The Application of UV-LEDs to Printed Circuit Board Process

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ABSTRACT

This study investigated using high power UV light emitting diode (LED) to replace the traditional UV lamp in printed circuit board process. It was expected to take the advantages of energy conservation, long life and quick response of UV-LEDs. The feasibility of this replacement was evaluated.

There were two kinds of light modules in this work; Type 1 composed of six 1-Watt UV-LEDs arranging as a circle of diameter in 50 mm. Type 2 was equipped with twelve 3-Watt LEDs soldered on a MCPCB of 100 mm in diameter. Both modules emitted a spectrum distribution peaking at a wavelength of 400 nm. The angle of view measuring apparatus was completed for measuring light module angle of view and UV intensity. In order to obtain collimated light source, the parabolic reflectors were used for Type 1. The reflectors showed the six to ten times enhancement of intensity and the improvement of the angle of view from 140° to 30°.

In order to approach the practical process, only the original light source was replaced by UV-LED light modules. Other parameters on the automation system remained unchanged. After etching, the patterns were observed and measured by image measurement software. Following the PCB standards, only results with relative errors under 15% were accepted. At present, the minimum reproducible feature size is 75 μm by Type 2 light source with 50 mm or 100 mm distance between light source and mask. The results show the feasibility and potential usage of UV-LED in PCB lithography.

1. INTRODUCTION

Recently, light emitting diodes (LEDs) are becoming more and more popular as being illuminating light sources. LEDs exhibit several advantages, such as energy conservation, long life, compact and fast response. For those reasons, there are more and more applications in our life. Moreover, UV-LEDs have been explored as the light source in exposure system [1-2]. Application of UV-LED to photolithography was proven feasible [3]. At present, UV-LED with a peak wavelength at 210 nm can be manufactured successfully [4]. Generally, the wavelength influences the minimum printed feature size, The shorter wavelength should be able to reproduce smaller patterns [5]. Besides, the gap between mask and substrate also affects the critical dimension [6]. Consequently, the usage of UV-LEDs in the PCB process was explored in this study.

2. EXPERIMENTAL METHODS

Two types of UV-LED light modules were assembled and used as the light sources. Type 1 consumed 1-Watt of electricity, and Type 2 was ranked 3-Watts. The spectrum distribution of LED modules were measured (shown in Figure 1). Type 1 and 2 exhibited spectrum distributions peaking at 400 nm.

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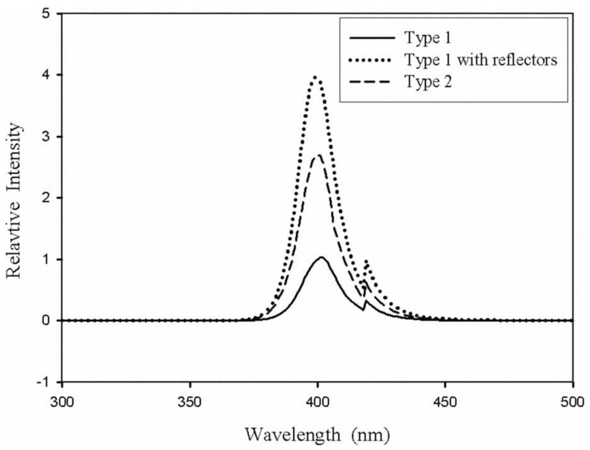

Figure 1 Spectrum distribution of Type 1 (without or with reflectors) and Type 2 UV-LED modules

Including peak wavelength described above, some electric and optical characteristics of the two UV-LED light modules tested in this study are listed in Table 1.

Table 1 Electric and optical characteristics of Type 1 and 2 UV-LED modules

Item	Type 1	Type 2
Number of UV-LED	6	12
Power Rating (W)	1	3
Wavelength Range (nm)	395-410	395-410
Angle of View (°)	140 /30	150
UVA Intensity @ 200 mm (μW/cm^2)	92.5± 4.2/ 411.3± 65.1	404.9± 12.2

*Values after the slash (/) are values with usage of reflector

For Type 1, six UV-LEDs were arranged as a ring of 25 mm in radius, and expected to acquire a uniform UV intensity in the exposure area. Type 2 composed of twelve UV-LEDs on the MCPCB of 100 mm in diameter. UV-LEDs were installed on a heat sink to form a light module. Besides, a parabolic reflector module was used to improve intensity and angle of view in this study. The reflector module was specially designed for Type 1 module. The photographs of the light modules are shown in Figure 2.

