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OVERVIEW OF THE USE OF X-RAY EQUIPMENT IN ELECTRONICS QUALITY TESTS

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Abstract. *Surface-mount technology is now widely used in the production of many components. The development of the miniaturised electronics industry forces the development of increasingly accurate inspection methods. X-ray and computed tomography are methods to accurately assess the quality of a circuit board. The article discusses the basics of image formation of the tested electronics, the development of the design of the devices used and examples of x-ray, computed tomography applications.*

Keywords: defect inspection, electronic components, industrial radioscopic systems, X-ray, computed tomography

PRZEGLĄD WYKORZYSTANIA URZĄDZEŃ RENTGENOWSKICH W BADANIACH JAKOŚCI ELEKTRONIKI

Streszczenie. *Obecnie technologia montażu powierzchniowego jest szeroko stosowana w produkcji wielu podzespołów. Rozwój zminiaturyzowanego przemysłu elektronicznego wymusza rozwój coraz to dokładniejszych metod inspekcji. Metodami pozwalającymi w dokładny sposób ocenić jakość płytki drukowanej jest wykorzystanie promieniowania rentgenowskiego i tomografii komputerowej. W artykule omówiono podstawy powstawania obrazów badanej elektroniki, rozwój konstrukcji wykorzystywanych urządzeń, przykłady zastosowań RTG i tomografii komputerowej.*

Słowa kluczowe: kontrola defektów, komponenty elektroniczne, przemysłowe systemy radioskopowe, promieniowanie rentgenowskie, tomografia komputerowa

Introduction

The emergence of surface assembly and miniaturization of electronics made it possible to develop smaller mobile devices [3]. Assessing the quality of manufactured components and electronics assemblies in the electronics industry encounters many difficulties. There are many problems with the quality of the components in the components, the production process and the selection of the [14].

The following components are assessed on the surface of the circuit boards: their soldering method, the size of the mounting holes, the presence of paths, mechanical damage [1]. The presence of many solders on the surface of the tiles requires automation of the entire evaluation process. Automated devices are created for this purpose. These include automatic optical inspection [4, 5], laser head measurements, X-ray tubes and computed tomography. The technical requirements set at different stages of production challenge research laboratories [9]. During non-destructive testing, electronics are exposed to extremely high or low temperatures, humidity, vibrations, impacts.

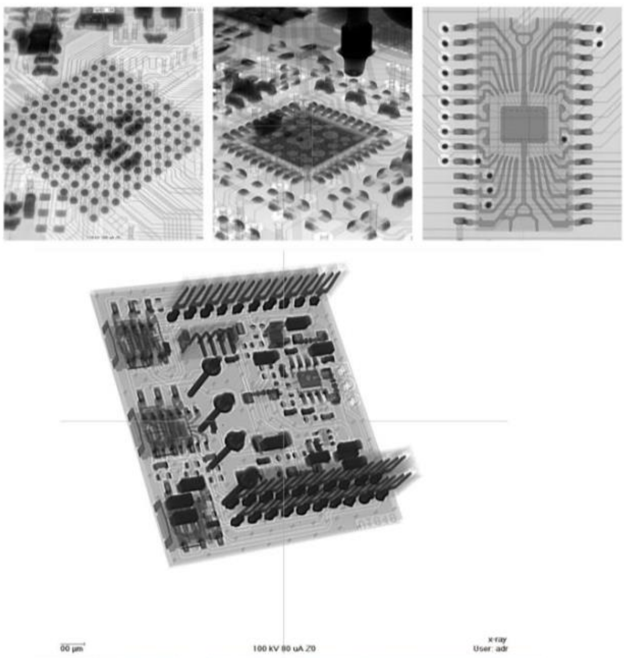

Fig. 1. Examples of tests performed on an X-ray inspection device [12]

The most common defects on the printed surface of the board include excess soldering, displacement of the geometry of small elements, tilt of the elements relative to the board, soldering porosity, excess soldering, unwanted splashes. Fig. 1 shows examples of images of SMD tiles tested. Increasingly, applications are using 3D visualization so that opera-track can better assess the quality of the manufactured product.

1. Basics of radiology inspection

X-rays are a type of electromagnetic radiation with a wavelength from a few pm to 10 nm [6]. Electromagnetic radiation is distinguished by an oscillating electrical and magnetic field in the system, shifted relative to each other at an angle of 90 degrees (Fig. 2). X radiation is characterized by a certain wavelength and frequency.

