Ultraviolet LEDS as a Source of Emission for Resist Exposure on Printed Circuit Boards

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Abstract

In this paper results of research of the parameters and characteristics of ultraviolet LEDs in exposure usage, where stable optical flow is required are presented. And the self-designed tools and technique in printed circuit board production and construction of a simple stand for photometry is described.

1 Introduction

Rush production of printed circuit boards (PCBs) and rapid prototyping of radio-electronic goods has become a feature of engineering departments of big companies. This reduces the turnaround time of development and debugging electronic circuits. In this way, the production of high-quality printed boards for device prototypes is sought-after technology, due to widespread trends of microminiaturization in electronics.

Highly stable sources of ultraviolet (UV) light are required for PCBs reproductions and before designing devices based on them, the problem of the uncertainty of their characteristics and the question of reliability arise.

Principal criteria in the selection of UV light sources include: photosensitivity (wave length) of 320-450 nm; UV-emission energy of 400-600 mJ/cm2 (on the resist's surface); small-angle scattering; light source should have a linear degradation property.

This also determines the set of four major issues and their corresponding areas of research: a) Evaluation of existing possibilities and exposure methods of a protected image and finishing coat, as well as the search for new options; b) Analysis of collected results and tracking of defects in the process that greatly affect the quality of the coating; c) Design and production of a working project display with a vacuum table and with the possibility of installing a UV lamp and LEDs; d) Study of the reproducibility of manufactured printed circuit board prototypes of certain specifications.

The aim of research is to investigate degradation properties and the period of time spent in a stable range of the UV-LED. [1]

2 Literature review

The problem in factory PCB creation process is side exposure of the photomask pattern, which leads to a distortion of the geometric dimensions and proportions of the reproduction result. This is partially resolved by vacuum clamping the photomask, but this poses a significant disadvantage: upon increasing the vacuum percentage in the stand, the photomask clamps may adhere to the resist and template. Therefore, the problem of lateral exposure is not resolved only by increasing the contact force of the photomask.

A power increase of UV radiation leads to an undesirable penetration of UV radiation directly through protected areas of the photomask. To increase the uniformity of a declining UV emission, it is possible to install a reflector (mirror). This increases the complexity of technical implementation and, when incorrectly focused, leads to a deterioration of the final result (due to the varying geometrical sizes of the board images, the focus varies).

The logical solution would be to increase the number of light sources with the narrowest directional pattern per square decimeter.
As is generally known, LEDs are light sources with a known directional pattern, in contrast with fluorescent lamps, which have circular radiation patterns. It is possible to use light strips with SMD LEDs, which have an optical system with a directional pattern, wider than the through-hole LEDs with an embedded (built-in) lens, but narrower than that found in fluorescent lamps. One of the advantages of LED strips with SMD LEDs is their low cost.

3 Proposed Device Description

We have designed and assembled a device for photoresist exposure, consisting of two main parts: a vacuum clamp unit (the bottom half of the device) and a combination of UV lamp with the cooling system (the top half of the device) (see Fig. 1). The distance between the photo mask and the source of radiation is fixed (due to the lamp casing, which plays a role protecting in the outer source of radiation).

Figure 1: Photoresist exposure device

The vacuum clamp block is based on the principle of pumping air between the board and the photomask so that a special membrane keeps it tightly. The pump generates a reduced pressure in the chamber.

The cooling system of the thermo-controlled surface includes aluminum sheets, on which a copper heat exchanger is installed. It is connected to a cooling coil by tubes through a circulation pump, located outside of the structure. The cooling system keeps a temperature on the level of 50 ±5 ºC, by the fact.

4 Photometric stand

The constructed stand consists of the prototyping board with a matrix of phototransistors, a thermal-controller surface with LED strips, a data logger, and programmed software for a personal computer. The debuging board STM32F0-Discovery with (pre-) written software fulfills the role of the logger.

The photometer consists of a board with 16 photosensors and a temperature sensor.