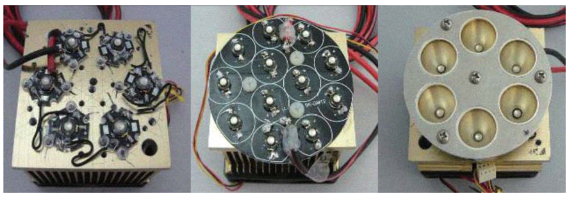

Figure 2 Photograph of the two UV-LED light modules (left two) and Type 1 with parabolic reflectors (right)

At present, PCB manufacturers used automation systems to complete the exposure, development, and etching processes. In this study, the corresponding experiments were done in COM-WELL Electronics. The original light sources in the PCB process were replaced by the two UV-LED light modules, but the rest of the processes, such as development and etching, remained the same. Consequently, the results will be effectively references for practical applications. The exposure process worked on a manual exposure machine (CSUN MFG. LTD., UVE-M525), a contact printer. The 10 μm negative photoresist was applied in experiments. The exposure system UVE-M525 used two 7kW metal halide lamps for exposing. The intensity was >40 mW/cm^2 at 365 nm, and exposure uniformity was >85%. Generally, 80- 120 mJ/cm^2 was required in PCB process. The lamp production capacity was 2.5- 3 panel/ min in size 559 × 660 mm^2, and exposure time was around 4 seconds.

The parallelism and intensity of the light source affected the exposure performance significantly. Using the radiometer is a precisely and accurately method to measure radiation intensity. A measurement system (shown in Fig. 3) was assembled for the tests of the two UV-LED light modules. A rotation stage was used to vary the orientation of the light module, and the intensity variation was acquired by an ultraviolet power meter (SENTRY, ST-510). Based on that, the relationship of angle and intensity can be detected by the equipment.

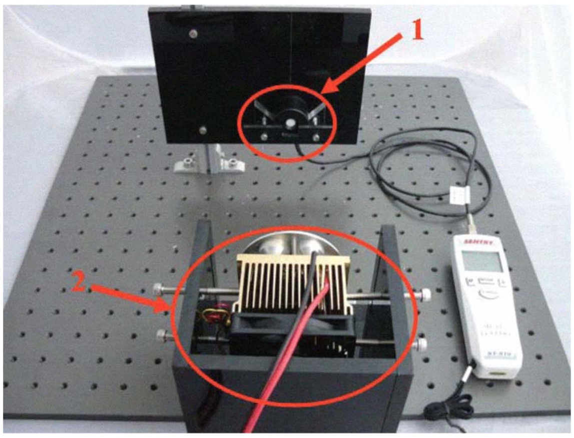

Figure 3 Picture of measurement equipment (1: sensor of ultraviolet power meter; 2: light source holder that installed on a rotational micro-stage)

Parabolic reflectors were used to concentrate UV-LED emission to achieve a higher intensity and a better parallelism. Besides, to obtain a higher intensity, the reflectors were deposited with a sliver film in the interior. . The Figure 4 shows intensity with angle of view for various light modules. The result shows that the parabolic reflectors are enable to enhance intensity about six to ten times, and decrease angle of view from 140° to 30°.

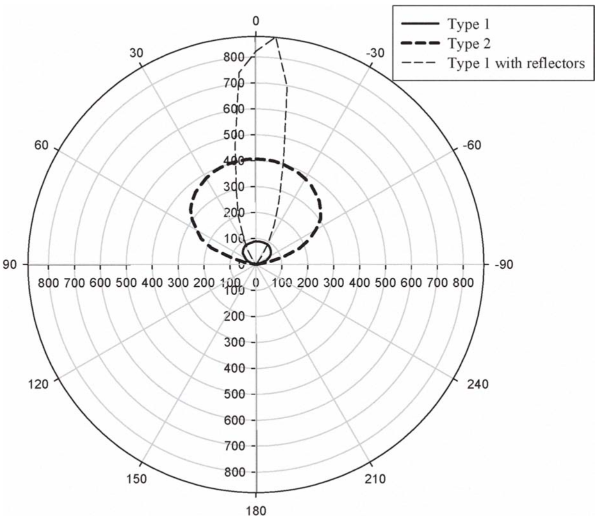

Figure 4 Angle of view diagrams for light modules studied in this work.

