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DRY FILM PHOTORESIST APPLICATION TO A PRINTED CIRCUIT BOARD (PCB) USING A MASKLESS PHOTOLITHOGRAPHY METHOD

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ABSTRACT

This paper offers an alternative method of making PCB routing using a negative dry film photoresist and a maskless photolithography method. The objective of this research is to determine the correct parameters for the process of making PCB design easier, cheaper and safer. Electronic circuit design was created on a laptop or PC using Autodesk EAGLE software with a combination of result is black and blue light color. PCB routing design was inserted into a PowerPoint slide to display on a commercial Digital Light Processing (DLP) projector. No modifications were made to a projector, which was mounted directly on a stand with a downward facing position. The projector lamp replaced an ultraviolet or X-ray source during the exposure process, exposing PCB coated in negative dry film photoresist. After the exposure process, the PCB was inserted into the developer solution, causing the blue light irradiated part to remain while the blackened sections dissolved. The PCB was then added to an etching solution to scrape the copper unprotected by the photoresist. The PCB was finally soaked in a remover solution to remove the photoresist. Once complete, the process generated a laptop-designed PCB routing. Electrical lines can be created using this method with a size of 100 µm and a lane edge deviation of 5 µm. The goal of research to make PCB routing cheaper, easier and safer was achieved. Evidenced by the installation of electronic components and then tested, the results are all components function well.

Keywords: Dry film photoresist; Lithography; Maskless; Maskless lithography; PCB

1. INTRODUCTION

The manufacture of PCB routing can be performed manually. That is, drawing electrical paths directly on a PCB using a permanent marker, and then placing the board into an etchant solution. The advantages of such methods are its ease and inexpensive nature, but it cannot be used to create identical profiles in large quantities, and the resulting lines are significantly rough. In the transfer method (mold removal), PCB paper is printed with a laser printer then ironed onto a PCB, transferring the electric line profile to the board before being inserted into an enchanting solution. The transfer method can make identical paths and more complicated profile shapes than the manual process. However, its disadvantages include broken lines that must be connected with a permanent marker and PCB line size that remains significantly rough.

PCB laser printer technology can erode a PCB with a laser beam (Triano & Collins, 2013;

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Alwaidh et al., 2014), which allows complicated and smooth profiles to be generated. Yet, such work takes a long time, requires expensive machines and tools, and is inherently dangerous due to laser beam utilization. A PCB milling method mechanically scrapes the PCB (Seo et al., 2011; Ḃaez et al., 2012) to create complicated profiles with matching repetitive quality. The disadvantage of the milling method is that the pattern is rough, takes a long time, is expensive, the tool breaks easily.

The most widely used, and still developing, the method is lithography, which is distinguished by its use of light sources. Specifically, ultraviolet (UV) lithography (Bertsch et al., 1999; Hirai et al., 2006) uses UV rays to produce micro profiles and X-ray lithography (Romanato et al., 2004; Nazmov, 2015; Zhao et al., 2017) uses X-ray beams capable of producing nanoscale profiles. Although lithography can provide high-quality products quickly, it is significantly expensive and dangerous. Of the several existing methods, each with its challenges in PCB routing creation, there is not yet a method capable of producing complicated paths with small and smooth profiles at a low cost while maintaining easy and safe manufacture.

Some method improvements have been made by replacing UV light and X-rays with visible projector light and maskless lithography method (Rajan et al., 2013). The exposure process described by Rajan et al. (2013) was sourced from a DLP projector. However, the projector required modification and an added stereo microscope, making it less than straightforward and preventing this method from being applied to copper or a PCB.

Modifying maskless lithography with Digital Mirror Device (DMD), the use of mercury lamp light has been performed successfully (Zhong et al., 2014). The modifications produced maskless real-time results with no alignment errors as well as time and cost savings. Despite this, the method is not simple and rendering it not yet inapplicable to copper or PCB.

