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OVERVIEW OF AOI USE IN SURFACE-MOUNT TECHNOLOGY CONTROL

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Abstract. *Surface-mount technology is now widely used in the production of printed circuit boards in the electronics industry and has gained many supporters. The miniaturization of electronic components has forced the introduction of machines for visual inspection of assembly correctness, which is more accurate and faster than the human eye, magnifier or microscope. Automatic Optical Inspection (AOI) is a control process that detects defects and errors in the initial PCB manufacturing process. It has become an indispensable element of contract assembly, increasing the quality of services offered and production efficiency. It uses new designs of measuring heads, miniaturization of equipment, software processing the obtained images of boards, and complicated image transformation algorithms.*

Keywords: Automatic Optical Inspection, defect inspection, solder joints, surface-mount technology

PRZEGLĄD WYKORZYSTANIA AOI W PROCESIE KONTROLI MONTAŻU POWIERZCHNIOWEGO

Streszczenie. *Technologia montażu powierzchniowego jest obecnie szeroko stosowana w produkcji zespołów obwodów drukowanych w przemyśle elektronicznym. Zyskała ona bardzo wielu zwolenników. Miniaturyzacja komponentów elektronicznych wymusiła wprowadzenie maszyn wizualnej kontroli poprawności montażu, bardziej dokładnych i szybszych niż ludzkie oko, lupa czy mikroskop. Automatyczna Inspekcja Optyczna (AOI) to proces kontroli wykrywania wad i błędów w początkowym procesie produkcji obwodów drukowanych. Staje się nieodzownym elementem montażu kontraktowego, wpływając na zwiększenie jakości oferowanych usług i efektywności produkcji. Wykorzystywane są w niej nowe konstrukcje głowic pomiarowych, miniaturyzacja sprzętu, oprogramowanie przetwarzące otrzymane obrazy płytek, skomplikowane algorytmy przekształcania obrazu.*

Słowa kluczowe: Automatyczna kontrola optyczna, kontrola defektów, połączenia lutowane, technologia montażu powierzchniowego

Introduction

In many respects, surface mounting technology is assessed as better than through-hole mounting. The occurrence of defective products when using this technology is mainly due to technological problems, but sometimes it is also caused by management problems or human error [23]. Automatic Optical Inspection is used to control SMT [20]. It is here that any assembly errors are easily detected. The AOI device scans the printed circuits in terms of features characteristic of PCB surfaces [28].

1. Basics of AOI

Components used for surface-mount technology are characterized by small dimensions. They have flat housings and “flange” solder tips that engage the end of the housing. On the other hand, the soldering tips are of larger sizes [10]. Figure 1 shows some of the electronic components used in the production of PCBs. The components attach directly to the boards. When more elements are required on a smaller surface, the plate is printed on both sides. Connecting the leads takes place in a specially designed furnace.

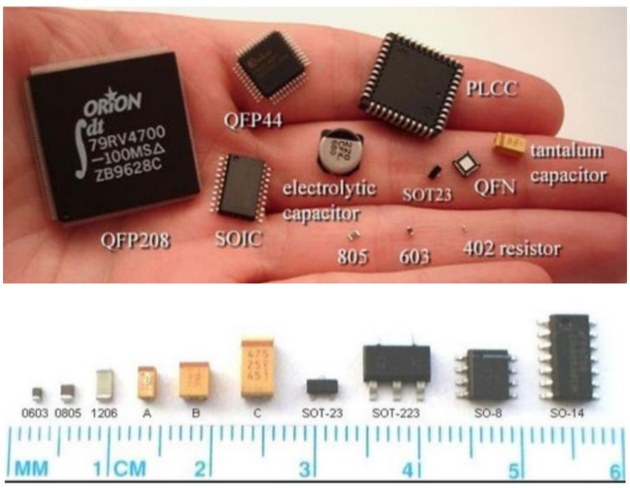

Fig. 1. Components used in PCB production using surface-mount technology [11]

The lack of reliability and repeatability of manual controls required a more thorough approach using automated systems. Equipment based on AOI tests such parameters as shape detection, and the presence of the required components. Top face coplanarity, component width, length, and height, angles, component polarity, component surface text, solder volume and height, bearing and solder deficit are checked. The height of the arms and the feet of the legs, and the short circuit between the solder joints are also tested.