After several trials, the best exposure time and distance between light module and mask were found for each module. After development and etching processes, the PCBs with printed and etched patterns were observed under microscope to evaluate the performance of the two light modules. On the other hand, the width of pattern can be measure by image measurement software.

3. Results and Discussion

3.1 Light module intensity distribution

A portable ultraviolet power meter (SENTRY, ST-510) was used to investigate the intensity variation. Figure 5 shows the intensity distribution of the light modules, where the solid dots denote the locations of the UV-LEDs.

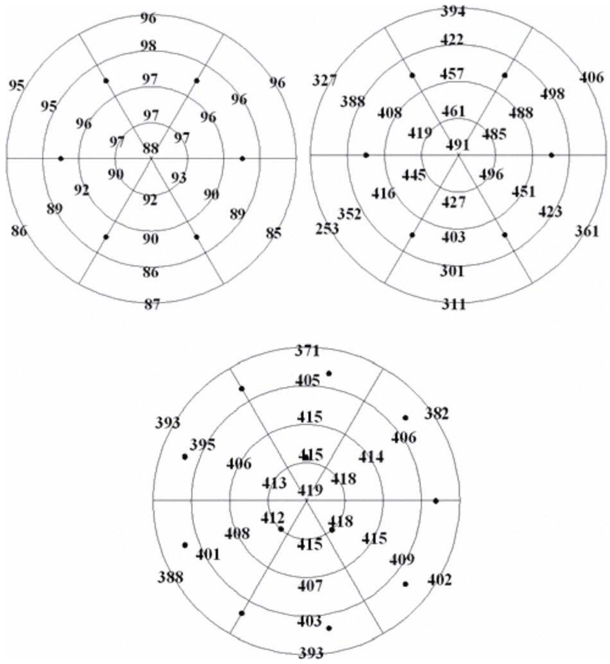

Figure 5 Intensity distributions of Type 1 without or with reflector (top) and Type 2 (bottom) light modules

Generally, the intensity decreases from the central region.. Using parabolic reflectors indeed increase intensity effectively. Table 2 shows the exposure time and distance between light module and mask to produce the corresponding minimum feature size. The size deviation after etching less than 15% is acceptable.

Table 2 Minimum reproducible sizes for Type 1 light module with parabolic reflectors.

Distance (mm) / Exposure time (sec)	50	100	150	200
30	X	200	100	100
35	250	180	100	100
40	X	180	100	100
45	180	180	120	120
50	120	250	120	120
55	120	250	120	120

Table 3 shows results of Type 2. It is obviously that process can be completed with less exposure time. The intensity (measured 100 mm away) of Type 2 is 1.5 mW/cm^2, and theoretical exposure times are pretty close to experimental results.

Table 3 Minimum reproducible sizes for Type 2 light module.

Distance (mm) / Exposure time (sec)	50	100	150	200
5	75	75	250	250
10	75	75	180	250
15	120	75	X	X
20	120	180	250	X
25	180	X	X	X

3.2 Printed patterns

Some typical patterns are shown in Figure 6. Figure 6 (a) shows a well-etched pattern from Type 1 with reflectors in where the width variation is limited. In contrast, (b) shows the worst case where the width variation is not acceptable. For negative photoresist, the over-etched patterns imply under-exposure. (c) shows the cross-section of patterns after etching to verify the effective attachment.

(a) (b) (c)

Figure 6 Photographs of typical etched patterns

Even though the reflector module increases the intensity, the intensity at the outer area is still low. On the other hand, the Type 2 with more LEDs but without reflector module exhibits a smaller reproducible size. There should be a compromise between optical design and number of LEDs. For PCB lithography process, the required parallelism seems not as sensitively as G-line or I-line of IC process. The replacement of mercury lamps can be achieved successfully by a UV-LED array.

4. Conclusions

This research investigated using UV-LEDs to replace the mercury lamps in the PCB lithography process. Using a parabolic reflector module, the intensity and angle of view can be improved apparently. At present, the minimum reproducible size on PCB is 75 μm for certain parameter combination. The results show the feasibility and potential usage of UV-LED in PCB lithography.

References

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