The maskless photolithography method was then modified further by using an unmodified commercial DLP projector (Suwandi et al., 2014), and was successfully applied to copper by using bacteria Acidithiobacillus ferrooxidans NBRC 14262 as a scraper (a form of biomachining). This process produced a path profile with the smallest size of 180 μm and 26 μm deviations. The weakness of the method was that the erosion process took a long time (2–3 days). A DLP projector was also used in a seedless-electroplating process with maskless lithography replacing the *Lithographie, Galvanoformung, Abformung* (LIGA) process (Whulanza et al., 2015), and this process successfully deposited nickel onto a silicon wafer.

This paper will attempt to improve the visible light maskless photolithography method by replacing a negative tone photoresist with a negative dry film photoresist. This replacement will eliminate some processes, such as pre-baking and spin coating, making the process more straightforward. Then, the copper etching process before using bacteria was replaced with liquid etching so that it was faster.

2. MASKLESS PHOTOLITHOGRAPHY METHOD

Visible light maskless photolithography is a modification of the lithography method. Generally, lithography uses UV light or X-Ray beams, while this method employs a DLP projector-beam connected to a laptop or PC. The mold masking pattern is replaced with design patterns created directly on the laptop, a maskless method.

The maskless photolithography scheme is illustrated in Figure 1. The profile on the laptop (1) will be emitted by the DLP projector (2). Rays from the computer are then focused on the lens under the projector (3), with the focus obtained by adjusting the distance from projector-lens (a) and the distance between the lens and the PCB (b). The focused beam will thus expose the photoresist attached to the PCB (4). Focusing the projector's beam is done by adjusting the keystone (5) and zoom (6).

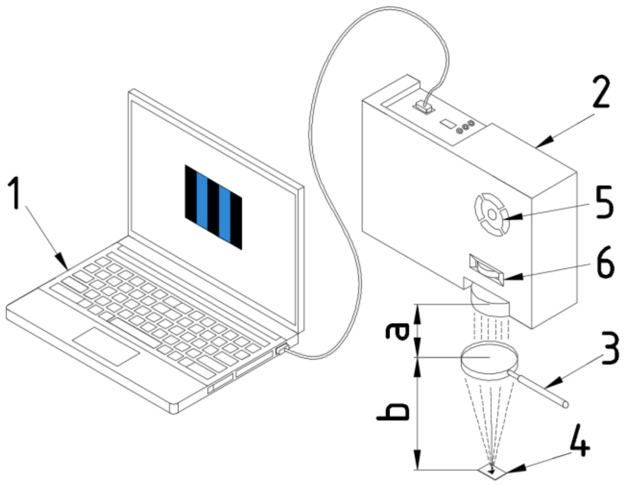


Figure 1 Maskless photolithography scheme

The step by step process for making this PCB routing is illustrated in Figure 2. A Single-side PCB has two layers of substrate and copper (a). At the top of the PCB attached a negative photoresist (b). The exposure process occurs because the photoresist is very sensitive to light. The negative photoresist exposed to the light's blue color will react, while the exposed black color will not respond (c). In the developing process, the photoresist affected by the bright blue color will remain attached to the PCB, while the photoresist affected by the black color will be dissolved by the developer solution (d). The PCB will then be incorporated into an etchant solution to scrape copper on the PCB, which is not protected by photoresists (e). After the PCB routing is formed, there are still photoresists attached to the routing. The final process of the PCB is incorporated into the removal solution to destroy the photoresist (f).

