Jarosław ZDROJEWSKI, Sławomir BUJNOWSKI,
Ryszard WOCIANIEC, Adam MARCHEWKA
UTP University of Science and Technology, Bydgoszcz
jaroslaw.zdrojewski@utp.edu.pl, slawomir.bujnowski@utp.edu.pl,
ryw@utp.edu.pl, adam.marchewka@utp.edu.pl

MULTI CAMERA OPTICAL SYSTEM FOR ALIGNMENT AND INSPECTION DURING PCB MANUFACTURING PROCESSES

Key words

Panel and film alignment, camera, optical inspection, supervision of the manufacturing process.

Summary

The paper presents a method of multipoint alignment using optical inspection of printed circuit board layers during manufacturing processes and exposure stage. The presented system is based on eight movable monochrome CCD cameras that supplies input data for the complex registration system. The article presents an analysis of the results of experiments for selected types of targets using the proposed location optimization method, allowing the evaluation of the correctness and stability of the system. The paper also presents an analysis of the efficiency and limitations of the proposed approach. In the article, the advantages of using the proposed method in the PCB manufacturing process are discussed.

Introduction

Printed circuit board manufacturing processes are complex. To get the proper results, the board has to go through many production stages. One of them, exposure (or printing), is crucial. It entails copper pattering on each layer, masking the pads and contacts, coating the layers, and making the pads and contacts "solder ready." Basically, the manufacturing cycle begins with the project files, including the specifications sent to the producer. It is conducted in a technological process consisting of following stages: exposure, development, etching, building assembly, lamination (for multilayer circuits), drilling, plating, solder masking, and label printing [2]. The whole process gets even more complicated when some connections in the multilayer printed circuit board are made using buried or blind holes. The majority of these stages require continuous control, which is mostly conducted automatically in optical measuring devices. The geometry and electrical parameters of the constructed circuit are measured to keep observed deviations within defined tolerance limits in order to reach the quality of the final product through applying the required corrections to the technological process [4].

Fig 1. Exposure system: a) alignment frame and solder mask panel ready for registration ad exposure, b) multi camera optical system for alignment and inspection, c) top view of then registration camera

The printing process is realized using exposure machines, currently being very sophisticated tools to expose a single layer of the circuit and to maintain alignment, control geometry, and track-layer position by a complex alignment process using a multi-camera optical system. A good example of the system is the printer shown in Figure 1a. The presented system is able to lead not only double-sided printing but also active registration of both sides – film alignment to the marks located on the panel. To have this ability, it has two separated sets of cameras. Each set belongs to a given side of panel and is dedicated to grab images and measure panel and film marks using image processing software [1, 8, 9, 10]. The data of the measured marks is directly used in the control process during alignment to move the axes assigned to the given film frame.

In the configuration of the system presented in Figures 1b and c, all cameras move in the X and Y direction with a range limited by specified minimal and maximal panel size. All four cameras located on the left can reach and measure some features on the left side of the panel, right ones on the right. A similar split exists for the top and bottom camera groups. Because the printer has to deal with fiducial targets, the system is using LED based illumination, and the etched marks are visible thanks to the reflection light bouncing back from the mask covered copper to the camera.

1. Films alignment based on multi reference marks

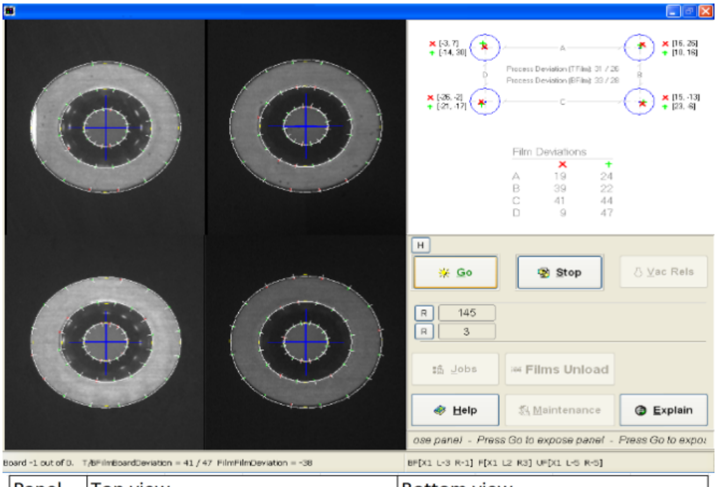
The registration system should be a compromise between the number of measurement points on the board, the number of cameras used, and the time needed to evaluate input data, which includes images from all sources [5]. Taking into account the requirements and the experience of production techniques for manual registration, two solutions were considered. The first uses two cameras per panel side and two marks on the board layout and films. In this case, the marks are located centrally in the symmetry axis of the two shorter sides of the panel. The second solution assumes the use of four cameras per panel side and appropriate marks located in the corners of the board. In general, if printer is running double-sided exposure and alignment on both side is required, two or four registration marks on the bottom of the panel and the same two or four on the top are needed.

