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PLC Based Exposure Unit for PCB Fabrication

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Abstract:-The present exposure system is operated manually which suffers from exposure mismatches resulting in poor PCB quality. The proposed system overcomes this shortcoming and improves quality of PCB, enhances safety to radiations and made suitable for industrial environment. The processis semi-automated. The total solution comprises ofcontroller implementation throughhardware and software in PLC environment.Thispaperalsodescribes photolithographic processandcompares the results for the quality of the PCB before and after automation.

Keywords:*PCB-Printed Circuit Boards,photolithography,exposure unit,industrial application,UVexposure.*

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1. INTRODUCTION

There is no technological breakthrough in PCB fabrication process even though there is an exponential growth in the electronic industry.

The Photolithographic practice of PCB fabrication is most used universally across small, medium or large scale facilities. All these sectors coexist for diversity of factors like scale, cost, functionality and reliability. Also PCB industry is put to lots of competition and customer requirements in functionality and quality delivery within a cycle time to remain ever competent. Many customized methods exist to control the exposure unit for a given application. The project aims at designing a retrofit to an existing contactor logic based to PLC based control to address the shortcomings of the former method.

2. PHOTOLITHOGRAPHY

Photolithography (also called “optical lithography” or “UV lithography”) is a method used in fabrication to selectively dispose of parts of a skinny film or the majority of a substrate. Photolithography uses light to copy the geometric design from a photomask to a light-sensitive photochemical “photoresist”, or simply “resist,” [1].

Photolithography is used because it can create really small patterns and gives the possibility of exactly controlling the shape and size of the objects it creates. Its main disadvantages are that it is not very effective in the creation of shapes that are not so smooth and calls for clean operating conditions [2].

The procedureof PCB fabrication using photolithography hasseveralstepsinseriesandisshown in figure1.

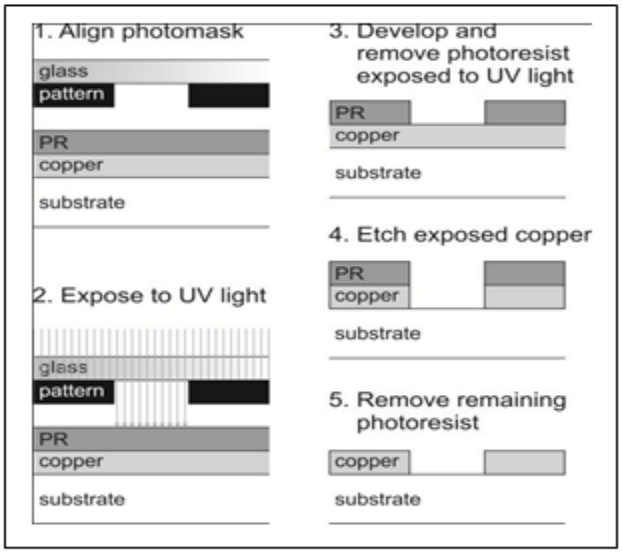

Figure1 Process for photolithography

2.1 Cleaningandphotoresistapplication

The preparation for PCB boards are essentially pre sensitized copper clad boardsi.e. the boards which are pre enclosed by a photo resist material. These are expensive but give better results. Incase if plane copper clad board is considered it is necessary to remove the surface contaminations before photoresist layer is applied using photoresist spray mechanism.

2.2 Exposure

The photoresist (PCB BORD ALONG WITH PHOTO MASK) is exposed to a pattern of high intense light (U-V). The exposure to light causes chemical change which solidifies the photosensitive material called photoresist.

Developing

After exposing the PCB, the board is immersed in a solution that removes exposed/unexposed photoresist depending on whether it is positive or negative photo resist. The developer is a solution of sodium hydroxide (NaOH) in water.

2.3 Etching

In etching, a liquid chemical agent removes the uppermost layer of the substrate in the areas that are not protected by photoresist. Etching solution is a solution of (FeCl3) with water or HCl with hydrogen peroxide.

3. PLC BASED EXPOSURE UNIT

Most of commercial exposure units are operated manually which requires highly skilled labour to operate these machines. Employing highly skilled labour also poses problems like training, retention, safety to radiationsand quality. To overcome these shortcoming it needs to be automated by design and development of a retrofit.

Automation of exposure machine involves design, development and implementation of hardware and software in PLC environment.

