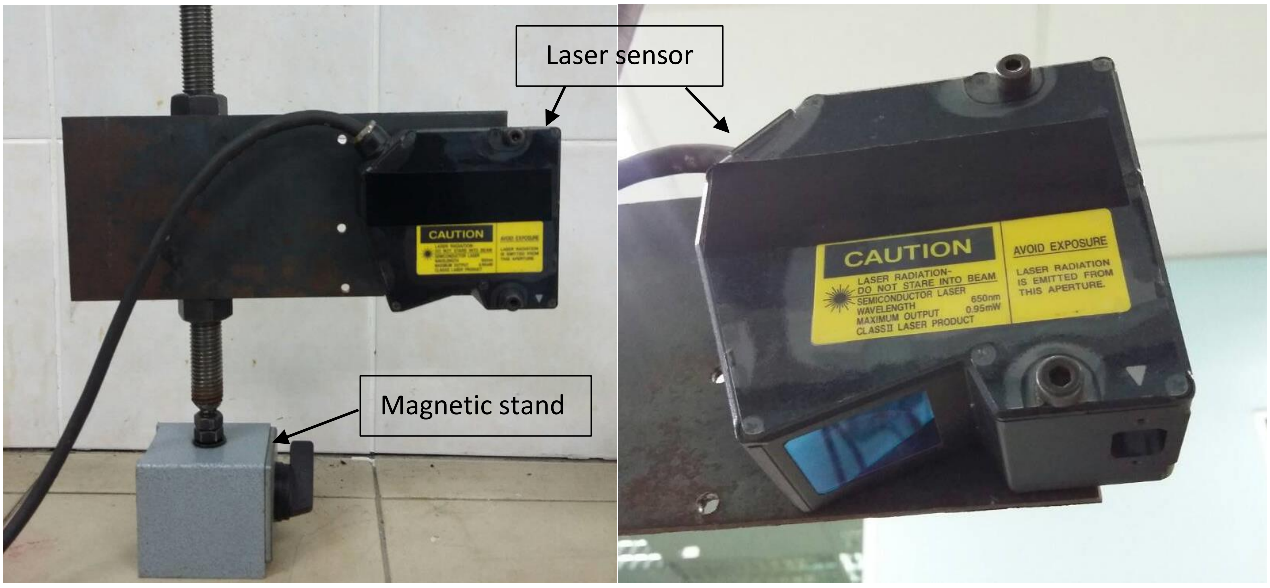


Figure 3.12: KEYENCE LK-G152 laser sensor

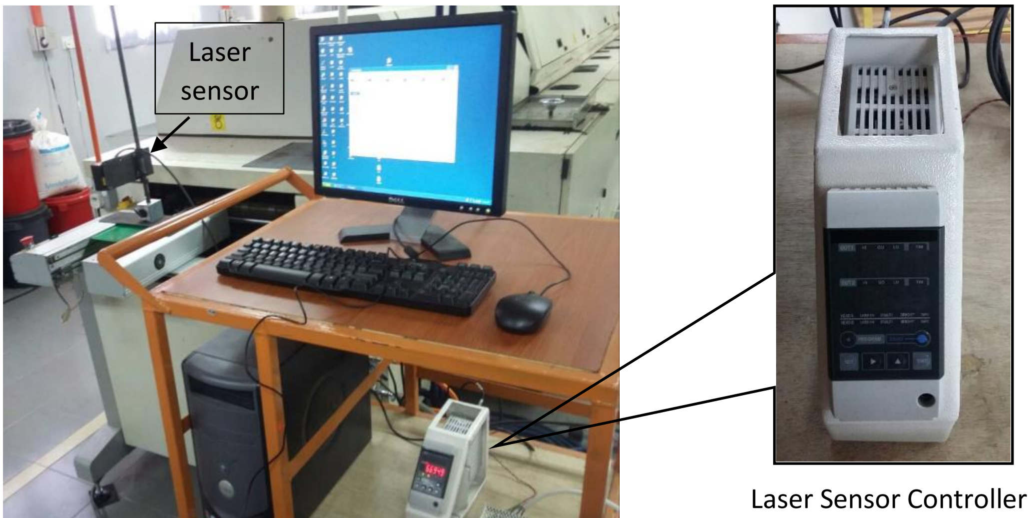


Figure 3.13: KEYENCE LK-G152 laser sensor connected with controller at the reflow oven outlet