Regardless of the number of marks and number of cameras, film positioning is aimed at optimization. Optimization the task of minimizing the position deviations, which depend on both instable film size and the variable location of the panel holes used as registration marks.

System can operate in two different tolerance modes [3]: dimensional deviations (film to board) and alignment deviation. The basic mode is the mode of DA (Dimensions/Alignment) in which dimensional tolerance [7] and the alignment tolerance are defined separately. In this mode, the measuring system will calculate the position of the registration marks based on processed input images from the cameras. Using this data, the system will separately calculate dimensional deviations for both the films and the alignment deviations film to board or film to film. All calculated values will be compared with a given tolerance level. If the dimensional deviation is greater than the dimensional tolerance (DT), the system will stop the registration procedure and an error message describing the reason will be presented to the operator. In the case of crossing the tolerance limit for the alignment deviations (AT), the registration process will be repeated and new deviations will be compared once more with the given tolerance values.

2. Experimental results

At the start of the research, it was assumed that, during the production process, a comparison between single and double camera layer mode has to be made. To reach this goal, a special type of target was introduced. It was crucial to have good alignment conditions for configuration of the 8 cameras, and it was necessary to have access to the data [6], usually supplied by a single set of sources based on 4 corner marks and holes on the top film.



Panel	Top view				Bottom view			
nb	x	yl	yr	pd	x	yl	yr	pd
1	-6	14	9	30	-7	12	12	37
2	4	12	15	38	1	10	15	45
3	-12	-7	11	33	-14	-8	12	40
4	-6	-6	-2	25	-9	-3	3	32
5	-12	1	3	27	-14	-5	2	34
6	-13	2	13	30	-15	3	13	37
7	-6	-12	-13	34	-9	-11	-14	41
8	-3	-13	-2	33	-7	-13	-6	41
9	-12	-8	-1	31	-9	-7	-2	38
10	12	-3	-11	32	12	-5	-10	39
AVG	-5,35	-2,01	2,15	31,20	-7,10	-2,72	2,50	38,31
B/T %					1,33	1,35	1,16	1,228

Fig. 2. Results showing the results screen of the control program and table including a comparison of alignment error and process deviations

Final verification was made on the optical measuring machine, where each single side was measured independently. Results of the research process are presented on Figure 2. Figure 2 shows the ratio of the reduction of two important factors. The average value of the align error was reduced by 28.1%, and process deviation was reduced by 22.8%. The presented data do not include the values representing bottom film alignment, because the conditions for this layer have not been altered from standard operation. It is important to notice that outer layer exposure was made on the same printer and the level of error reduction is basically limited by the precision or imprecision accepted in the previous production stage. Of course, in any case, imprecision represented by alignment error is limited by alignment strategy tolerances defined in the job.

Conclusion

The multi-camera optical system for alignment and inspection supports production quality control and provides opportunities for measurable benefits in terms of minimizing both the alignment error and impact of films and panel dimensional deviation. In comparison to the standard single side camera setup, significant improvement for the top film position in relations to the etched top outer layer was noticed. Beside an enhanced hardware configuration, stable and reproducible operation was observed. Threats to the proper operation of the registration process are interferences from external friction, which is a side effect of the sticky mask panel surface and the bottom film. Those limitations have a large impact in the situation when the alignment process has to be repeated under conditions defined by job tolerances.

Applying of multi-camera optical system for alignment and inspection in the process of printing mask panels allows one to enhance registration capability, alignment process control, and printing feedback in better selectivity and accuracy compared to the regular procedure. Final alignment quality can be ensured and verified right before printing.

The use of the multi-camera optical system for alignment and inspection allows obtaining significantly better mask printing results. The achieved reduction in process deviation displays the possibility for a strong recommendation for the mask printing applications.

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Wielokamerowy system pozycjonowania klisz w procesie wytwarzania PCB

Słowa kluczowe

Pozycjonowanie klisz i paneli, kamera, inspekcja optyczna, nadzór procesu wytwarzania.

Streszczenie

W artykule opisano metodę wielopunktowego pozycjonowania przy użyciu inspekcji optycznej warstw obwodu drukowanego w czasie wytwarzania i na etapie naświetlania. Prezentowany system zbudowano w oparciu o osiem przemieszczalnych, monochromatycznych kamer CCD dostarczających dane wejściowe do złożonego układu pozycjonującego. W artykule przedstawiono analizę wyników eksperymentów dla wybranych typów znaczników i zadanej metody optymalizacji, co pozwoliło na ocenę poprawności zachowania i stabilności układu. Artykuł zawiera analizę efektywności i ograniczeń przedstawionego rozwiązania. Poddano dyskusji zalety użycia zaproponowanej metody w wytwarzaniu PCB.