2. Development of technical solutions

Today, many companies offer AOI equipment that provides comprehensive proof test coverage and minimizes false calls [29]. There are many design solutions available to provide the user with the best possible assistance in the quality control process in terms of the adopted budget [25]. The technological development of AOI-based equipment continues. The hardware development started with an inspection system using a two-dimensional machine to detect solder defects after brazing [32]. These include solder bridges and missing components. This could improve electronics productivity and create assembly lines. Further advances in surface mount technology created a need for more precise ways of controlling component placement and assessing soldering quality [33]. Initially, an inspection system based on two-dimensional vision defined the future direction of changes in plate quality control.

Automated optical 3D inspection systems provide a precise metrology system, eliminating shadows, image cropping and distortion, providing reliable data and high-resolution 3D visualization for even the most complex product geometries [34].

2.1. Hardware design

The passage of time and the desire to obtain an accurate method of welding boards forced the development of such equipment. As surface mount technology advances, greater defect detection is being introduced to the processes to meet stringent requirements. Efficiency and quality indicators are also important.

The most commonly used automated inspection methods are based on vision, infrared (IR) [31] and X-rays [14]. The constructed structures allowed for the detection of defects at the surface level, determination of the mass of solder present, and determination of linear and angular alignment. X-ray inspection was used to obtain pictures of the soldered joints.

There have even been online inspections of surface mount components using vision and infrared sensors [6]. The use of vision and infrared sensors allowed for the separation of solder joint defects. The vision sensor used in the construction provided information about defects at the surface level. On the other hand, the infrared sensor informed about a defect of solder paste. Diagonal and flat lighting techniques were used. 2D grayscale images of the plaques were obtained and further processed to uncover the corresponding defects. The limitations of the automated systems resulted from the range of the individual sensors in classification of the known defect range.

Paper [27] presents a technique of controlling the solder paste by means of directional LED lighting obtained from a camera mounted from the top. The use of lighting allows 2D images to be obtained. This is a quick method that shows the defects of a lack of solder. To better illustrate other defects, directional side lighting was used in the construction to obtain 2.5D images.

During the testing, a sequence of three images is collected. Image processing is then performed to detect geometric defects in the solder paste. The proposed method also detected other defects, previously invisible by using only light from above.

An example of a vision system was also presented in [4]. The upper vision module was mounted on a gantry that was attached to a movable cart. The location of the upper CMOS camera can be precisely adjusted along the Y and Z directions for positioning. The overhead vision module consisted of an ImagingSource DMK41BUC02, a metal oxide semi–con–ductor (CMOS) camera combined with a Moritex MML1-ST65 telecentric lens and a horizontal backlight illuminator – Figure 2a. As shown in Figure 2b, the side vision module consisted of a CMOS DMK41BUC02 imaging source camera (side CMOS camera) in combination with a Moritex MML1-ST65 telecentric lens, ring illuminator, and vertical illuminator. The ring illuminator was installed on the lens barrel. The illuminator was installed on the side plate of the module.

