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LabVIEW Simulation for Electroplating Process of Plated-Through Hole (PTH) in Multilayer Printed Circuit Board (PCB)

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Abstract. Plated-through hole (PTH) is essential part which it connects one layer to other layers in multilayer printed circuit board (PCB). PTH is commonly made by electroplating process with copper as based conductive material. This research objective to simulate the electroplating process in which mass of copper generated using LabVIEW which it is used together with Faraday's law of electrolysis. The simulation using LabVIEW software and experiment are applied in this study. The simulation and the calculation results of copper mass on the PCB and PTH surfaces were displayed in LabVIEW interface. On the other hand, the experiment is also conducted to form PTH and determine the mass of copper experimentally on the PCB and PTH surfaces. The experiment results showed that PTH was successfully formed in multilayer PCB with electroplating process. The results of copper mass adhered in multilayer PCB in which they were obtained from LabVIEW simulation or calculation are not much different with the copper masses obtained experimentally. The copper masses obtained from experiment tend smaller than the calculation.

1. Introduction

Electroplating is one of the hardest surface adjustment technologies for pre-treatment product. Besides used in electrochemical impedance of lithium battery [1], electrochemical reaction and electric current are applied in this electroplating for making metal coatings. The coating materials frequently used in electroplating are silver, gold, tin, zinc, cadmium, copper, nickel, chromium, and so on [2]. Electroplating is widely used in electronics, aerospace, automotive [3], microelectronic mechanic system (MEMS) technology [4,5,6] and engineering industries. This electroplating has many advantages such as corrosion prevention, aesthetic finishes, coating component [3], lower resistivity, better anti-electromigration ability, and higher thermal exchange rate [7].

The electroplating results that consist of surface smooth, copper grain, and resistivity are affected by many parameters such as electric field distribution, electric current density, temperature and stirring style [8,9]. In copper electroplating, the most dominant factor is the current density because the electrodepositing speed and the grain size are decided by the current density [10]. The copper electroplating is commonly used in printed circuit board (PCB) manufacturing [11,12]. The double layer and multilayer PCB need the electroplating process to make the conductive surface in plated-through hole (PTH) [12].

In order to learn more about the electroplating process in multilayer PCB, the simulation of electroplating process is needed. In this study, LabVIEW simulation is utilized to learn the electroplating process in multilayer PCB. LabVIEW is applied together with Faraday's law of electrolysis.

2. LabVIEW Simulation

LabVIEW programs are also called virtual instruments. A LabVIEW virtual instrument consists of a front panel, a block diagram, and a connector pane. A front panel is considered as a user interface. In front panel, the user can insert the inputs (sliders, knobs, values entered from the keyboard, push buttons, selector switches) and the outputs (indicators, LEDs, graphs, strip charts, sounds) [13].

A block diagram is considered as a LabVIEW program. Block diagrams integrate terminals, subVIs, functions, constants, structures, and wires, which transfer data among other block diagram objects. Furthermore, a connector panel is a set of terminals on the icon that corresponds to the controls and indicators of a VI, similar to the parameter list of a function call in text-based programming languages [13]. In this research, LabVIEW is applied together with Faraday's law of electrolysis as in equation (1) [3].

$$m = \frac{A}{n} \frac{I\,t}{96500} \tag{1}$$

Where *m*, *A*, *n*, *I*, *t*, and 96500 are mass of deposited material (gram), atomic weight of deposited material, valency of deposited material, applied current (Ampere), time (s), and Faraday's constant (Coloumb/gram), respectively [3].

3. Experimental procedure

The copper mass adhering on printed circuit board (PCB) and plated-through hole (PTH) surface is also determined with the experiment. The experiment was conducted through some steps such as desiging PTH in PCB, preparing material, pressing the FR-4 material, drilling, brushing, cleaning, immersing in the conductive carbon solution, drying, electroplating process, cleaning, drying, and measuring the copper mass.