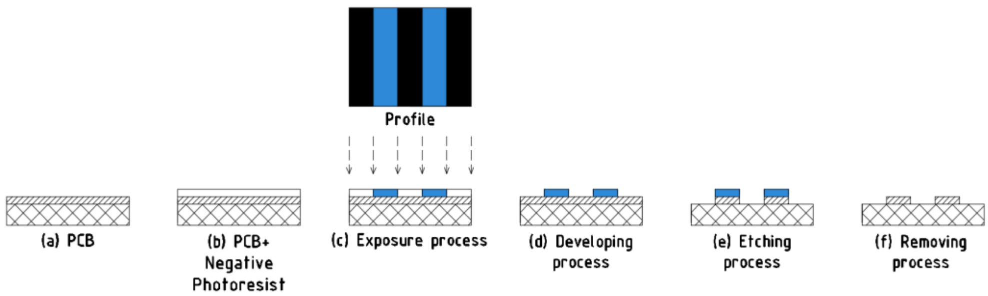


Figure 2 Step-by-step process of PCB routing creation

2.1. Preparation

A single-sided PCB fiber of 3×4 cm was cut, polished with Autosol metal polish, and washed with alcohol 70%. The negative dry film photoresist, DuPont T215 (DuPont, 1997), is affixed to the top surface of the PCB. The DLP projector used was an InFocus IN114A (InFocus, 2014) with the following specifications: XGA resolution (1024×768); 3,200 lumens; contrast ratio 15,000:1. The projector was an unmodified commercial model, mounted on a stand facing downwards. A 3× magnification lens (Figure1 no.3) was mounted 3.5 cm under the projector (fig.1 sec. a) and 10 cm from the base (Figure 1 sec. b), to focus its beam. The projector's image is further focused by adjusting the Keystone and zoom.

The method used to put the lens is still using a manual. This uncertainty included the setting of the projector's distance to the lens and the distance from the lens to the PCB to determine the focus of the image. The accuracy of using this method depended on the operator's eyesight focus.

2.2. Developing Time without Exposure

The dry film photoresist required dissolution in a developer solution (water and sodium carbonate, ratio = 100 ml : 1 gram) to set a base time. A 3×4 cm PCB was cut and weighed to determine its weight without photoresist. The measurement confirmed an average weight of approximately 3.191 grams ± 0.05. The PCB was then coated with negative dry film photoresist and weighed again, obtaining an average weight of about 3.247 grams ± 0.05. A reduction between the weight of the PCB with photoresist and the initial PCB weight equaled the weight of the photoresist attached to PCB, an average weight of about 0.055 grams ± 0.03. The PCB with photoresist was then inserted into the developer solution. Upon each interval of one minute, the PCB was weighed to determine the percentage of the developing process that had been completed. The results of this developing time without exposure are shown in Figure 3.

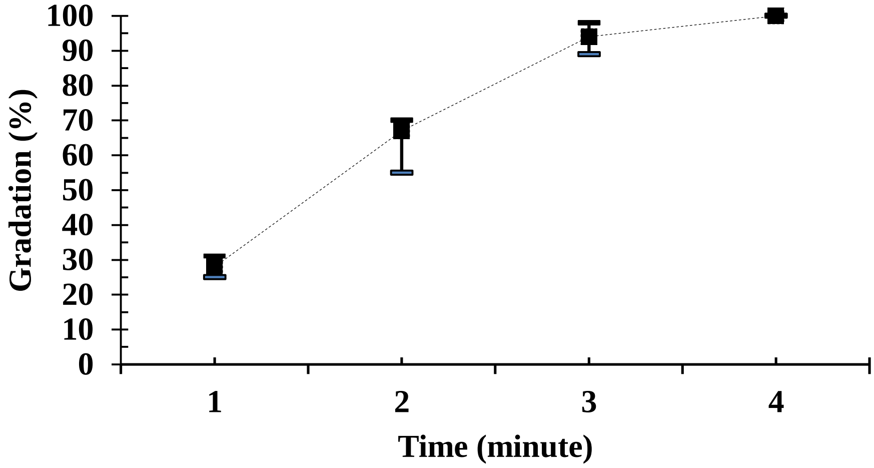


Figure 3 Developing time without exposure

By the fourth minute, the negative dry film photoresist on the PCB had been developed (fully eroded), as indicated by the PCB weight equaling its initial weight.

2.3. Developing Time with Black Color Exposure

This process aimed to determine the effect of black color from the DLP projector on dry film photoresist. The process was almost identical to the previous process (section 2.2), starting with a PCB being cut to a size of 3×4 cm. The PCB was then weighed to determine its initial weight, confirming an average weight of about 3.174 grams ± 0.005. Dry film photoresist was subsequently attached to the PCB and weighed, revealing an average weight of about 3.227 grams ± 0.005. The average weight of negative dry film photoresist was therefore around 0.053 grams ± 0.002. The PCB with photoresist dry film was exposed to a black color from the DLP projector beam, generated from a laptop connected to the projector. The exposure process was performed for seven minutes (Suwandi et al., 2014) using black (R = 0, G = 0, B = 0) by setting the custom color on Powerpoint. After exposure, the PCB with photoresist was inserted into the developing solution for a variation of time from one to five minutes. Percentages of the photoresist's gradual weight change, caused by erosion were recorded and can be seen in Figure 4.