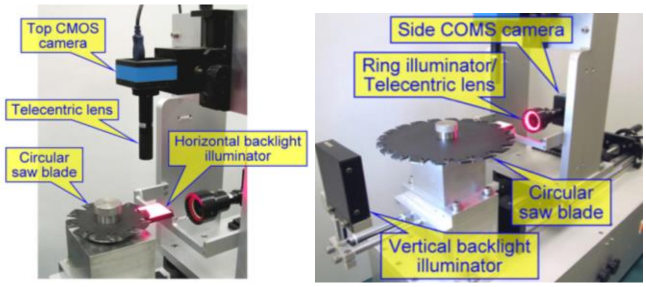

Fig. 2. The constructed AOI system: a) setup of the AOI system for radial runout inspection; b) setup of the AOI system for axial runout inspection [4]

In [24], an illuminator was used for the automatic optical inspection system. The structure of the designed illuminator consisted of three arrays of light emitting diodes (LEDs). The diodes used have different colors and radiation angles. The resulting new model of illuminator radiation and solder joint irradiance was tested, with promising results. The optimized dimensions of the illuminator, based on the irradiation intensity model, gave rise to a new research project.

Modern inspection systems provide comprehensive checks of the body of the element and the solder joint by combining a 2D texture with a 3D inspection. Additionally, they detect and prevent misplaced components. Figure 3 shows the components of the AOI measuring head. It includes: laser, high-resolution camera, telecentric optics, angular cameras, and LED lighting.

The device, equipped with many features, ensures efficient and reliable control. The design of the AOI equipment enables precise vision setup, although it is important to position individual boards. The ability to search for an element by name is useful for repairs, and it has an optimized user interface that signals both successful operation and errors via colors.

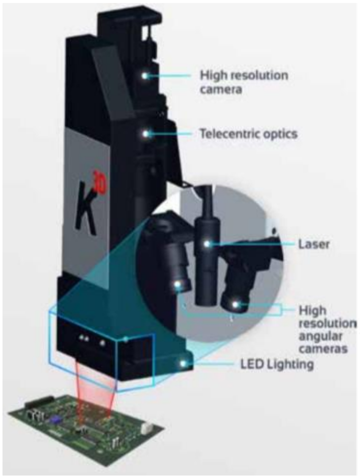

Fig. 3. Diagram of the AOI measuring head [12]

2.2. AOI systems

Fully integrated control of the tile production process would not be possible without the creation of software that allows you to measure its components. Even the best audit data requires intelligent information management. The software packages available on the market today provide a data source for solder paste inspection (SPI) and automatic optical inspection (AOI) data. Another important tool is the advanced image library tools with algorithmic help [8]. They contain industry-certified images in data libraries, so you can view the process in real time, and quickly drill down into the details in the picture and take corrective action. This saves time correlating databases, and more time getting to the root cause of the fault.

In [18], an optimal design of an automatic inspection system for processing light-emitting diode (LED) chips was discussed. The system is based on a support vector machine (SVM). To effectively design a defect classification system based on an SVM, many qualitative parameters need to be designed [2]. Figure 4 shows the procedure for using the system from [18]. It is based on two types of classification, experiment planning, component analysis, and defect classification result verification. The process enables micro-defect breakdown and quick classification, high accuracy and stability. It is applicable to high-precision LED detection, and can be used to accurately inspect mass production LEDs to effectively replace visual inspection, saving labor costs.

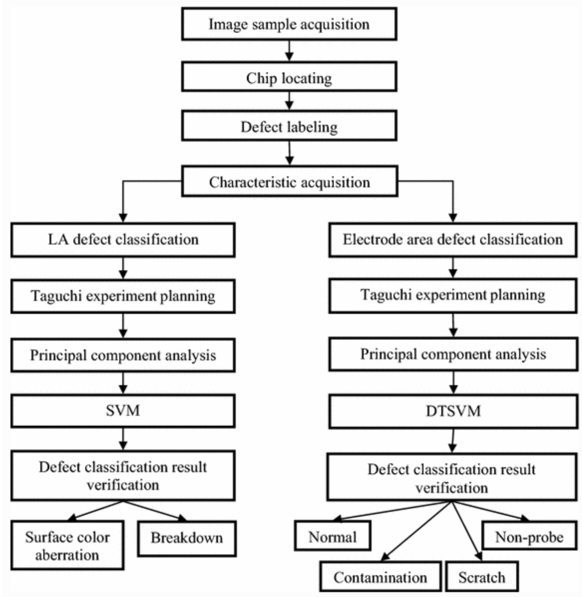

Fig. 4. Defect inspection system – flow chart [18]