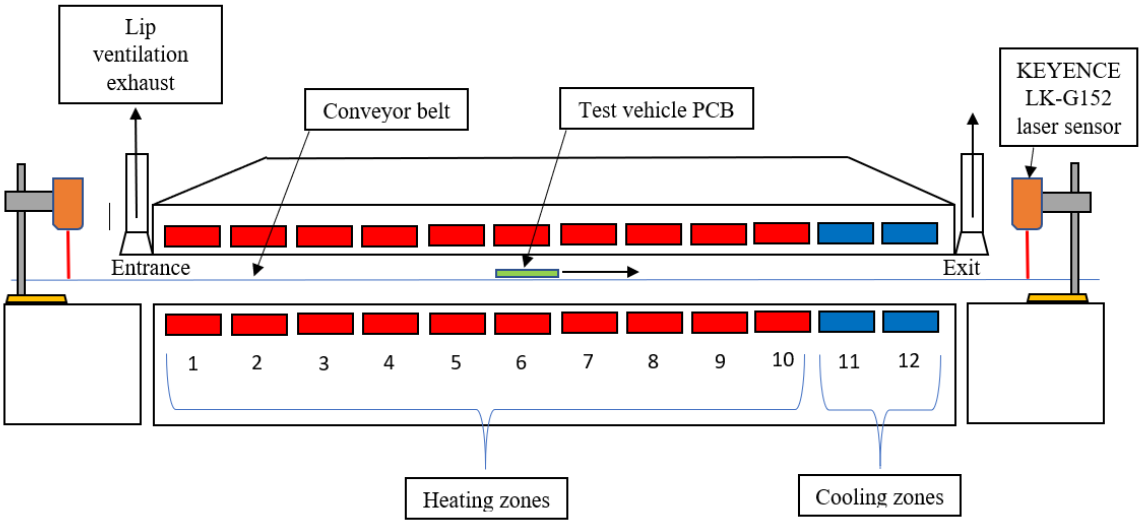


Figure 3.14: Schematic diagram of BTU Paragon 150 Convection Reflow Oven and KEYENCE LK-G152 laser sensor setup

Temperature profile and other setting were set at the computer connected with the BTU Paragon 150 Convection Reflow Oven. For the experiment, two type of temperature profile are used as comparison for better control of RPCB and FPCB deformation during reflow soldering process. Soaking and Slumping temperature profile are shown in Table 3.1 and Table 3.2. Figure 3.14 and Figure 3.15 shows temperature profile over time for the reflow soldering process. The conveyor speed was set as 30 inch/min. After that, the test vehicle was placed on the reflow oven entrance conveyor to start the experiment. The laser sensor will measure the deformation of RPCB and FPCB at outlet and the quality of solder joints were inspected and recorded.

Table 3.1: Soaking temperature profile

Soaking Temperature Profile		
Temperature Zone Name	Temperature	Time (second)
Heating zone 1	100	30
Heating zone 2	150	60
Heating zone 3	160	90
Heating zone 4	170	120
Heating zone 5	180	150
Heating zone 6	195	180
Heating zone 7	210	210
Heating zone 8	225	240
Heating zone 9	240	270
Heating zone 10	255	300
Cooling zone 1	30	350
Cooling zone 2	30	400