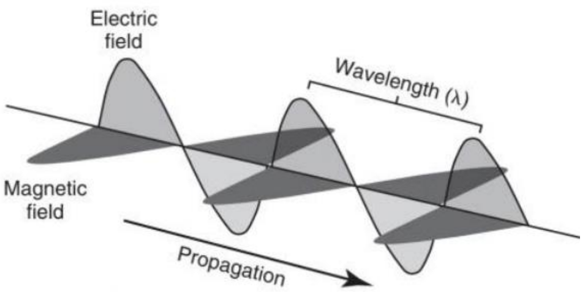

Fig. 2. X-rays propagation [28]

X-ray radiation is obtained by an X-ray tube and electrons quickly hitting a metal element. It is built of glass vacuum banks, in which they are connected to a high-voltage source of cathode and anode. The vacuum produced prevents electrons from interacting with air molecules. So they move very quickly [6]. The cathode, usually made of tungsten fiber, emits electrons. Electrons are accelerated in the electric field and emit X-rays when they collide with the anode. X-ray tube operation requires anode cooling [11, 26].

X-ray check-up scans allow accurate monitoring of several platelet quality criteria (PCB). Unlike X-ray inspection scans, CT scans provide complete 3D information [23, 29]. X-ray inspection is possible even without sufficient lighting. The resulting tomography sections allow the reconstruction of images in two and three dimensions. As part of ct software development, automatic 3D reconstruction is becoming faster and more efficient [8, 7, 20].

X radiation can penetrate various materials. Their density determines the color in the resulting image and allows you to distinguish the materials from each other. [17, 18]. Fig. 3 shows the differences in absorption, photon transmission for different materials. The higher the density of the material, the lower its apenetration. High dose absorption gives a smaller number of transmitted photons. The opposite occurs for materials with low absorption efficiency.

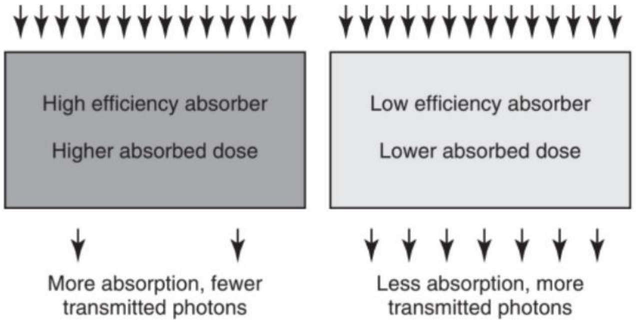

Fig. 3. Comparison of two materials with different properties very significant for X-ray imaging [28]

2. Solutions development for industrial radioscopic systems

In [21] x-ray inspection is used for technological processes in 2 and 3 dimensions, due to the use of projections from multiple projections of the test element. An important aspect in X-ray examinations is the amount of radiation dose that the tested electronics take. To increase the measurement accuracy of many manufacturers increases the amount of radiation energy. There are elements sensitive to it.

In [10] results obtained through X-ray and CT inspections. The authors paid particular attention to the difference in the resulting image received. Radioscopy allows inspection in two dimensions, computed tomography in addition to measuring objects in 2D gives the possibility of its full visualization in 3D. Also important is the process of reconstructing images, where a lot of time is devoted to developing the best algorithms to prepare a model of the projected element in 3D. Real-time 3D computed tomography imaging is possible with pulsed multipixel sources. The use of small CNT FE cathode and fast switching gives new measurement capabilities [24].

3. Industry systems based on X-ray

Automating the process makes it a reliable method to monitor the prototyping process, implement serial production and quality control at different stages. The emergence of many systems based on X-rays allowed for inspection of many components of electronics. During the production of electronics, many defects related to solder connections are created. X-rays are used to determine their quality.

The use of image processing algorithms obtained through X-rays is becoming an important part-time. The difficulty lies in segmenting the solder connections and the spaces in them. To this end, a weave network used to classify images after segmentation was created in [30].

In order for X-ray inspection to be an even more perfect way of imaging, further work is needed to improve it [21]. X-ray sensors were improved to provide better contrast and resolution to the resulting images. It is also important to continuously improve the algorithms responsible for transforming the images received. Machine learning methods, process speed and efficiency, hierarchical control are taken care of.

In [31] investigated how empty spatial solder connections affect its quality. The size, place and frequency of defects were taken into account. The SMT X-ray radiography control process is proposed in [25]. Table 1 provides a comparison of inspections of the main types of defects on SMT boards concerning defects in brazed connectors. In [21] defects such as: solder bridges, open connects, lifted lead, aignment between pad and lead, solder thickness and others were observed using visual inspection and X-rays.