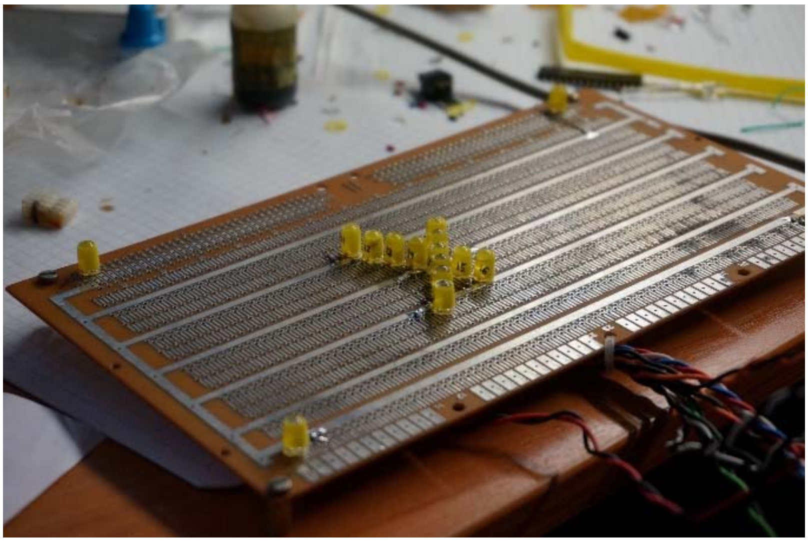


Figure 2: Photometer

A complete structural diagram of the setup is shown in Fig. 3

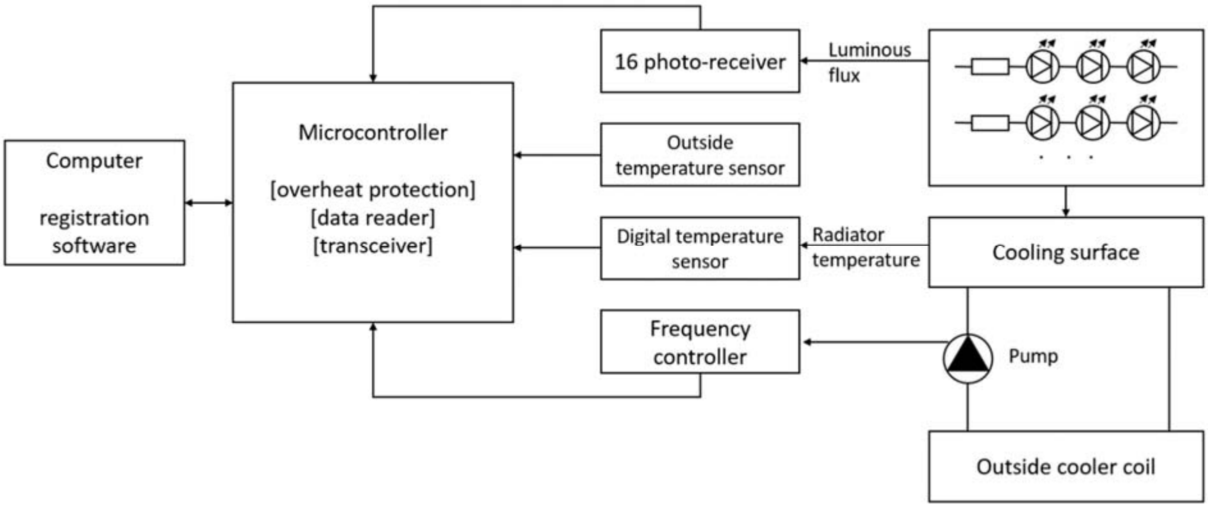


Figure 3: Diagram of the device

5 Study of LED characteristics

The stand measures luminous flux emanating from the emitter. Data was gathered during a period of 750 hours of continuous operation at a temperature of 50±5 ºC and processed.

Shown above is a graph of normalized luminous flux over time. Approximately, the degradation properties can be divided into four parts.

In area I was an estimation of the initial luminous flux at an initial temperature of +25 ºC (0 to A hours). Next, the temperature was set to the operating mode of the photometric bench – +50 °C with the aim of obtaining a more noticeable amount of degradation for 750 hours than at 25 ºC.

In area II a decline was observed, due to the deterioration of parameters of the current layer spread in the field of ohmic contacts [2]. This is due to local defects in resistance spot brazing of the threads connecting terminals of the LED housing with a chip (the manufacturer's). In the end, in the area of the ohmic contact increases the internal quantum yield [2] (the energy consumed) for heating the area. Therefore, this area of degradation quickly disappeared until area III. Normalized luminous flux decreases because of the reducing voltage drop in this region.