Based on the development of the process of controlling micro-defects of the surface of LED chips, the application of an intelligent algorithm in industrial automation for the inspection and division of LED defects will be discussed. After image acquisition, chip localization and characteristic defect acquisition, planning of the image characteristic value and classifier design takes place (Taguchi method combined with PCA). An SVM is used to distinguish between surface color aberrations. A DTSVM helps to distinguish between normal, debris, scratch and missing probe. By comparing this against traditional DT, NN (Nearest Neighbour Algorithm) and LIBSVM (A Library for Support Vector Machines) [2], it has been verified that the established classifier has better accuracy and reliability for industrial automation control.

Equipment based on AOI tests such parameters as: shape detection, the presence of the required components, the coplanarity of the upper surface, the width, length, and height of the component, the angles, and the component polarity. It also checks the text on the component surface, the soldering volume and height, bearing and soldering deficit, the height of the arms and the feet of the legs, and a short circuit between soldering. The software ensuresmissed unmounted elements, skipping damaged boards, and parameterization of patterns [4].

Additionally, the import and export of pick & place files via the built-in converter is very functional [26]. The systems also provides the export of data supporting cost estimation, editing of component housings with the possibility of creating new types, and support for individual stages of work on the project. One of the latest features of inspection machines is that they can be networked to allow immediate feedback to the previous machine to enable automatic adjustments [22]. With the introduction of 3D technology, this process became more reliable; 3D inspection allows for more accurate measurements and provides a more stable inspection process [13].

The combination of software and stable production makes it possible to continuously improve the product in the production process. Human interaction will always be involved when solving technological problems. This is because product quality is related to the quality of the material, the product design and the manufacturing process [5]. Improving product quality affects people, machinery and materials. It is also important to implement a process-oriented overall quality control system.

2.3. Processing of images received by AOI

Many methods were used to process the images obtained with AOI. They include a number of automatic methods [16, 30] and integrated systems [1, 3, 21]. Article [7] discusses the quality control of inserts using one of these technologies: a component twist or pin defect. At the beginning of the development of the field, binarization techniques, torsional angle estimation methods and various techniques of morphological image processing were compared.

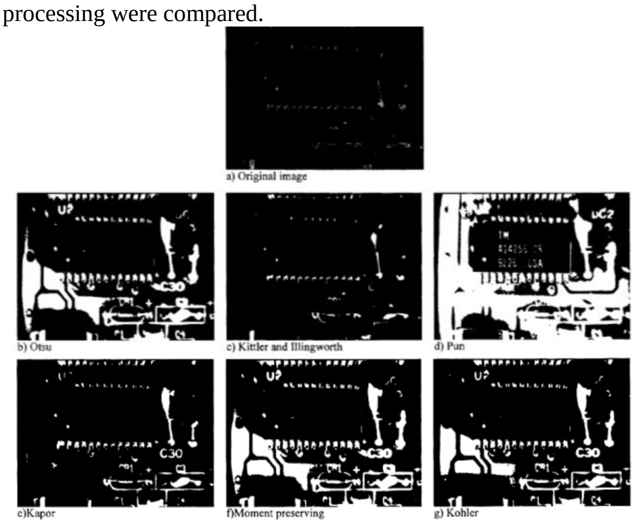

Fig. 5. Results of the thresholding methods [7]

Figure 5 shows the effects after thresholding the original image with different 6 methods. Pun and Otsu thresholding have been found to be beneficial for this particular application. Morphological methods provide robust tools for detecting missing pins and un-drilled washers.