Table 1. Comparison of defects occurring on brazed connectors. Markings used: ++ VERY RELIABLE , + RELIABLE, o FAIRLY RELIABLE [21]

Features	X-Ray Inspection	Visual Inspection
Solder bridges	++	+
Open connects/lifted lead	+	+
Alignment between pad and lead	+	o
Solder thickness/volume	++	−
Shape of heel fillet	+	−
Shape of toe/center fillet	+	o
Wetting angles	+	o
Cold or disturbed joint	−	+
Dull solder	−	+
Porosity and voids	++	−
Solder balls	+	o

In [16] X-ray images (Fig 4a) were analysed. To this end, an algorithm based on contour ball joints. classicization was created. Scientists have developed a radar greyhound. If the result of the analysis falls outside a specified circle (Fig. 4b), it is considered bad. Figure 4c was considered to be the correct level of 10, the higher results were considered to be reshaped BGA. In Fig. 3a in the yellow circle marked objects that did not pass the quality control process.

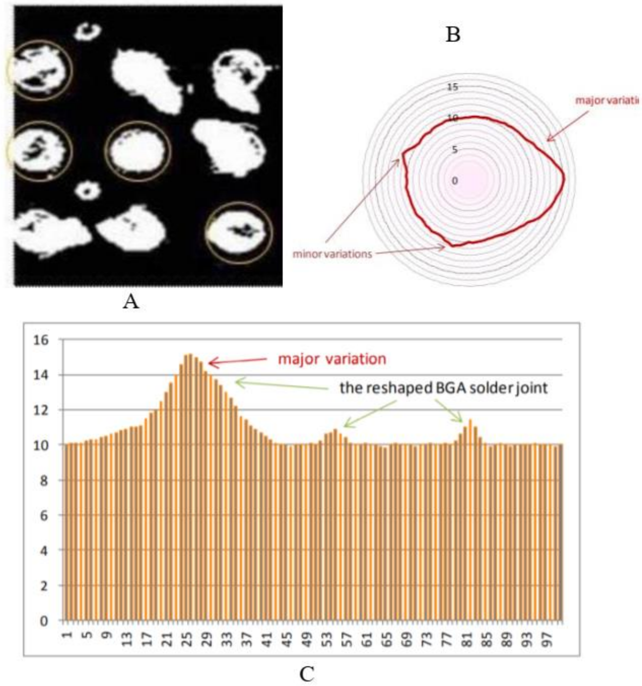

Fig. 4. Image classification x-ray ball joints: A – original images, in yellow circles element classified as vicious balls; B – radar chart; C – contour plot [16]

In [32] the quality of chips, chip washers was checked for soldering process. The development of x-ray lamp and detector technology enables work on nanofocus and multifocus X-ray systems. Developed software, image processing algorithms, increased stability, position constancy allows the use of X-rays for electronics control [19].

4. Industry systems based on CT

The use of computed tomography in the electrical industry has greatly accelerated the way quality control and individual tiles. Many methods based on X-ray systems have been used in non-destructive test (NDT) inspection and testing processes.

In [13] uses a quantitative, three-dimensional method of analysis of soldering properties and defects by CT, the use of which gives a number of new methodological possibilities In a precise and efficient way, a quality control process for PCB components can be ensured. The process allows for the catching of defective components and an increase in the quality of manufactured assemblies or components ingested in electrical equipment and systems [15].

In [27] oblique CT allows you to examine the quality of the shape of the solder tumor. Due to the limitations of the mechanical structure and the speed of performing scans in [27] a different approach to oblique CT and 3D reconstruction is presented. The use of an open X-ray generator and the FBP 3D method (Filtered Reverse Projection) yielded very good results. Projection from different directions is possible using a rotary flat panel detector transfer. Solutions are also being created based on Planar Tomography Computer (PCT) [21]. It enables much faster reconstruction based on the linear movements of the test object.

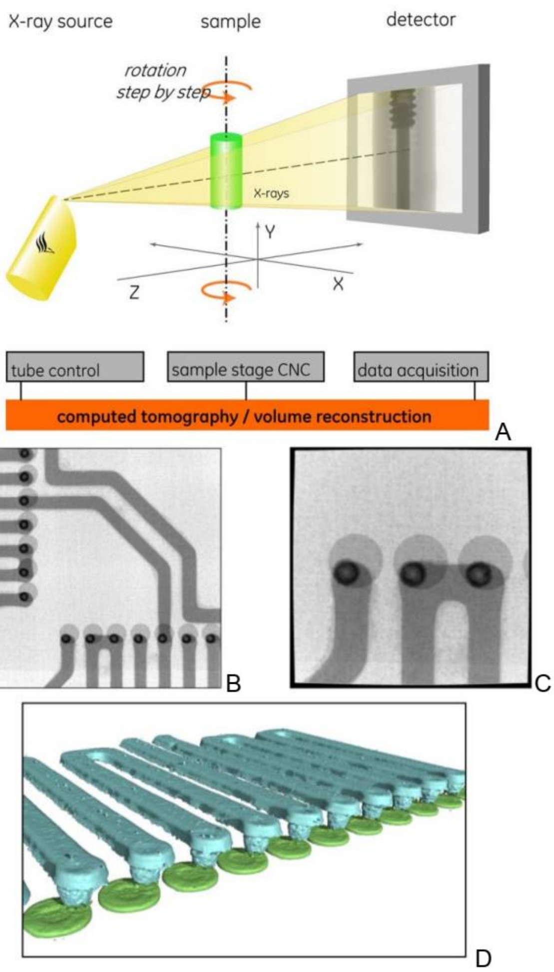

Fig. 5. A – functional and structural diagram CT; B – X-ray images (1 µm/pixel); C – X-ray image (0.4 µm/pixel); D – Visualization of 3D CT, voxel 1.2 µm, through diameter about 50 µm [26]

