ELECTRON TECHNOLOGY
ISSN 1897-2381
http://www.ite.waw.pl/etij/
Internet Journal

SCANNING ACOUSTIC MICROSCOPY FOR NON-DESTRUCTIVE TESTS OF ELECTRONIC COMPONENTS

A. SUTOR, G. WINKLER, G. BISCHOFF

Technical University of Ilmenau, Electronics Technology Group, Ilmenau
P.O. Box 10 05 65, D-98694 Ilmenau, Germany

Received September 24, 2006; accepted November 2, 2006; published November 17, 2006

ABSTRACT

Scanning acoustic microscopy (SAM) is an attractive tool in the non-destructive inspection of printed circuit boards, thick films, thin layers and microelectronics packages. For example it permits to detect subsurface delaminations, cracks and pores (air bubbles) for different materials: metals, plastics, ceramics or composites. The examples of different electronic components and circuits observed in SONOSCAN D-9000 ultrasonic microscope with frequencies of transducers between 10 MHz and 230 MHz are presented in this paper.

1. Introduction

Most of physicochemical microinspection techniques require a long sample preparation and are almost always destructive. The first acoustic microscope, using acoustic impedance to produce high resolution images of sample interior structure, was built by Lemons and Quate in 1974. At present Scanning Acoustic Microscopy (SAM) is very attractive because this technique is non-destructive, it allows subsurface imaging and it provides information about different properties of the sample (hardness, viscosity, adhesion, density, and topography) under the surface [1–4]. This paper presents chosen results of this analysis technique made at the Technical University of Ilmenau for electronic packages, LTCC structures and LTCC gas sensors.

2. Testing Method

All presented results were obtained using SONOSCAN D-9000 ultrasonic microscope (scan size from 2.66×1.95 to 332.9×249.7 mm^2, scan speed between 25.4 and 609.6 mm/s, scan resolution 512×480 pixels) [5]. A wide range of transducer frequencies, from 10 MHz to 230 MHz provides the capability to conduct observation on a number of electronic products and components, regardless of the sample thickness or resolution required. SAM basically consists of sending a sound wave (generated by piezoelectric crystal) through the specimen, and interpreting the interaction of the sound wave with the specimen. This wave travels to the specimen through a medium, which is usually deionized water. The wave travels through the specimen's material at the material's velocity and a part of it is reflected back everytime when it hits an object with other acoustic impedance (defect) within the material. Scanning acoustic microscopy has several modes. Some of them, the most often used, are shown in Fig. 1. The A-Scan Mode is the real-time oscillo-

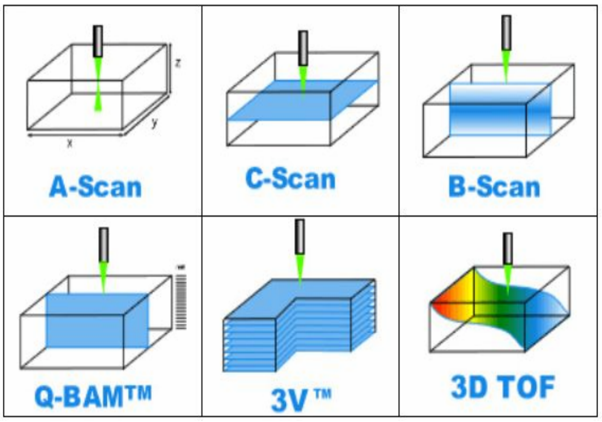

Fig. 1. Different imaging modes in scanning acoustic microscopes [5].

scope waveform of the acoustic signals based on the reflected echoes, or acoustic data collected at a single X-Y portion or point. The C-Scan Mode is the display of the image of reflected echoes at the focused plane of interest, or acoustical data collected along an X-Y plane at depth Z. The B-Scan Mode is the cross-sectional display showing the ultrasonic reflection of the various interfaces along the depth of the package. Usually the B-Scan images are based on the C-Scan image for precise determination of the depth of flaws detected. Q-BAM^{TM} (Quantitative B-Scan Analysis Mode i.e. quantitative, virtual cross-sectional view), 3V^{TM} (Three-Dimensional Virtual

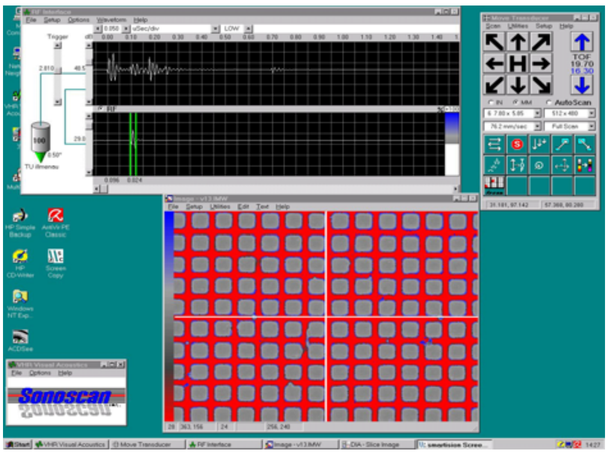

Fig. 2. View of steering panel for so-called A-Scan Mode (top) and image of LTCC structure of gridded plane [6] made in C-Scan Mode.