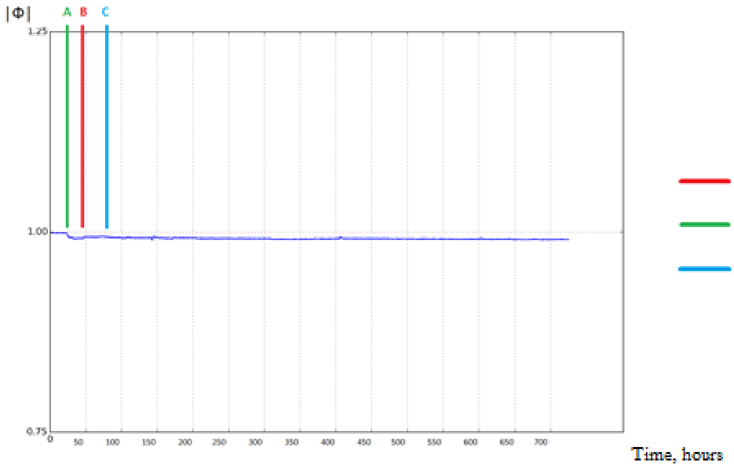
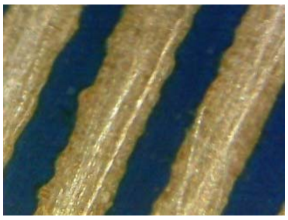


Figure 4: Time characteristics

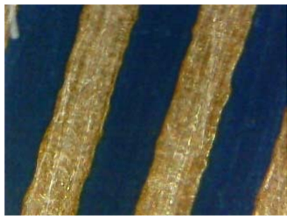
The III area of degradation ended with the destruction of the electroluminescent section located under the welded contact section. As is known, the quantum yield (internal and external) is constant, in accordance with Einstein's models [3]. Losses to nonradiative recombination are reduced and external quantum yield is increased (luminous flux increases).

In the IV area, there is a gradual decrease in the intensity of electroluminescence [4]. The authors [4] describe this process as the formation of donor defects, compensating the acceptor, and increases the nonradiative recombination and the luminescent intensity of the yellow band defects.

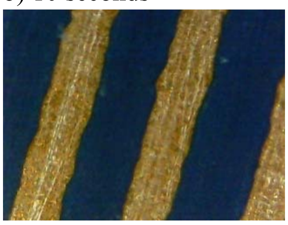
a) Overall view of the board



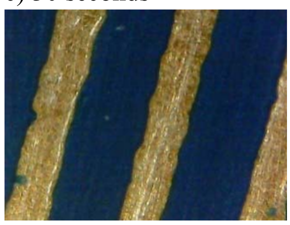
b) 10 seconds



c) 30 seconds



d) 40 seconds



e) 60 seconds

Figure 5: Time characteristics

As seen from the graph, the dependence has a linear characteristic (in the region IV). The relative intensity of electroluminescence in the IV area slightly decreases (from C to 750 hours), which makes possible the fixation of the exposure time and, consequently, allows the usage of the LED strip as the source of ultraviolet light in the exposure setting.

As the experiment demonstrated, the use of UV SMD LEDs ensure sufficient luminous flux for polymerization of the resist. Measurements for the solder mask FSR8000 showed that a high rate (for prototyping) exposure is 35 seconds.

6 Conclusion

The resulting time of exposure (see Fig. 5) is valid for the resulting state of the LEDs. During the operation, p-n junction may deteriorate and, therefore, will change the exposure time. In a case where the properties of the luminous flux are linear, and the rate of degradation is low, the proposed method can be used in the production of prototypes of printed circuit boards.

Existing methods of exposure have drawbacks, which, however, potentially can be solved using UV LEDs. Degradation characteristics throughout the life of the installation of a UV PCB printer should be close to linear, which controls the exposure time of a particular photoresist. The assembled setup allowed the acquisition of data. According to the study results, a degradation property was obtained that covers several times the operational lifetime of the setup. It is demonstrated that the property is linear, and the degree of degradation is almost negligible within this time range. Proper cooling of semiconductor light sources significantly increases their service life. Currently, manufacturers of LEDs are conducting studies to improve the area of current spreading.

References

1. S.G. Nikiforov, Story about “infinity” youth of LEDs. { Volume 4, Semiconductor lighting equipment, 2010
2. S.G. Nikiforov, Development of control methods for characteristics degradation of LEDs by AlGaInP and AlGaInN { Moscow Institute of metals, PhD dissertation, 2006.
3. F. Schubert, LEDs, 3rd edition { Fizmatlit, 2008, 496 p.
4. A.E. Yunovich, Divacancies nitrogen - a possible cause of the yellow band in the spectra of luminescence of gallium nitride { Volume 32/10, 1998