Researchers are working on different focal length x-ray lamps. Higher resolution of the resulting image can be achieved by modifying the focal length of the beam. Among these modifications, microfocus should be calculated [23, 29]. Nanofocus and microfocus CT are increasingly used in the study of miniature electronics components. In [26] nanofocus images have been obtained using X-ray microscope and CT. The system in figure 5 provides CT reconstruction software and region-of-interest-CT (ROI-CT). The use of x-ray image enhancers in 2D allows you to achieve much better image quality. For CT, however, image quality has been improved with low noise and a DXR detector.

In [2] compared images obtained from full CT and off-lin PCT. Both tools allow for 3D rendering, full CT is better suited for Z and X, Y 2D planar view image quality. In PCT 2D images are done at an angle in advance, the data set is much more limited, reconstruction does not give the full result. In full µCT we have a different shape. Figure 6B shows a view from the software window, which can measure the thickness of the soldering.

Another good solution is the FE source, which guarantees control over the position of the beam emitter at the nanofocus [26]. Individually addressed electron beams allow you to control the shape of the X-ray beam. Multipixel sources [8, 29] used in CT have a number of advantages. These include: higher spatial resolution and subsequent formation of the radiation beam. The images shown in Figure 7 were created by CT based on an electron control system and x-ray beam shape.

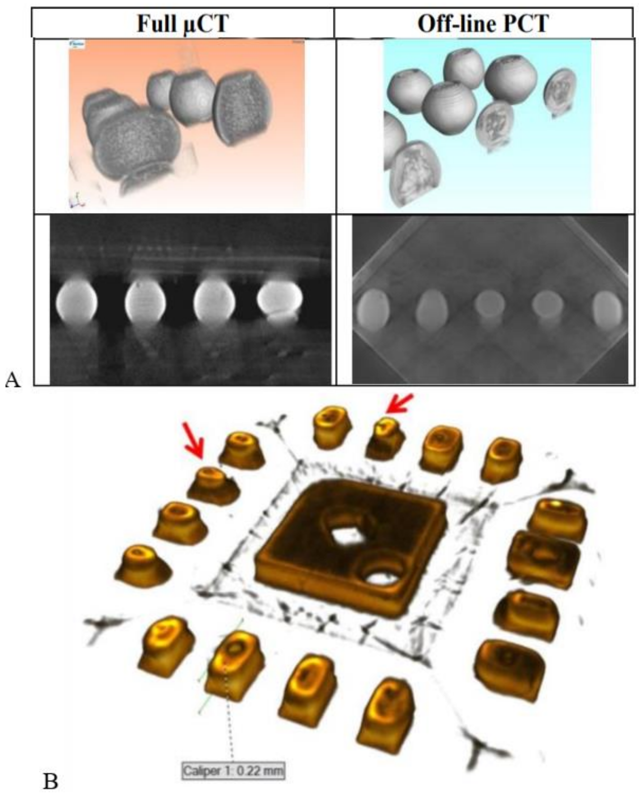

Fig. 6. A – Comparison of images obtained using full µCT and offline PCT methods; B – PCT 3D model with marked missing connections (red arrows) [14]

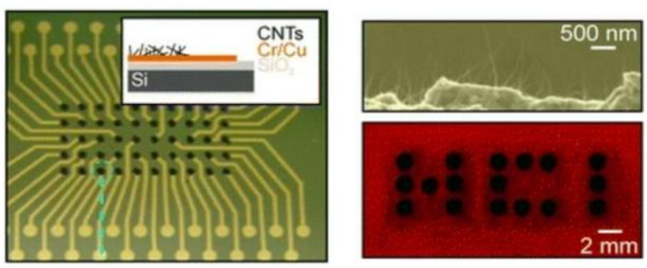

Fig. 7. Comparison of two materials with different properties very significant for X-ray imaging [23, 29]

5. Summary

The use of surface mounted devices (SMD) creates the development of imaging technologies during the production process. The methods of imaging the soldering joint of the substrate, assessed in many works, showed that the proposed systems allowed satisfactorily obtaining information on which components are good and which are defective. Of course, the results of this work were very diverse. The measurement systems developed by scientists have found wide application in implementations in factories around the world.

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