Volumetric viewing) and 3D TOF (Three-Dimensional Time of Flight profile) are the remaining scan images shown in Fig. 1. Of course modern ultrasonic microscope permits to realize different observation modes through proper arrangement of steering panel (as is visible in Fig. 2).

3. Application – Review

This chapter presents chosen examples of ultrasonic inspection performed at the Technical University of Ilmenau. The results of various image modes were presented for various tested electronic structures (components).

Silicon integrated circuits mounted to the package by Pb-Sn and experimental lead-free solders are compared in Fig. 3. Possible air bubbles under Si chip can be observed. Examples of various non-defective LTCC structures – gridded plane and cooling channel in liquid cooled LTCC substrates for high power applications are presented in Fig. 4. Three versions of LTCC gas sensor are shown in Figs. 5 and 6. Version 1 demands complicated meander necessary for obtaining proper heater resistance and uniform temperature distribution. But time to time shortings similar to observed in Fig. 5 (C-Scan) appeared and this made impossible to receive proper temperature distribution. Therefore next technological versions of gas sensor were made on much smaller substrate with much simpler heater topology and small active area of sensing layer placed just in the middle of substrate and in the middle of heater (Fig. 6).

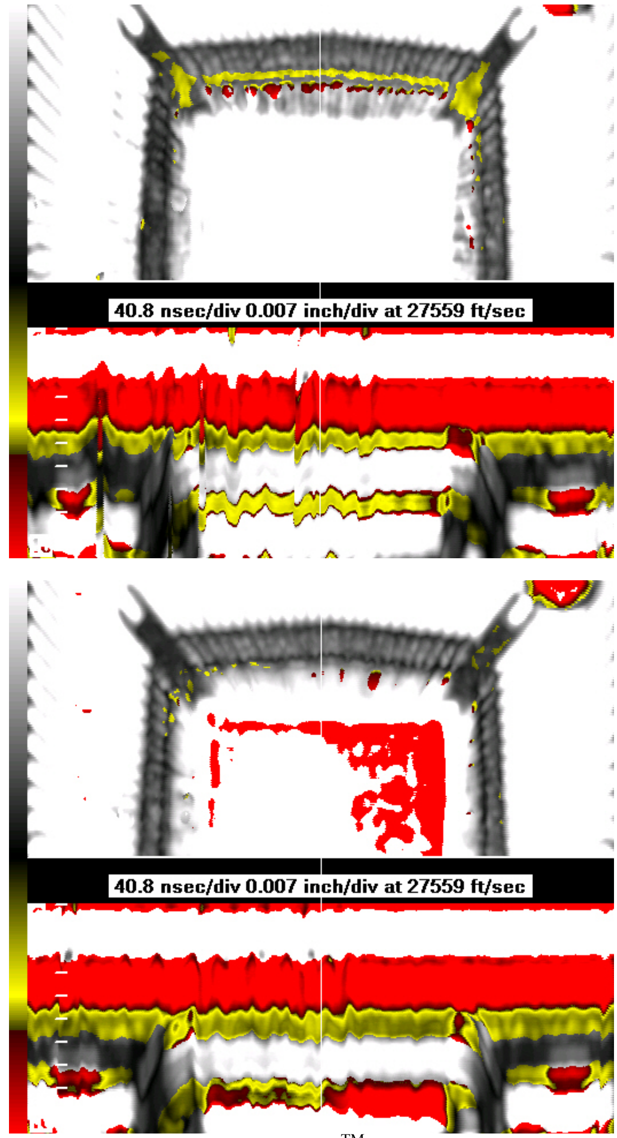

Fig. 3. Comparison of Q-BAM^{TM} images of silicon chip mounted to the package with the aid of Pb-Sn solder, soldering temperature 235°C (top) and experimental lead-free solder, soldering temperature 260°C (bottom); transducer frequency 15 MHz. Popcorn effect or air bubbles under chip (red color in the right bottom corner) are visible in the right ultragraph.