As Figure 4's graph indicates, the exposure process using a DLP projector with black color did not affect the dry film, proven by the full erosion of the photoresist at 4 minutes, equivalent to a developing process without exposure. These results allow 4 minutes to be used as a reference when developing. For certainty, this time can be increased to 5 minutes for the next experiment's developing process

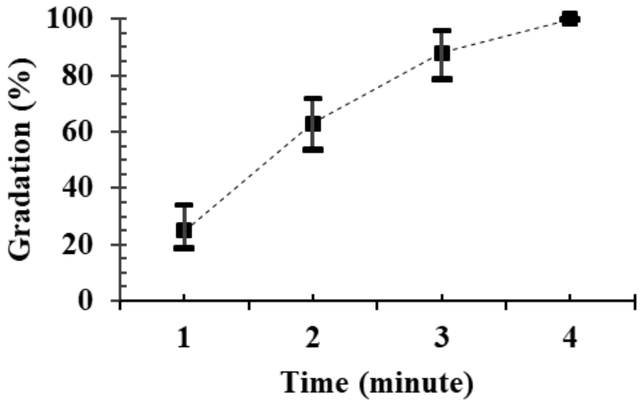


Figure 4 Developing time with black color exposure

2.4. Exposure Time with Light Blue Color and Developing without Shaking

This experiment aimed to determine the effect of light blue color (R = 0, G = 172, B = 240) emitted from the DLP projector upon negative dry film photoresist. The light blue color was selected based on previous maskless photolithography experiments (Suwandi et al., 2014). This experiment's steps are identical to the previous process (section 2.3), changing black for light blue color and increasing the exposure time to five minutes. A subsequent test was undertaken where the PCB was inserted into the developer solution for five minutes without shaking. The gradation percentage of the photoresist eroded by the developing process, without shaking, can be seen in Figure 5.

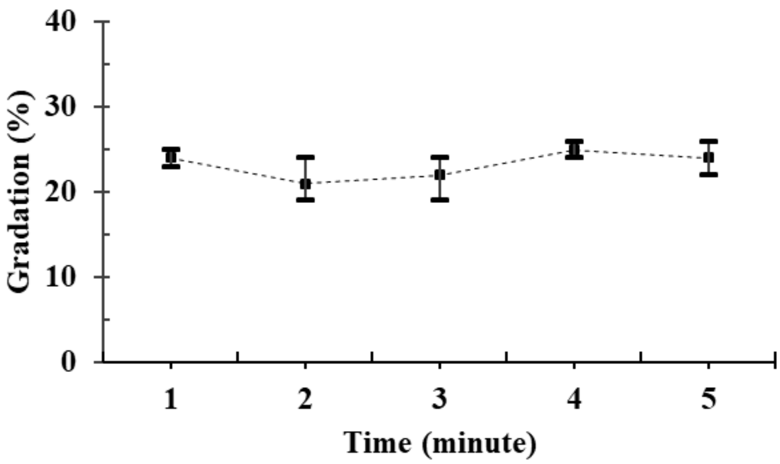


Figure 5 Exposure time with light blue color and no shaking

Figure 5's graph illustrates that exposure to light blue color and a developing process without shaking did not produce consistent data. This inconsistency was caused by the dry film photoresist peeling while still attached to the PCB.

2.5. Exposure Time with Light Blue Color and Developing with Shaking

Following the same process steps as the previous experiment (see section 2.4), this test will be adding shaking to the developing process, addressing the peeling photoresist and obtaining the actual weight of the photoresist attached to the PCB.

With the addition of the shaking process, the reduced degradation of the weight of the photoresist became precise. At minutes three, four, and five, the percentage of dry-film gradation remained almost constant at a value of 24.3% with different deviations. For decision, the developing process time for a light blue color with shaking was three minutes. The resulting gradation percentage resistance on the developing process with shaking is shown in Figure 6.