3.1 Exposure machine:

Figure2PLC based Exposure Machine for PCB fabrication

Specifications:

- Dimension: 1,350 (w) X2,700 (l) X 1,750(h) in mm, weight approx. 1,030kg
- Electric power: 3phase 3wire 220-460V, 100-200 A, 50/60 Hz
- Lamp cooling method: indirect cooling method
- Exposure method: automatic shutter method
- Exposure frame: upper material: Mylar (thickness 125µm)
- Bottom material: glass (thickness: 6mm)
- Effective exposure area: 610X820mm^2
- Intensity uniformity: more than 80%
- Lamp: SMX-7000H super METAX 2numbers;(life500hrs) Intensity 30mw/cm^2
- MXA-7000H UV METALAX 2 numbers ;(life500hrs) Intensity 110mw/cm^2
- Integrator UV m -15x 2sets
- Power cable: bigger than 22mm^2
- External water: 15^{o}c 20 Lt/min
- (External water should not contain minerals such as iron, copper, lime etc.)
- Pure water: approx. 30Lt
- Room temperature: 22^{o}C.

3.2 Design of control panel:

In the process of automating the exposure systemdesigning of control panel is the most important step as it is the hardware for development which controls the process.

In order to design control panel the steps followed are

3.2.1 Preparation for Design

First and foremost step includes gathering details regarding number of limit switches, position sensors which acts as Inputs to PLC.Similarlyvalves, motors, Contactors, relayetc. acts as outputs of PLC.

These inventory should be ready with all the ratings in place. These details would facilitate selection of PLC with number of inputs and outputs.

The selection of the devices for input and output for PLC for a given task is an art in itself, because it demands understanding of the requirements of the process with conflicts and constraints. Knowledge of process, experience, intuition and empiricism play a big role in design and implementation. Typically the voltage rating of terminal devices being 24-110 V the relay board would suffice the purpose else contactors of suitable ratings would be selected.

The complete system is energized by SMPS which draws power from isolation transformer. The commercially available SMPS of standard ratings is used.

Motor drives are selected for given motor ratings and is fully protected with MCBs and Motor Protection Circuit Breakers.

3.2.2 Wiring Diagram

Once the inventory is in place with PLC selected and also ensuring the protection at unit level, the components are tied for the given application by proper Power Wiring and Control Wiring Diagrams.

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1. power wiring

Power wiringfocuses on energizing the selected devices by design for control panel. The components such as Contactor, Transformer, SMPS, MCB, MPCB, Motor, Drives etc. are energized. Depending on the current rating of the equipment choice of wire diameter is made.

2. Control wiring

As the name indicates the wiring includes the devices such as PLC-Relay,PLC-Contactors, Drives, sensors etc. Here the current rating is very small, generally about 4-20 mA requiring0.5 sq. mm cable.

The schematic of thecontrol panel is shown in Figure 3. Designed control panel is shown in figure 4.