The prepared material was FR-4 PCB material, distilled water, conductive carbon solution (black hole solution), and copper (II) sulfate pentahydrate ($CuSO_4.5H_2O$, meltex). The first step made a PCB stack from three FR-4 PCB materials using glue as adhesive and pressing them to make PCB with four layers. The pressing process was conducted at 12 bar with temperature 170 ^oC for 30 minutes. The second step was the drilling process which it works following the PCB design. The PCB design was created using Altium (PCB design software). The third step was brushing and cleaning. The distilled water was used during brushing and cleaning. The fourth step is immersing the PCB surface in the conductive carbon solution (black hole solution) for 5 minutes and drying at 80 ^oC for 10 minutes. The fifth step is the electroplating process. Before the electroplating process is running, the multilayer PCB was weighed with the scale (Kern FCB bench scale). The electroplating process was conducted for three PCB, but the applied current were different for each PCB in which the applied currents were 15 A, 20 A, and 25 A. Each electroplating process needed 45 minutes. Cleaning and drying of PCB were done after the electroplating process was finished. The last step is weighing the copper mass adhering on the PCB and PTH surfaces.

4. Results and discussion

LabVIEW software is applied to simulate how to work electrochemically the electroplating process. It simulates the movement of copper ion in copper(II) sulfate ($CuSO_4$) solution when the electrodes are given the current. On the other hand, LabVIEW also calculates the copper mass that adhering on the PCB and PTH surfaces. The equation (1) is applied in this calculation.

LabVIEW interface displays the table of input data (current, time, copper mass), the simulation of copper ionic movement, and the graph. The graph exhibits the relation between the applied current and the copper mass. The front panel also displays other parameters such as atomic weight of deposited material, valency of deposited material, and button for 'play' and 'stop' as shown in figure 1.

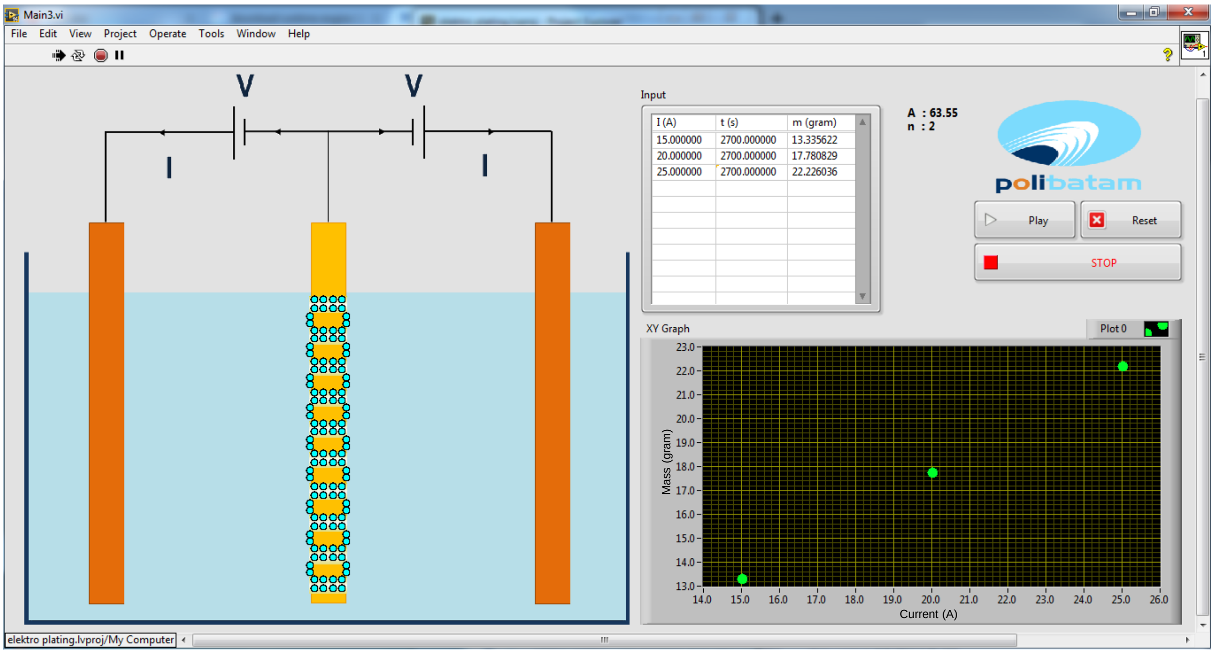


Figure 1. Interface of LabVIEW virtual instrument for electroplating simulation.

LabVIEW software utilizes the graphical program language placed in the diagram block. The program receives the input data from the front panel such as parameter data, 'play' button, 'stop' button, etc. All program used in electroplating simulation and calculation of copper mass are placed in the diagram block as shown in figure 2 and subprogram for the calculation of copper mass during simulation of electroplating process as shown in figure 3.