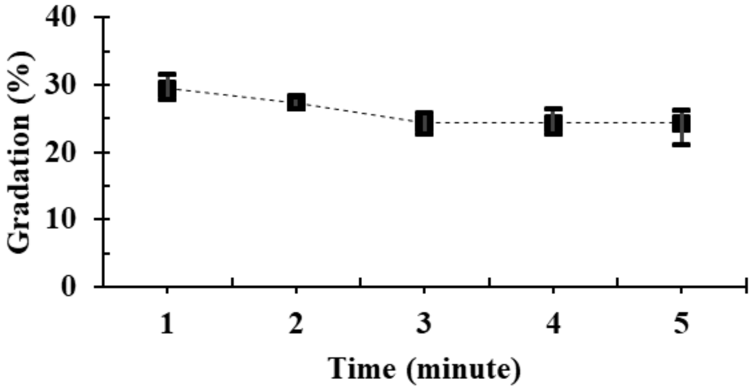


Figure 6 Developing time with light blue color and shaking

2.6. Etching Time

To determine etching times (PCB copper erosion), the following process was engaged. A 3×4 cm PCB was cut and put into an etching solution ($4H_2O + 2H_2O_2 + HCl$). The etching process is fast, with one to two minutes, the etching solution has eroded the PCB copper. So a decision was reached that the etching process took two minutes.

2.7. Removing Time

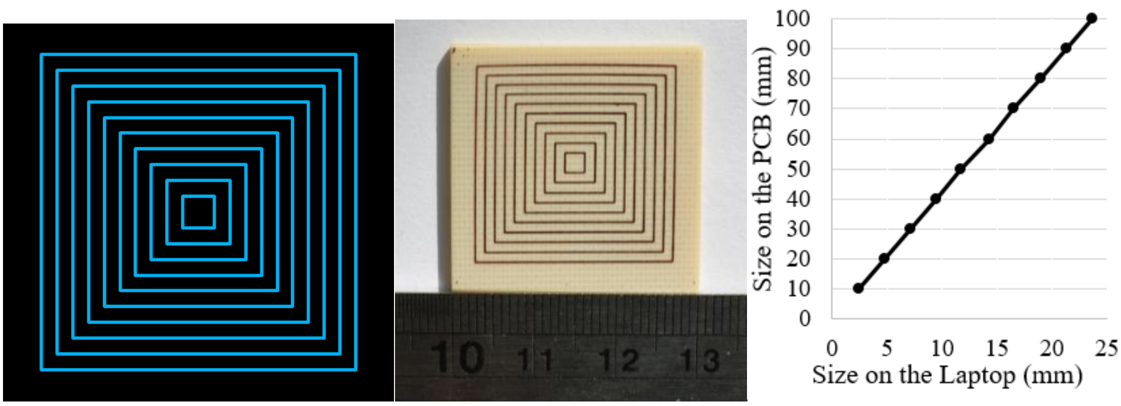
This process was done to lift dry film photoresist still attached to the PCB. Upon completion of the exposure process, the etching process of the PCB with dry film photoresist was inserted into a remover solution of water and sodium hydroxide at a ratio of 100 ml : 5 grams. The removal process was very fast, requiring only one minute to peel off all of the dry film photoresists

3. RESULTS AND DISCUSSION

After the time parameters of the maskless photolithography process were found, the process was applied to PCB routing.

3.1. Model and Real Profile Comparison

The size of the laptop model and the PCB profile required comparison to ensure the resulting profile. Square models of 10 mm to 100 mm were created on the laptop using a box colored light blue on a black background. The maskless photolithography process was then performed using previously established parameters (see sections 2.1 to 2.7): exposure of four minutes, development of three minutes, etching for two minutes, and removal for one minute.



(a) Model on the laptop (b) profile on the PCB (c) scale comparison

Figure 7 Model and real profile PCB comparison

Figure 7a displays the laptop model; Figure 7b shows the PCB profile resulting from the lithography process, and Figure 7c charts the ratio of the laptop model size and the PCB profile size. From these measurements, the model and profile comparison ratio was 4.22:1 with a deviation ± 0.1 mm.