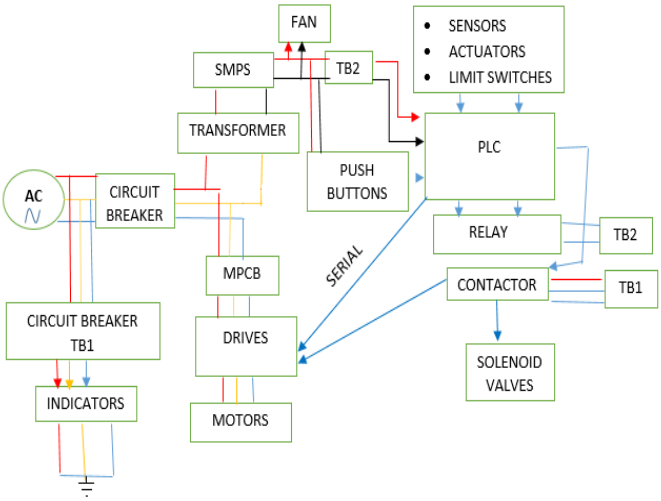

Figure3 Schematic of Control Panel

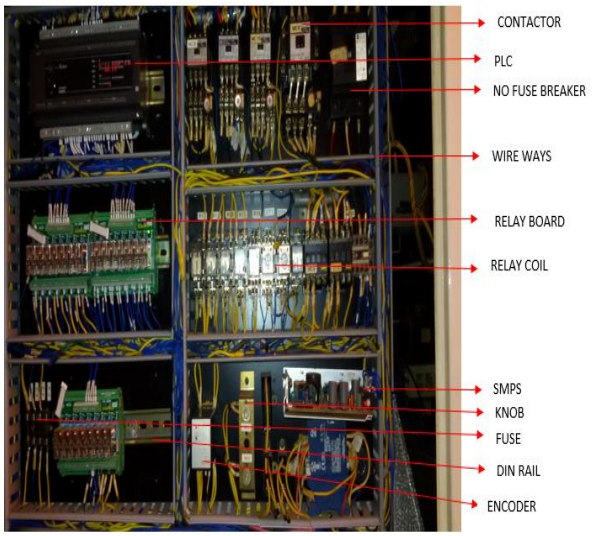

Figure4 Designed Control Panel

3.2.3 Development of Algorithm and Flowchart.

Once the control panel is designed the PLC has to be programmed. The Algorithm is prepared by knowing the whole process involved with the knowledge of instruction set.

1. Algorithm:

Step1: Energizethe machine and other accessories.
Step2: Check for errors if any rectify.
Step3: Place the work bit (PCB) and select for Auto/Manual operation.
Sep4: For manual operation turn on vacuum, push frame forward to the exposure area. Then open shutter, turn ON the lamps.
Step5: Integrator starts counting the intensity in terms of digital count.
Step6: the process halts when the present value is same as the set value. If present value is less than set value exposure continues until limit is reached. When limit is reached the shutter closes and lamp turns OFF.
Step7: turn OFF vacuum.
Step8: Frame reverses, ready for next operation.
Step9: If Process needs continue repeat step 3-9
Step10: if process is to be stopped push emergency stop switch and de-energize the machine.

2. Flowchart:

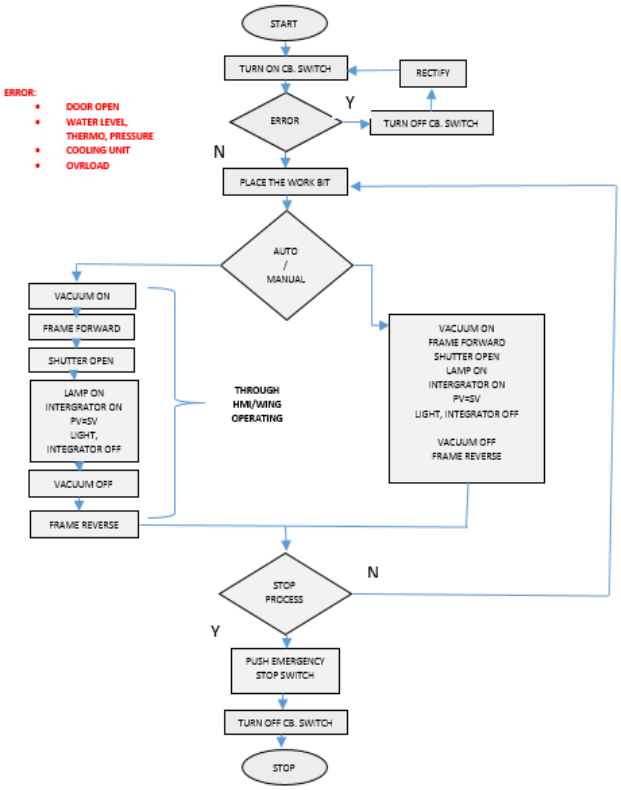

Figure5 Flowchart

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4. RESULTS:

The quality of PCBbefore and after automation by a retrofit are analyzed purely on the Stouffer readings.

Stouffer:

The Stouffer which is 21-Step Transparent Guide is known as "the plate maker's choice". It aids as a scale to assess the variables encountered in the exposure and processing of photolithographic plates and photographic materials by interaction. It is used with printed circuit boards, and most other photographic applications for judging quality in terms of contrast for emulsions, and hardness of coatings.

