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LASER PHOTOTHERMOACOUSTIC MICROSCOPY THRESHOLD OF SENSITIVITY TESTING

Wolkenstein S. S.[1], Kerentsev A.F. [2], Rubtsevitch I.I.[2], Khmyl A. A.[3]
[1]PJSC "PLANAR-SO", Minsk, Belarus
[2]JSC "INTEGRAL" -"INTEGRAL" Holding Managing Company
[3]BSUIR, Minsk, Belarus

Microcircuits and electronic devices structural design consists of a great number of permanent connections which are attended in ceramic cases structure, in mounted chips, in interconnections of various types, in diverse sealing, capping and capsulation arrangements. Any failure appeared in this chain of connections will inevitably result in unavoidable hardware fail.

Tightened requirements for the quality of ingoing materials and manufacturing process of microcircuits and electronic twofold purpose devices making for the intention of import substitution, national security, enhancement of their dexterity, increase of performance specification and operating characteristics effectiveness promote development of conventional (diffused worldwide trend) or creation of novel nondestructive evaluation and diagnostic methods.

Conventional nondestructive evaluation and diagnostic methods have many disadvantages. Optical and electron microscopy is unsuitable for opaque material interior study. X-ray equipment has low sensitivity to a bulk continuity violation and is blind relative to aluminium, nonconductive adhesives, etc. Ultrasonic microscopes are highly sensitive (≥100 nm) to a bulk continuity violation but they have certain restriction of application by using contact activation and immersion method of the action.

The problem can be solved through the exposure of an item surface to probing laser impulse radiation with acoustic waves in the sample to be registered by a converter built in the acoustic system. The waves are a result of thermoelastic structure deformation of the inspected item. Photoacoustic signal taken from the sensor depends on numerous local physical properties of the object's marked area. At raster probing the inspected object by in-focus laser beam a bulk wave response signal is formed as a result of superposition of three different processes [1]:

- radiation absorbed capacity variations due to alteration of optical properties of the object from one point to another;
- interaction of temperature waves with thermal discontinuities of the object;
- interaction of acoustic waves with elastic discontinuities of the object.

In order to receive and process photoacoustic signals there used a volume wave acoustic-electric converter unit with a wide band low noise amplifiers mounted on coordinate stages with aerostatic and crossed-axis helical gears. Bulk wave response data is accumulated and registered by a hardware signal processing module (know-how). In the process of scanning 16-gradation color-encoded pixel-by-pixel 2D image (laser photoacoustic topogram) of permanent connections contact areas with up to 2500^X magnification is registered on the screen of a color monitor, with low levels of photoacoustic signals pointing at contact areas with a more homogeneous structure (dark graded steps from 1 to 6) that provides for a physical contact and high levels pointing at inhomogeneous areas (light graded steps from 7 to 16) which indicates that the structure continuity is disturbed (fig. 1) [2].

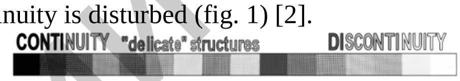

Fig. 1. Color 16-graded scale

More than four orders of linear X, Y displacement values (the range from 51200 up to several micrometers with spatial X, Y resolution from 200 to 0.5 micrometers) electromechanical drives possibility and flexibility of laser beam diameter variation (the range from 200 to 2 micrometers) afforded an opportunity to work out diagnostics and checking technique for examination of almost all types of permanent connections used in electronic and microelectronic modular assembly, such as:

- bonding dice of semiconductor devices and IC to the base of the packages and the die holders using eutectic, solder and adhesive compositions;
- microbonded connections by gold, aluminum, copper etc. wire using methods of thermosound, thermocompression, ultrasound and contact bonding;
- welded and soldered seams of the cases of semiconductor devices and ICs;
- hermetic sealing of ICs using different press-compounds;
- setting electronic components onto different substrates (SMD, COB);
- adhesion of metal coatings to different substrates.

During carrying out the research of radiation-resistant batch bonded ribbon leads manufacturing (fig. 2) were provided preparatory steps such as degreasing and aluminum oxide film deep etching relative to contact surfaces. Nondestructive testing was applied to bonded specimens made with three variations: 1) with contact surfaces only degreasing; 2) with contact surfaces degreasing and aluminum oxide film partial (10 s) etching; 3) with contact surfaces degreasing and aluminum oxide film deep etching.

