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Laboratory Vacuum Phototool for PCB Exposure

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Abstract
The work deals with laboratory multifunction exposure equipment for exposure of patterns in printed circuit boards (PCB) technology. It is intended for using in electrotechnologic laboratory for research, development and education. Fixation system is vacuum type, timing system is microcontroller-based with keyboard, display and memory. The equipment was tailored by preparation and evaluation of experimental samples of PCB testing patterns.

INTRODUCTION

The photolithography process is a wide used technological step in thick/thin film technologies including PCB fabrication, where it si a critical step during transfering the layout pattern on substrate surface. It consists of surface preparation, exposure through aligned photomask and developing. Photolithographic technique quality of the equipment influences quality of metallic foils on PCB. During the exposure and development process, the pattern of photomask is transferred to the photo resist formed on surface. Because the close contact of masking and photosensitive layer is necessary, they must be inserted into the area, where the inner pressure is considerably lower than the atmospheric pressure is [1-3]. Photosensitive polymers used in electronics are usually sensitive for near UV spectrum so that the effect of exposure sources is needed to evaluate by emitted power in such spectrum range. Various light sources as low/high pressure lamps and modern metal-halide lamps are used for exposure of patterns [4].

PCB EXPOSURE EQUIPMENT CONSTRUCTION

Equipment with 310 x 490 x 110 mm (width x length x height) dimensions and 3.9 kg weight includes embedded 60 W switching power supply for low-voltage circuitry. The control circuitry is based on one-chip microcontroller Atmel AT89C2051, what provides measuring and saving of elapsed time, indication of actual state, handling of 4-segment display, 12-button keyboard, serial memory and relay (Fig. 1).

Working area of the equipment is the flat glass plate. Fixation system is solved as two-part vacuum frame. Fixed part serves the compensation of frame thickness profile. Removable part consists of frame with hermetic silicone membrane, what is (unlike initial design) located up to the inner distance frame (Fig. 2).

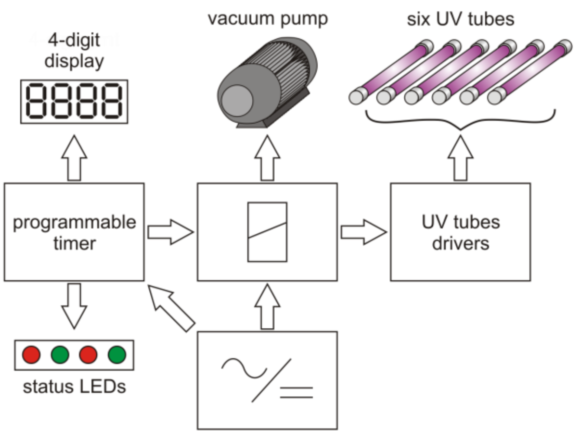

Fig. 1. Exposure equipment block scheme.

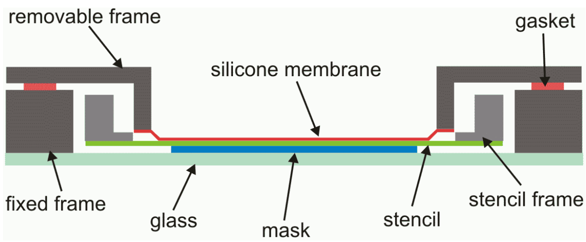

Fig. 2. Vacuum fixation system of exposure equipment.

Generally used light sources are vacuum bulb types. For that reason the source has not the point character, but the light is emitted in the volume of the gas bulb or tube. Ideal case is that the angle of incident ray towards substrate surface gives the right angle. The photosensitive media producers recommend the distance from light source to the substrate not seldom till 1.5 m because of emitted ray divergence minimization. So the tax for equipment compactness is the closeness of source framework to the substrate and high incident ray divergence of course (φ_2 in Fig. 3). In such case it is especially important to provide the excellent co-planarity and contact of masking pattern with photosensitive layer at substrate. The ray reflection from substrate is also noticeable.

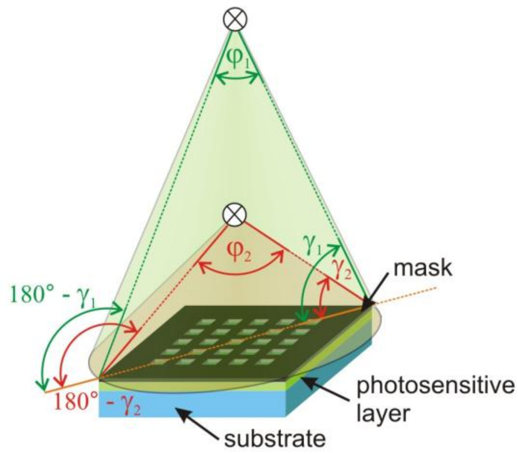

Fig. 3. View of exposition using point light source. In real conditions the source is not the point type and distance from source to substrate is limited.