3.2. The Resulting Routing Width

The capability of maskless photolithography process was measured using the product of the line thickness variation. Using models, such as Figure 7a, the line thickness variation began at 4 computer points (pts), the smallest unit of measure in typography, and scaled down to 1 pt with 0.5 pt per interval. The contemporary desktop publishing point (also called the PostScript point) was defined as 72 points to the inch (1 point = 1⁄72 inches = 25.4⁄72 mm = 0.3527 mm). Lines produced by lithography processes were measured using a digital microscope and checked using a multitester. The results are shown in Figure 8.

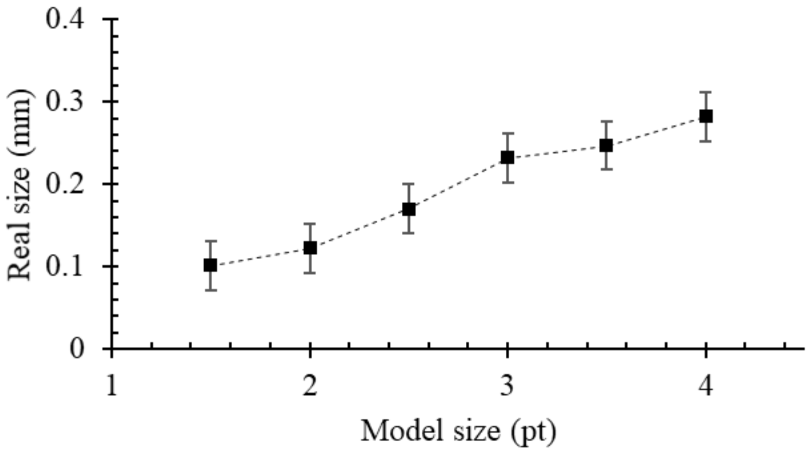
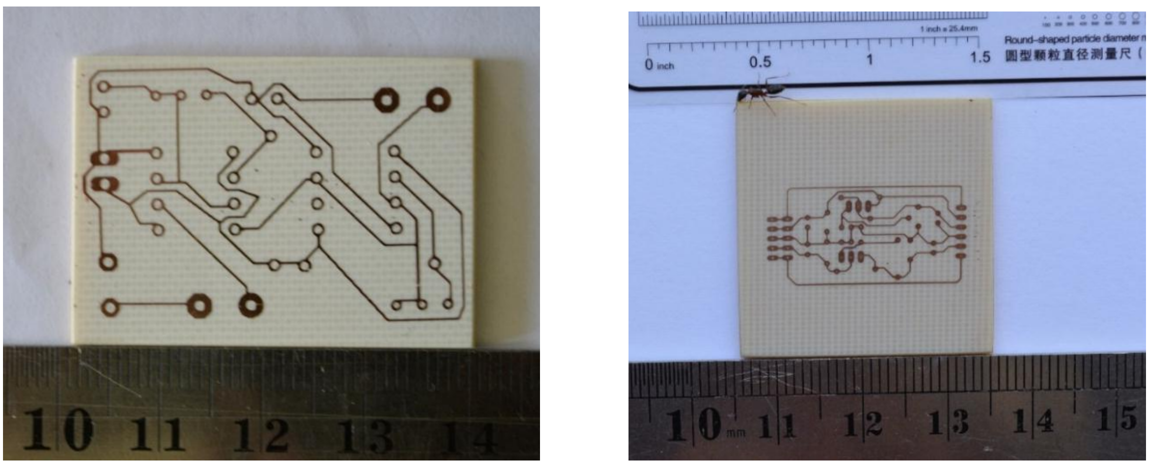


Figure 8 Routing size

From the experiment (Figure 8), the smallest line that could be produced by the lithography process had a thickness of 1.5 pt on the laptop, producing a line thickness of 100 µm ± 5 µm on the PCB. If the thickness of the model line was minimized again, a broken line was created.