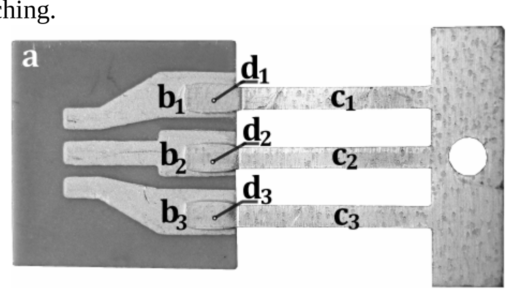

Fig. 2. Pilot specimen with radiation-resistant batch bonded ribbon leads (exterior view): ceramic base (a); aluminum bonding pads (b1, b2, b3); aluminum ribbon leads (c1, c2, c3); bonded spots (d1, d2, d3)

Consequently to nondestructive testing one can see typical characterization of bonded spots (d_1, d_2, d_3) internal structure for three variations of aforesaid research (fig. 6 a, b, c).

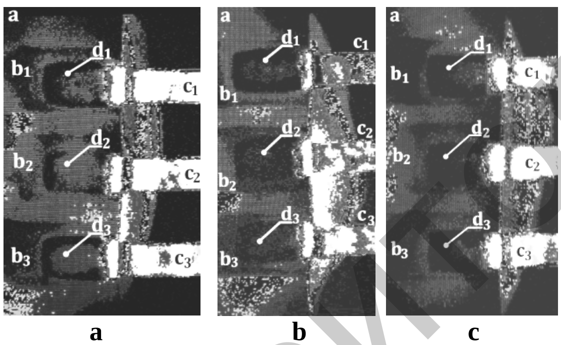

Fig. 3. Laser photoacoustic topograms of pilot specimens with radiation-resistant batch bonded ribbon leads: only with degreasing of contact surfaces (**a**); with degreasing and aluminum oxide film partial (10 s) etching of contact surfaces (**b**); with degreasing and aluminum oxide film deep etching of contact surfaces (**c**); (spatial X, Y resolution – 50 µm)

Laser photoacoustic topograms (fig. 3 a, b, c) analysis of traced bonded spots (d_1, d_2, d_3) internal structure displays aluminum oxide films (fig. 3 a, blue color) and juvenile surfaces creation in the issue of contact surfaces etching (fig. 3 b, c, black). This implyies that we can see on laser photoacoustic topograms incipient of aluminum oxide films which thickness averaged out as several nanometers conditioning the threshold of sensitivity to a continuity violation of present nondestructive testing method.

Owing to high sensitivity to permanent connections continuity violation serious shortcomings were revealed concerning radiation-resistant ribbon leads bonded spots d_1, d_2, d_3, d_4, d_6 applied in operational equipment specimen (fig. 4).

Only d_5, d_7 bonded spots (fig. 4) according to appropriate laser photoacoustic topogram subimages have ohmic regions (dark, blue) comparable to the cross-section of these aluminum ribbon leads. That indicates the satisfactory quality of these permanent connections. Other bonded spots (d_1, d_2, d_3, d_4, d_6,) according to appropriate laser photoacoustic topogram subimages have unsatisfactory quality of permanent connections because of insignificant ohmic regions square which is far less than cross-section of these aluminum ribbon leads. In addition the bonding pad b_5 adhesion is of unsatisfactory quality on account of laser photoacoustic topogram appropriate subimage red coloration.

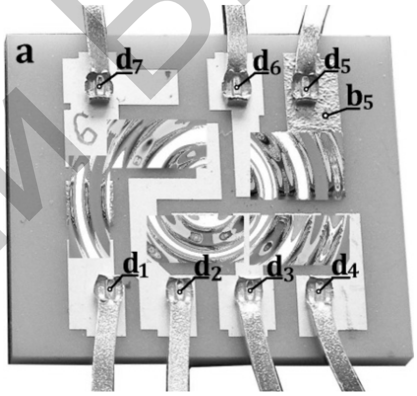

Fig. 4. Operational equipment specimen with radiation-resistant bonded ribbon leads exterior view: ceramic base (a); bonded spots (d1, d2, d3, d4, d5, d6, d7)