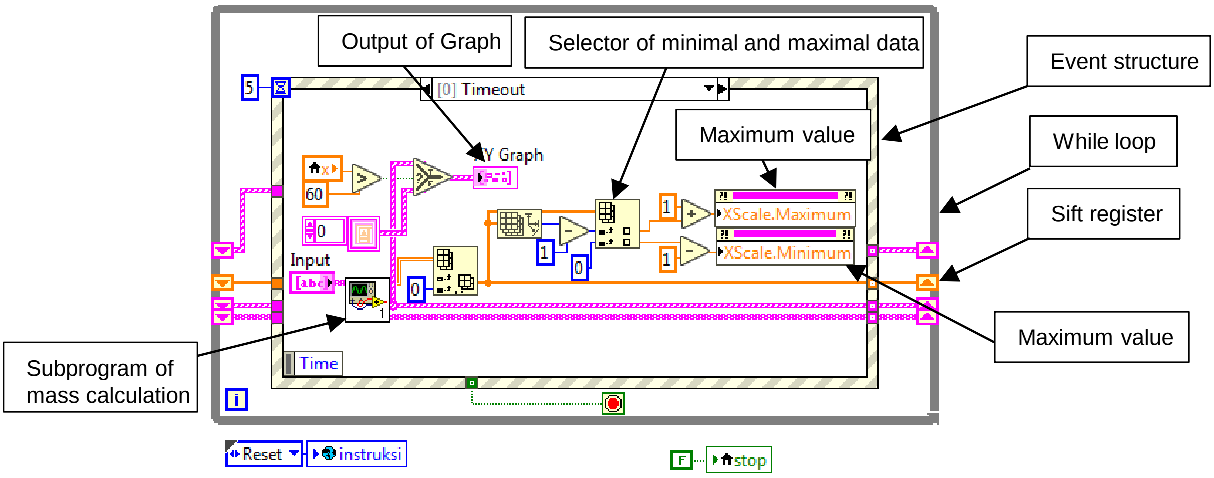


Figure 2. Block diagram of LabVIEW virtual instrument.

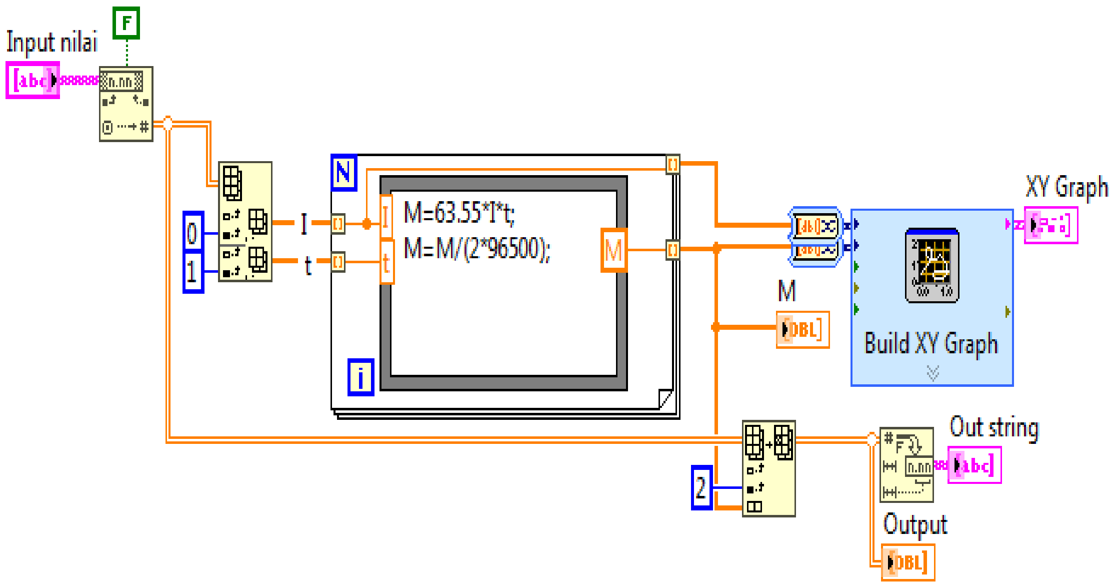
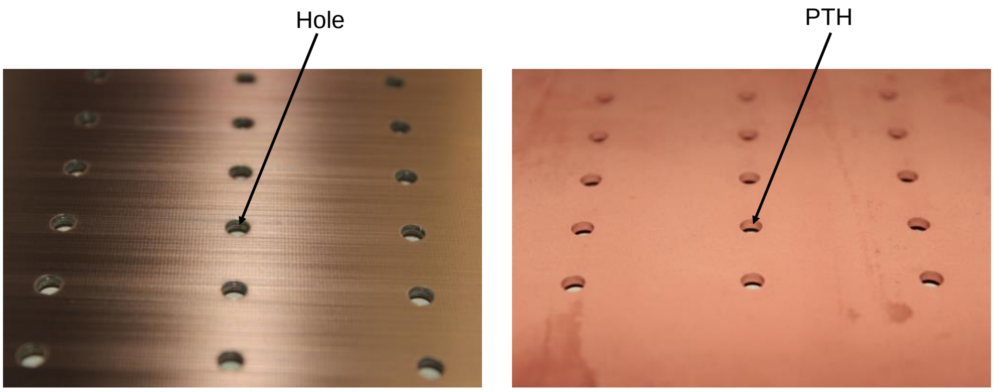