The vacuum frame allows exposure of standard PCB with maximum size limited by non-transparent aperture to 100 x 180 mm. Exposure light source consist of evenly distributed BLB-4W type luminescent UV light tubes. They contain embedded UV filter and in spectrum with 365 nm peak they emit with power of 4 W each. Nominal supply voltage of the tubes is 29 V, length/diameter is 150/16 mm and they use the G5 socket. The benefit of their using is the low start time and minimal needs for cooling. The number of tubes was experimentally stated to six pieces. They are switched by relay output, what is controlled by microcontroller timer circuitry with memory of tubes operation time. The result of intensity of UV light measurement (Fig. 4) is that the area of 65 x 65 mm in the center is within 10% UV intensity value dispersion.

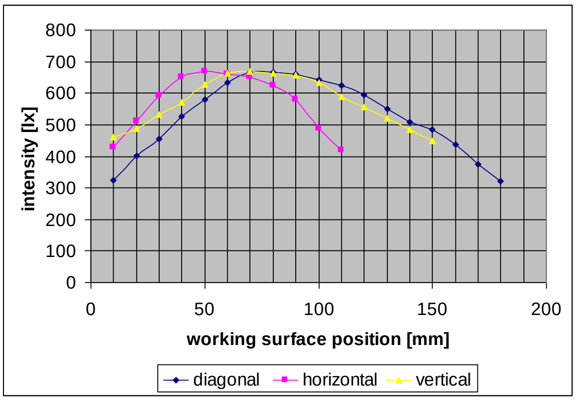

Fig. 4. UV source intensity profile vs. position on working surface.

After the PCB is inserted, removable frame is imbedded and vacuum pump is running, the system is isolated from the surrounding by depressed elastomer gasket. Vacuum set-up serves the uniform pressure compared to mechanic system. The external transport-mechanic vacuum pump was used as the vacuum source.

Fig. 5. Equipment with vacuum fixation system.

EXPERIMENTAL SAMPLES

Exposure equipment was adapted and tested for exposure of Positiv 20 photosensitive lacquer [5]. The nominal exposure time was determined for this widely used photosensitive media. The CAD testing pattern of 25.4 x 25.4 mm with 0.13, 0.2, 0.25, 0.4 and 0.5 mm lines were created for samples realization. Because the luminescent tubes are not emitting uniformly through the exposure region, the pattern was situated in the middle as well as in the periphery of working area.

Primarily the Positiv 20 photosensitive lacquer is intended for PCB production. Exposure of pattern through the transparent positive phototool allows the dissolution of exposed parts by developer. Photosensitive lacquer was applied by spraying from 0.2 m distance onto PCB copper surface and hardened at temperature of 70°C during 20 minutes. The phototool and PCB were aligned into vacuum frame system and the pattern was exposed during 15, 30, 45, 60, 75 and 90 seconds. Exposed layer was developed by aqueous 7 g/l NaOH solution and etched in $FeCl_3$ based solution (Fig. 6).

SAMPLES ANALYSIS

According to quality of obtained samples, the exposure time values were stated for Positiv 20 photosensitive lacquer:

- satisfactory exposure time is 60-75 s,
- samples with shorter exposure time were not sufficiently exposed and unsuccessfully developed,
- samples with exposure time above 90 s were partially overexposed, so the 0.13 mm lines were significantly tapered,
- marginal samples requires for about 15 s more exposure time than middle samples.

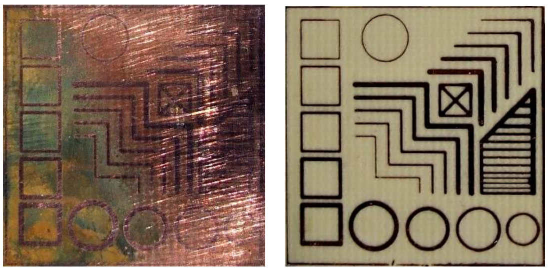

Fig. 6. Positiv 20 photosensitive lacquer exposure test samples: 45 s exposure (left, not sufficiently exposed) and 60 s exposure (right, sufficient)

CONCLUSIONS

The aim of this work was to construct the vacuum exposure equipment for PCB processes in education laboratory. Developed construction has concept of stand-alone, low-profile desk equipment. The equipment provides ability of pattern and substrate fixation by vacuum frame set. Exposure time is keyboard-adjustable by internal microcontroller-based timer with numerical segment display. Relay timer output switches the exposure unit and vacuum pump.

Equipment functionality was examined on testing samples of printed circuit boards with variable line testing pattern. Positiv 20 photosensitive lacquer was used as the photosensitive media. Optimal exposure time ranges was stated for this media processing after samples examination.

Realized exposure equipment is intended not only for experimental work in laboratory, but it is the practical instrument for students as well as for pedagogue staff during the education process. It is possible to improve the equipment by integration with suitable vacuum pump, so that it will be autonomous and simply portable.

ACKNOWLEDGEMENT

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