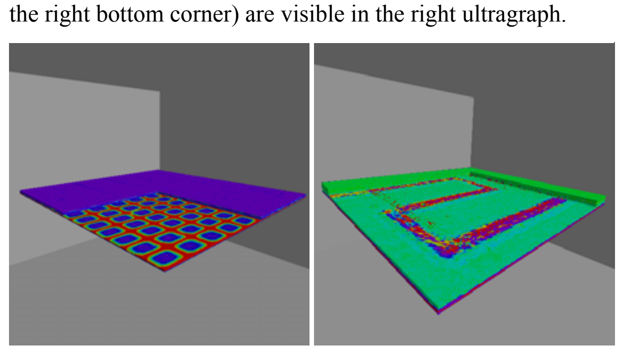

Fig. 4. 3V^{TM} images of two different LTCC structures (transducer frequency 100 MHz) – gridded plane [6] (left) and substrate with 0.8×0.35 mm cooling channel [7] (right).

4. Conclusions

The examples presented in this paper confirm usability of scanning acoustic microscopy for non-invasive and non-destructive inspection of various microelectronic circuits and packages. This method both can certificate very good and defect-free internal structure of different electronic structures (for example gridded plane, liquid cooled LTCC substrate or versions 2 and 3 of LTCC gas sensor – planar resolution of this method is dependent on transducer

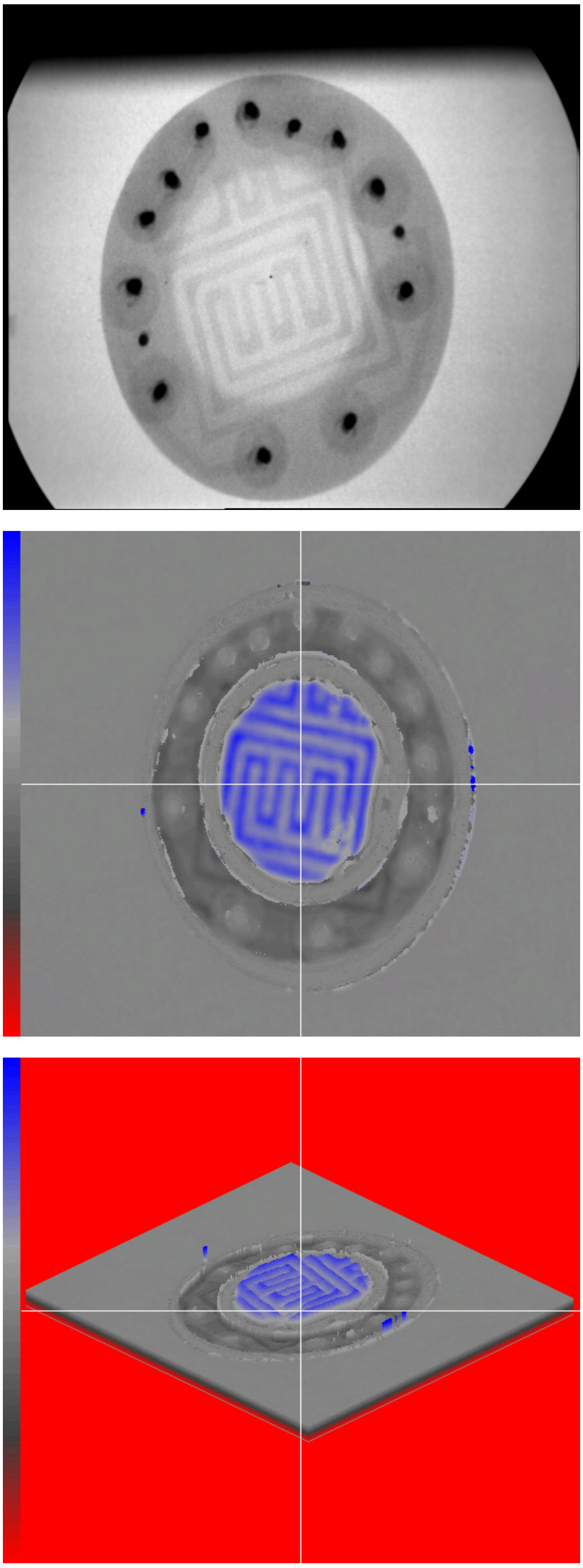

Fig. 5. X-ray, C-Scan, 3D-Profil of LTCC gas sensor (Version 1 – 6 mm diameter [8]), transducer frequency 50 MHz.

frequency and for 100 MHz transducer is equal to about 10 μm) as well as to indicate possible subsurface defects (eg. air bubbles in mounted silicon chips or partial shortings of heaters designed for version 1 of LTCC gas sensors).