Figure 3. Subprogram for the calculation of copper mass during simulation of electroplating process.

The calculation results of copper atomic masses adhering on the PCB and PTH surfaces using the equation (1) are 13.3 gram, 17.8 gram, and 22.2 gram for the applied current 15 A, 20 A, and 25 A, respectively. Besides calculation, the copper masses are also obtained experimentally. The copper masses are obtained from difference between the PCB mass before and after the electroplating process. Multilayer PCB before and after the electroplating process are shown in figure 4.



(a) (b)

Figure 4. Multilayer PCB (a) before and (b) after the electroplating process.

The calculation results are slightly different with the experiment results. The experiment results showed that the copper masses on the PCB and PTH surfaces are 13 gram, 16 gram, and 20 gram for the applied current 15 A, 20 A, and 25 A, respectively. There are slightly different between calculation results and experiment results for copper mass as shown in figure 5. The different results for the copper masses are possibly caused by impurity of $CuSO_4$ solution and the current difference in amperemeter and the real current.

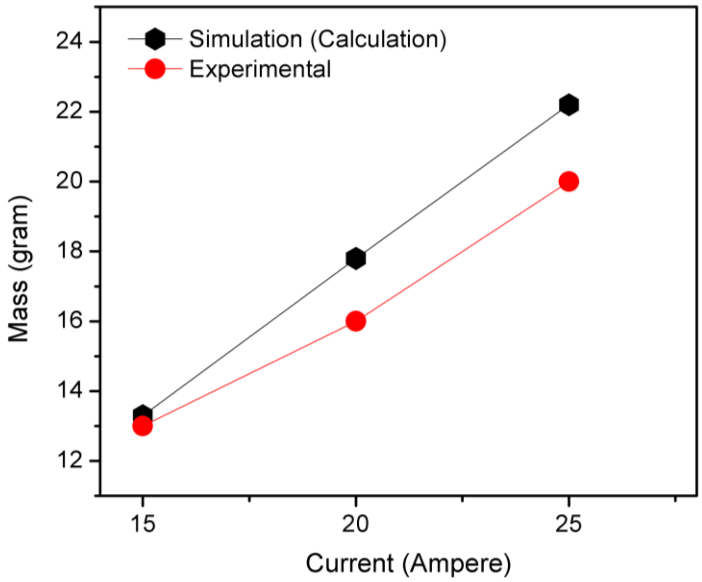


Figure 5. The copper masses obtained from calculation and experiment.

5. Conclusion

In this study, the simulation of electroplating process in multilayer printed circuit board (PCB) was successfully created by LabVIEW software. The calculation results for copper mass adhering on the PTH and PCB surfaces are 13.3 g, 17.8 g, and 22.2 g with the applied current 15 A, 20 A, and 25 A, respectively. Furthermore, the experiment results exhibit that the copper masses are 13 g, 16 g, and 20 g for the applied current 15 A, 20 A, and 25 A, respectively. The results of copper mass adhered in multilayer PCB obtained from LabVIEW simulation or calculation is not much different with the mass of copper obtained experimentally.

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