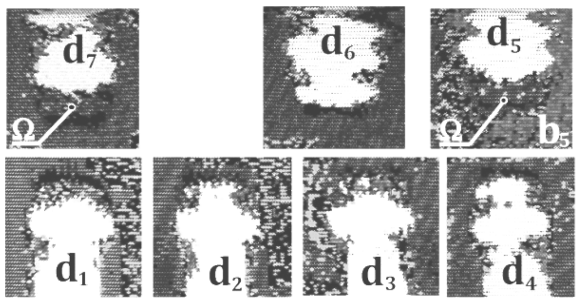

Fig. 5. Appropriate to Fig. 4 subimages of laser photoacoustic topogram. Among them bonded spots d5, d7 of satisfactory quality, d1, d2, d3, d4, d6 – unsatisfactory quality; b5 – bonding pad adhesion of unsatisfactory quality; (spatial X, Y resolution – 50 µm)

Above-stated serious critical defects revealed concerning radiation-resistant ribbon leads bonded spots d_1, d_2, d_3, d_4, d_6 and bonding pad b_5 bad quality of adhesion will lead to unavoidable time to failure decreasing induced by internal action of electrocorrosion, ponderomotive forces and low-strength of these permanent connections.

1. A.C. Tam, Rev. Mod. Phys., 1986, v.58, p. 381

2. Волкенштейн С.С., Дайняк И.В., Хмыль А.А. Сравнительная оценка альтернативных методов контроля качества и диагностики монтажных конструкций «п/п кристалл - подложка». «Доклады БГУИР», №2, 2016 г., с. 51-55.

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PROCEDURE FOR DESIGNING OPTIMIZED ACTUATORS OF THE ROBOTS USING BIOLOGICAL OBJECTS

Zimmermann K.[1], Lysenko V.[2], Mintchenia W.[2]
[1]Technical University Ilmenau
Ilmenau, Germany
[2] Belarusian National Technical University
Minsk, Belarus

The urge for individual mobility has led to the development of airplanes, trains and cars, which are much faster locomotion systems than human legs. Nevertheless, pedal locomotion systems and humanoid robots are main focal points of worldwide research in biologically inspired robotics. Biomimetical robots are developed by engineers and scientists in the life sciences by joint integrative analysis (i.e.,combining different analytical layers) of the construction and functionality of animal locomotion systems and the transfer of the construction principles to technical fields.

Currently, the development of “walking machines,” i.e., pedal locomotion, dominates the research of biologically inspired locomotion systems. The known solutions for “walking machines” range from uniquies for fundamental research to series manufacturing of commercial products for the entertainment industry. From bipedal to octopedal constructions, almost all biological prototypes have been constructed by engineers. Due to the dedication of BERNS of the University of Kaiserslautern, the walking machines catalogue (www.walking-machines.org) has given an excellent overview of available walking machines worldwide for many years. The motivation for this research direction is of very different nature [1].

In the literature several methods of techniques finding technical solutions, sets of software products supporting the process of technical systems design and a selection of technologies to be implemented are described. Nevertheless, having well developed tools of the analysis, these methods frequently have no effective solving tools for problems.

A new approach of special problem-solving methods at the initial design stages is presented. The methods are based on analysis and the combination of technical or biological objects and a legged robot. Described techniques allow us to create several new legged robots. A new class of micro robots and a new class of legged mechanisms is chosen to present the possibilities of the method. Merging the kinematics of a salamander with the kinematics of an octoped allows us to develop a new eight legged robot with only three actuators. Combining a flying insect and a piezotransducer with extremities supplies a new object - the piezomicrorobot. For movement of multi-legged robot through a pipe we use the trawling wave of the Holothouria.

Biological objects as prototypes are used preferably due to the fact that during millions of years of evolution their principles of motion have been developed contemplating minimal energy wasting. [1]

The essential design stage, which is discovering ideas for new functional principles of technical systems, is almost entirely based on the know-how of the engineer[2, 3]

The subject of our work is the development of new functional principles of legged robots.

By using a principle of work and kinematics of biological prototypes it is possible to develop new ideas for a moving robots improvement. Some biological objects use unusual ways of moving of the extremities to obtain the necessary trajectory. They change form and sizes of the body to create the necessary movement of legs.

By applying the introduced method new robots can be created. It is based on the combination of biological and technical objects. The developed method is based on the well-known principle known as the combination of alternative systems. It enables the transfer of characteristics and structure from one object (i.e. its kinematics) to another object leading to new desirable characteristics or optimisations of existing technical objects[4].

Multy-legged mobile systems classification is represented .In our opinion, there exist only 4-5 main principles of functioning of biologic objects for providing the necessary trajectory of the legs movement. The suggested classification and the analysis of biological prototypes have allowed us to