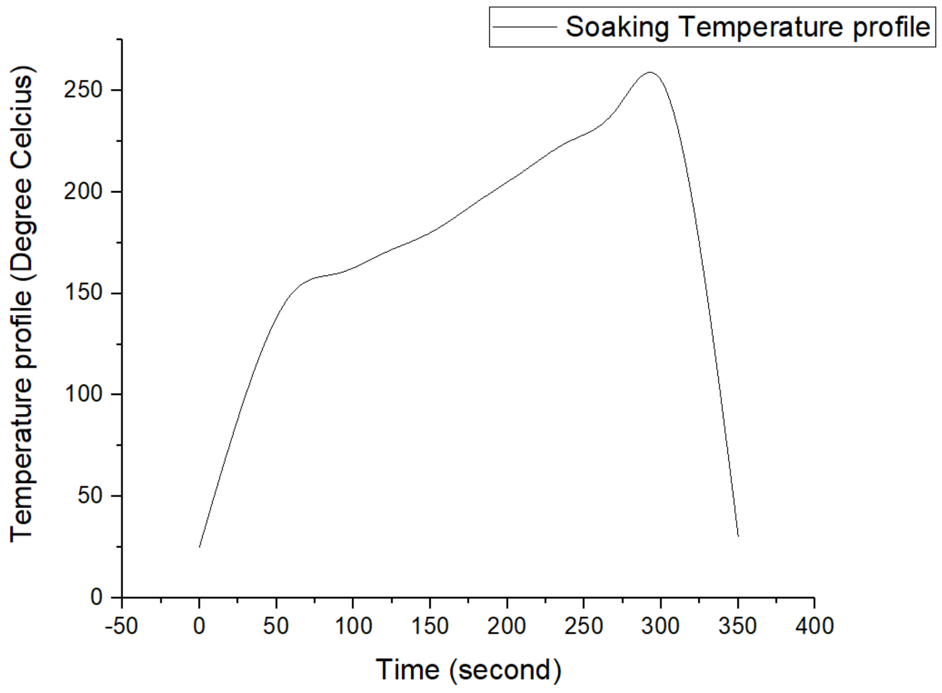


Figure 3.15: Graph of soaking temperature profile over time

Table 3.2: Ramp temperature profile

Ramp Temperature Profile		
Temperature Zone Name	Temperature	Time (second)
Heating zone 1	100	30
Heating zone 2	120	60
Heating zone 3	140	90
Heating zone 4	160	120
Heating zone 5	180	150
Heating zone 6	200	180
Heating zone 7	220	210
Heating zone 8	235	240
Heating zone 9	255	270
Heating zone 10	255	300
Cooling zone 1	30	350
Cooling zone 2	30	400