A very important process is to assess the quality of small elements on the board surface. One of them is a light emitting diode (SMD-LED). Visual inspection may result in misdiagnosis due to different recognition standards. An automatic SMD-LED defect detection system was developed in [11]. Non-contact control and defect recognition standardization were used here. The developed software detects common and important defects of the elements of the LED package, including missing element, no chip, wire offset and foreign material [8]. The diagram of the procedure is presented in Figure 6. Image processing starts with ROI selection, then texture anomaly is detected by multi-scale adaptive Fourier analysis (MAFA). The segmentation threshold is selected based on the entropy information to successfully segment the weld line. Figure 7 shows the program window, where the user can choose from the ROI image and provide the selected element for analysis. The result proves that the proposed method can correctly and efficiently segment the defect, in comparison to phase transform (PHOT) and multi-scale phase transform (MPHOT), and can be used in other fields of texture anomaly detection. The overall recognition rate of this system is 98.25%.

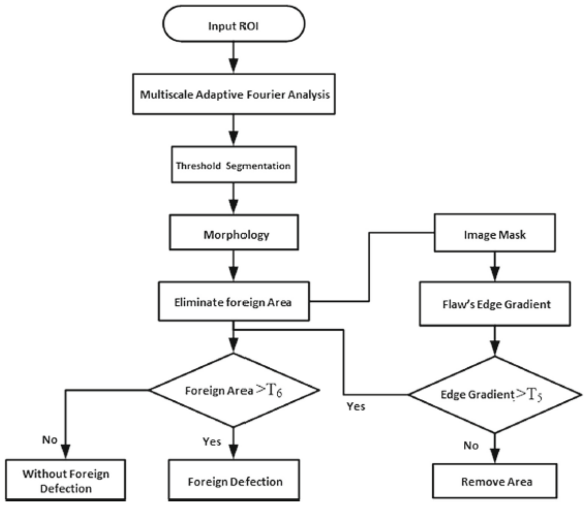

Fig. 6. Overall foreign material defect detection process from [8]

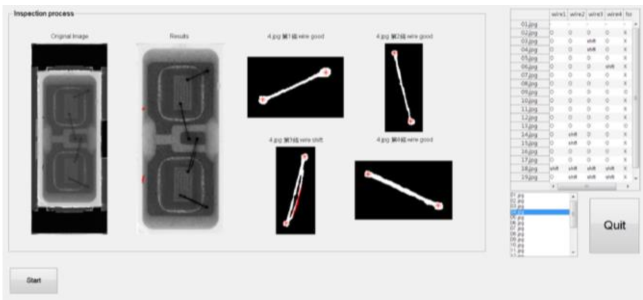

Fig. 7. View of program window from [8]

Article [9] presents an innovative approach to examining the defects of BGA components – the spherical grid system. These are high-density components with large-scale integration. The image transformation processes begin with adaptive thresholding in combination with a modified (ε, δ) segmentation of components. A grayscale image of the solder beads is obtained. The next step is to use the line-based grouping method to recognize the ball array. Due to the mentioned actions, the exact position and orientation of the BGA is obtained. The final step is to extract the ball element to diagnose any potential defects. The proposed procedure is satisfactory for most BGA systems with different spherical arrays.

3. Summary

The use of surface mounted devices (SMDs) creates the need to reduce costs while maintaining quality, reliability, process continuity and the possibility of their continuous modification. The complexity of the tests performed requires the continuous development of automated sequences used for quality control. However, for smaller productions, a combination of automatic optical inspection and electrical testing is used. The effectiveness of both of these activities is determined on the basis of the measurement accuracy and consistency of the measurements [19].

The advantages of surface-mount technology include automatization, miniaturization, high density of component placement, and the possibility of placing components on both sides of the printed circuit board. Low connection impedance improves properties at high frequencies. An additional advantage is the good mechanical properties under shock and vibration conditions resulting from the lower weight of the components. Surface mounting ensures quick assembly, the possibility of combining machines into a production line, and low production costs. All design, system and image processing solutions are part of the efforts to help increase the efficiency, quality and repeatability of plate inspection.

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