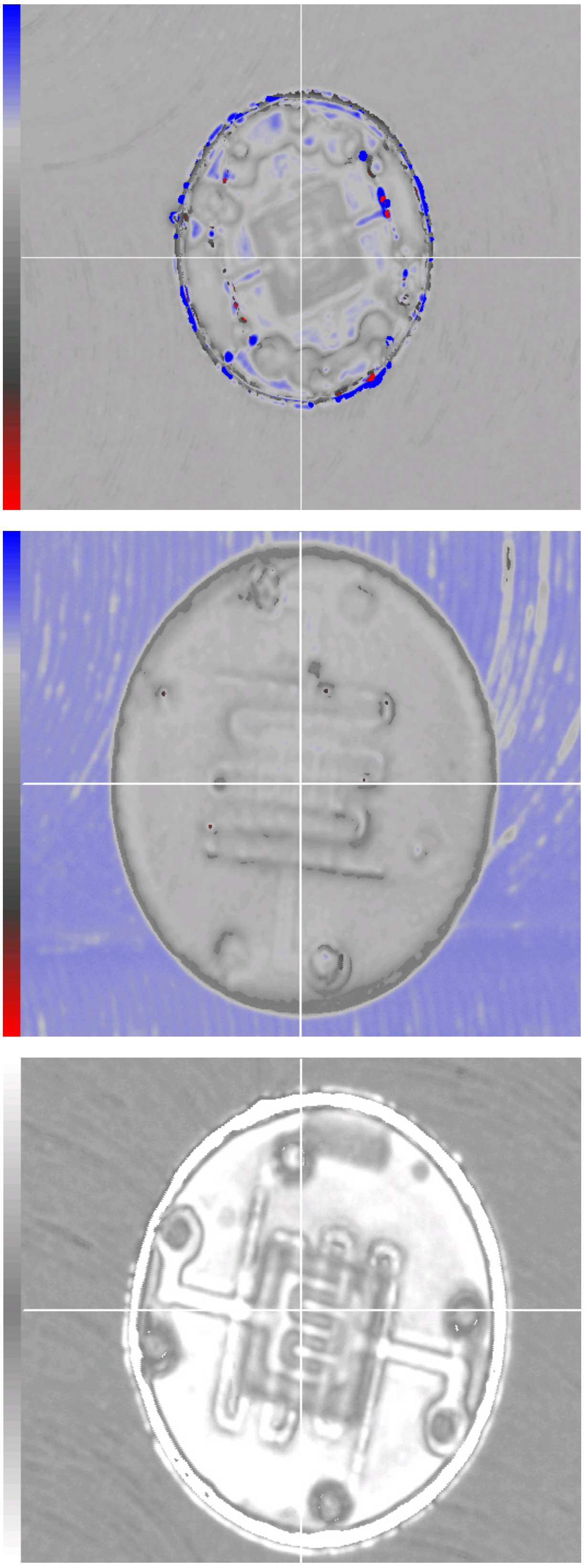

Fig. 6. C-Scan of LTCC gas sensor (Version 2 top photo and version 3 middle and bottom photos – all versions 4 mm diameter [8]), transducer frequency 100 MHz (top and bottom photos – visible all elements of the sensor, middle photo – underlined heater and contact areas).

REFERENCES

1. K.-J. WOLTER, M. SPECK, R. HEINZE, *Reliability Analysis in Microelectronic Packaging by Acoustic Microscopy,* Proc. 28th Int. Spring Sem. on Electronics Technology; Wiener Neustadt, May 2005, 422–429.
2. I. MAZIK, K.-J. WOLTER, D. DANIEL, *Ultraschall–Mikroskopie an Sensorpackages*, Sensoren im Fokus neuer Anwendungen, 5. Dresdner Sensor-Symp., Dresden: w.e.b., 2002, 213–216.
3. G. M. CREAN, C. M FLANNERY, S. C. O'MATHUNA, *Acoustic Microscopy Analysis of Microelectronic Interconnection and Packaging Technologies*, Advances in Acoustic Microscopy, Vol. 1, ed. by A. Briggs, Plenum Press, New York, 1995, 148.
4. G. PFANNSCHMIDT, *Characterisation of Electronic Components by Acoustic Microscopy,* Advances in Acoustic Microscopy, Vol. 2., ed. by A. Briggs and W. Arnold, Plenum Press, New York, 1996, 138.
5. SONOSCAN Inc: www.sonoscan.com
6. G. CHEN, K. L. VIRGA, G. WINKLER, J. L. PRINCE, *Modeling the Perfomance Embedded Gridded Plane Structures in LTCC*, Proc. 53rd Electronic Components and Technology Conf. New Orleans, LA, USA, May 27–30, 2003, 1413–1418.
7. T. THELEMANN, H. THUST, G. BISCHOFF T. KIRCHNER, *Liquid Cooled LTCC Substrates for High Power Applications*, Proc. Int. Symp. on Microelectronics (IMAPS USA) Chicago, USA, Oct. 1999, 636–641.
8. T. PISARKIEWICZ, A. SUTOR, P. POTEMPA, W. MAZIARZ, H. THUST, T. THELEMANN, *Microsensor Based on Low Temperature Cofired Ceramics and Gas-Sensitive Thin Film*, Thin Solid Films, 2003, **436**, 84–89.