3.3. Product Applications

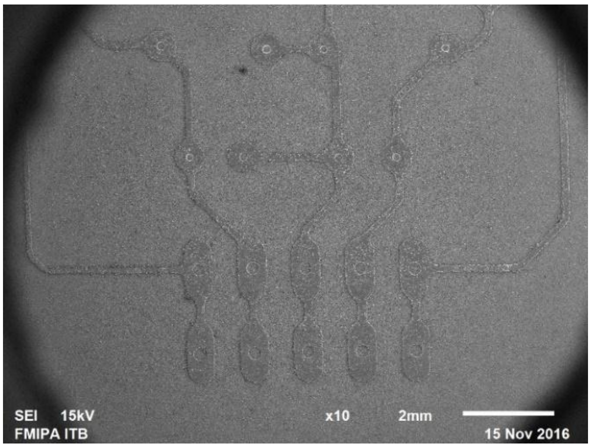
Having determined the capacity of negative dry film photoresist in the process of maskless photolithography using a DLP projector, PCB routing creation began. Some products made, such as Figure 9.



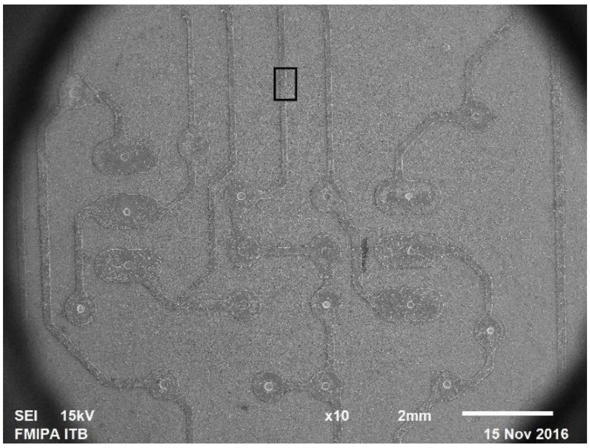
(a) Alarm circuit (b) Mini regulated power supply

Figure 9 Maskless lithography products

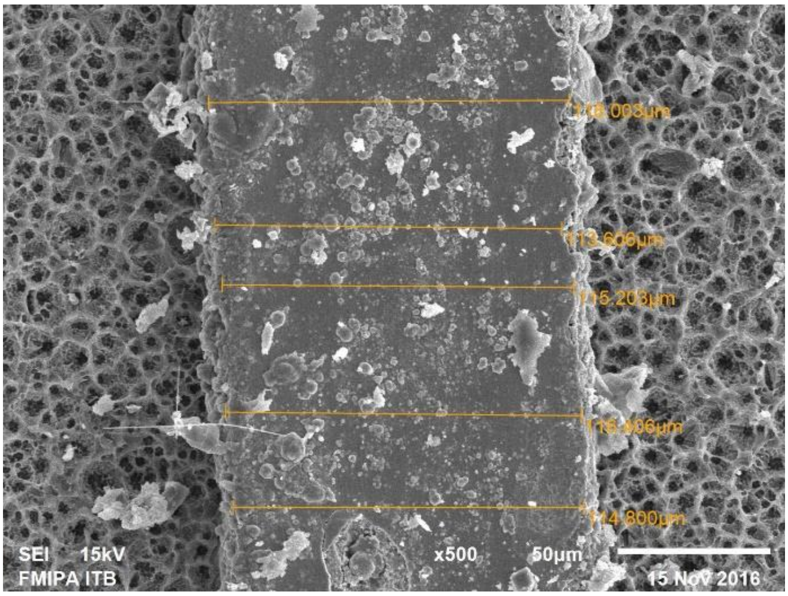
Figure 10 shows the magnification required to view the PCB routing profile form using a scanning electron microscope (SEM). After 500× magnification (Figure 10), the PCB routing has a size of 114 µm.



(a) Zoom 10× upper side



(b) Zoom 10× center side



(c) Zoom 500× line

Figure 10 Routing PCB for mini regulated power supply

4. CONCLUSION

A maskless photolithography process was performed successfully using an infocus in114a dlp projector and applying dry film photoresists within established parameters of exposure time: four minutes, developing time: three minutes, etching time: two minutes, and removing time: one minute. Some products maskless photolithography process that successfully made such a flip-flop lamp, mini power supply, and alarm. The smallest pcb routing width produced is 100 µm ± 5 µm.

5. ACKNOWLEDGEMENT

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