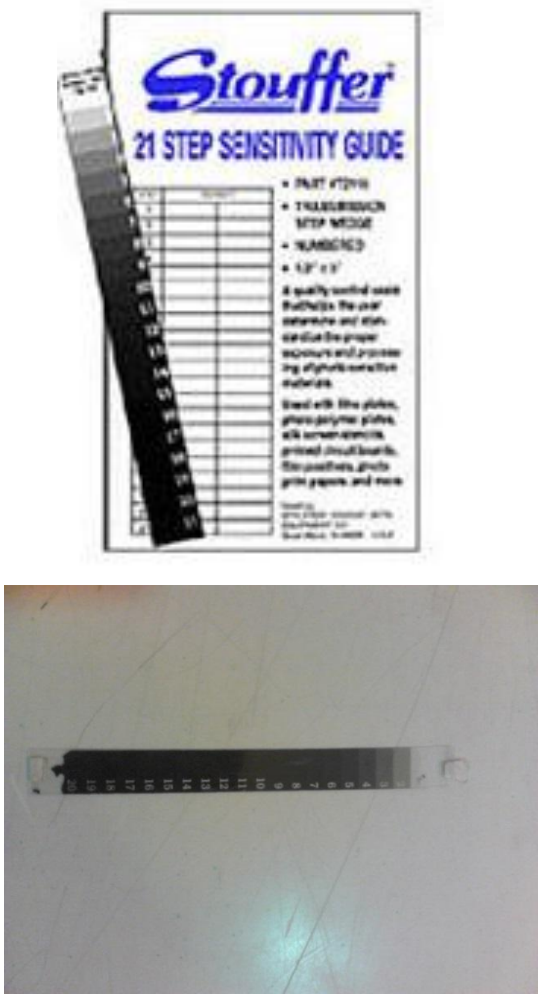

Figure6 Stouffer –21 step Sensitivity Guide

Case1:Results before automation

The PCBs before automating the exposure machine was tested and Stouffer reading was found as shown in Figure7.

Before the exposure unit was automated the Stouffer reading was in the range of 16-17(worst case) & 10-19(best case) which indicates wide range variation in PCB quality, without proper healing of the photoresist material which indicates lack ofexposure. The worst case had to be discarded of being poor quality thus resulting in a huge wastage of processed material.

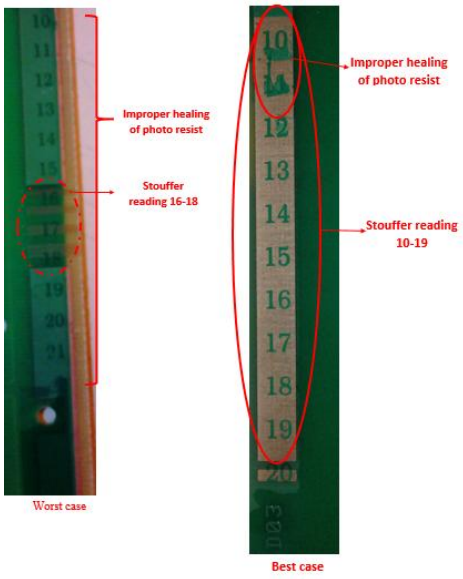

Figure7 Result of PCB before the Exposure Unit Was Automated

Case2: Results after automated retrofit

After upgrading the exposure machine to PLC based Exposure Machine (after retrofitting) result was taken and it is shown in figure.8.

The Stouffer reading is from 11-21 with complete curing of photo. This clearly shows better results obtained after automating the machine. Therefore PCBs quality are better after upgrading to PLC based control instead of manual control of exposure machine. Thus this retrofit enhances productivity and profitability.

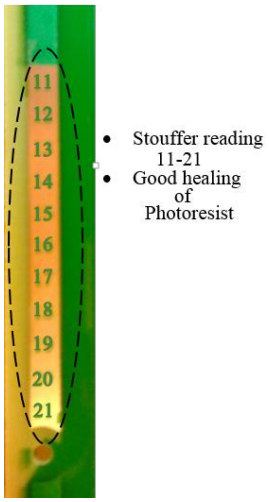

Figure8 Result of PCB Exposure after Automation

The standard exposure time for PCB is approximately about 120 seconds before automating, after automating the machine the exposure time was reduced to 80seconds this reduction of exposure time was achieved because of proper synchronization of process.

Conclusions:Retrofitting the machine with PLC provides state of the art control features for the application i.e. Exposure unit for PCB fabrication. PLC is versatile and has been industrially accepted worldwide for the ease of programmability. The use of PLC semi automates the application which ensures the quality of product reducing the cost and time of operation. Therefore these changes are brought in into the retrofit using PLC to improve the productivity and profitability.

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