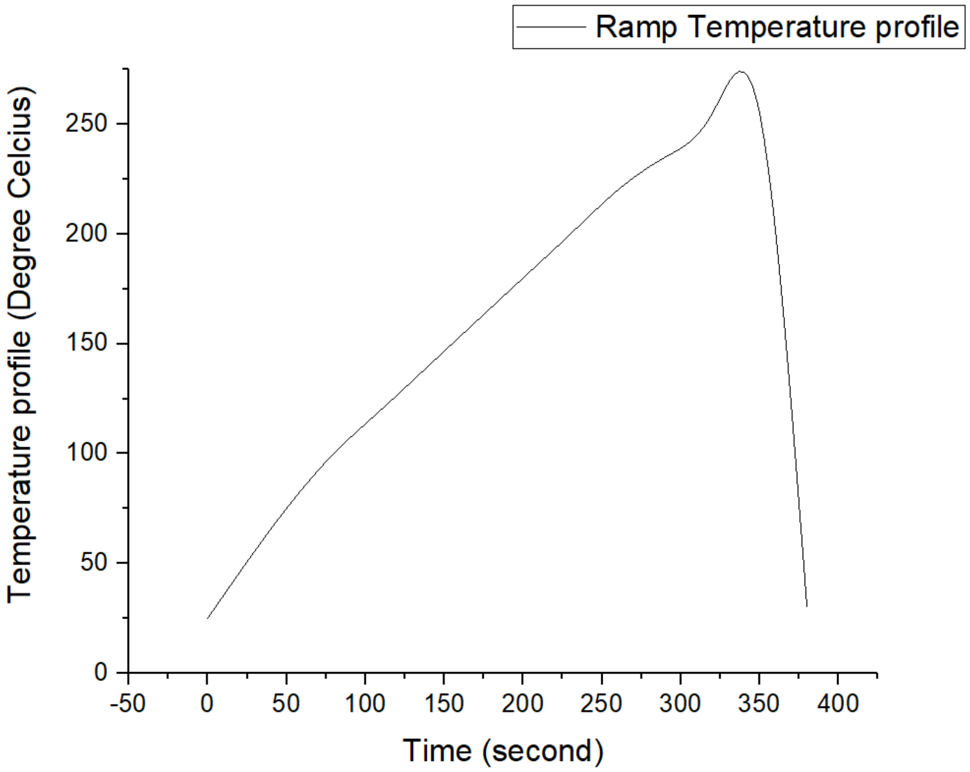


Figure 3.16: Graph of ramp temperature profile over time

3.3 Component Layout Setup for Component Placement on FPCB and RPCB

The components were placed on RPCB and FPCB with specific pattern to study the contribution of components placements on FPCB and RPCB deformation. There are three design of component placements which is Layout 1, Layout 2 and Layout 3 as shown in Table 3.3. Each Layout had different component placements configuration. Ramp temperature profile is use for this experiment because ramp temperature profile gives minimum deformation on FPCB. FPCB result for Layout 1 is compared with RPCB. Solder paste $Sn_{3.0}Ag_{0.5}Cu$ or SAC 305 was used in this experiment and capacitor used represent surface mount devices (SMDs). SAC 305 is selected compared to SAC 105 and SAC 405 because it is widely used for packaging electronic components. The solder printing process was performed manually by aligned stencil on the RPCB and FPCB test vehicle. When the stencil was properly aligned, the solder paste was fill by using squeeze at angle 60°. After solder printing, the diodes were placed on the RPCB and FPCB test vehicle by using forceps onto the solder paste properly.

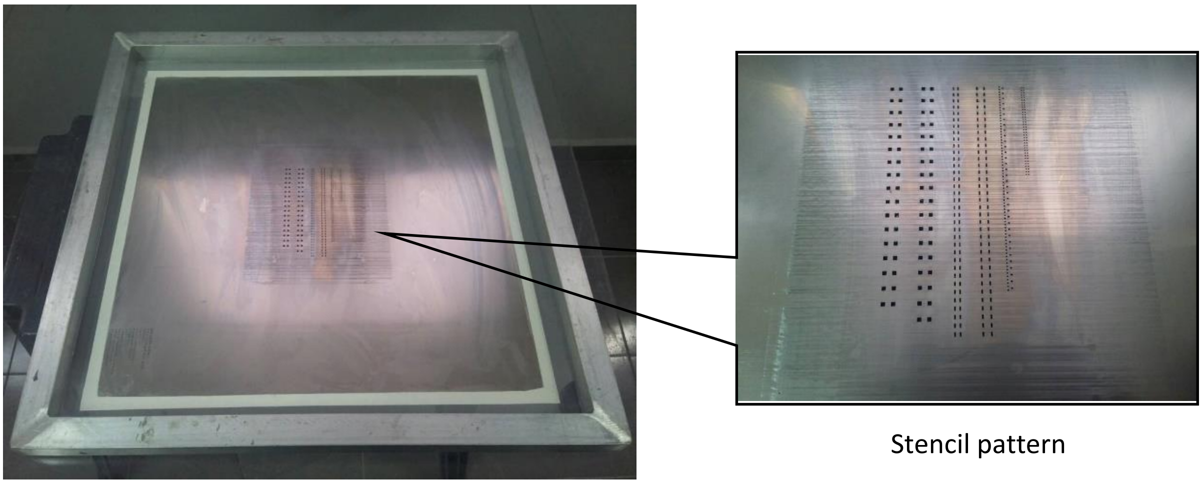


Figure 3.17: Stencil used in the solder printing process

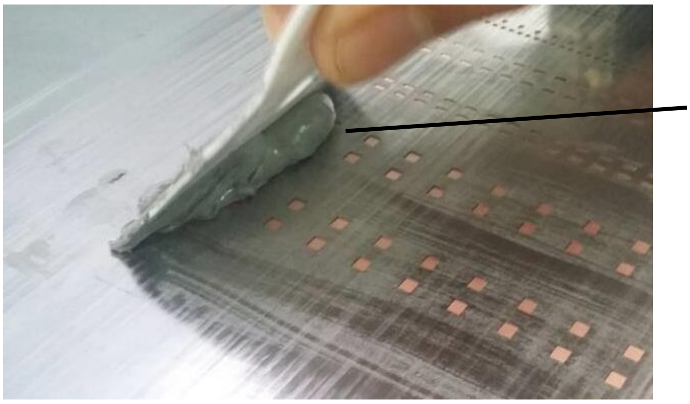


Figure 3.18: Solder paste being push by squeezes at 60°

Figure 3.19: Solder paste used in the experiment (SAC 305)