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Application of the signal processing in the case of ultrasonic inspection of PCB components

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Abstract

The improved detection and characterization of internal defects in printed circuit boards (PCB) has been investigated. The two different signal processing techniques have been used to increase the contrast of defective regions and in such a way to improve reliability of inspection. The experiments were carried out on a real PCB. The inspection was performed using the acoustic microscope produced by Ultrasonic Science Ltd. The examples of the internal defects measured by the scanning acoustic microscope are presented. The novel signal processing method based on the adaptive ultrasonic numerical model of the electronic device and appropriate selection in frequency domain has been proposed.
Keywords: ultrasonic microscopy, signal processing

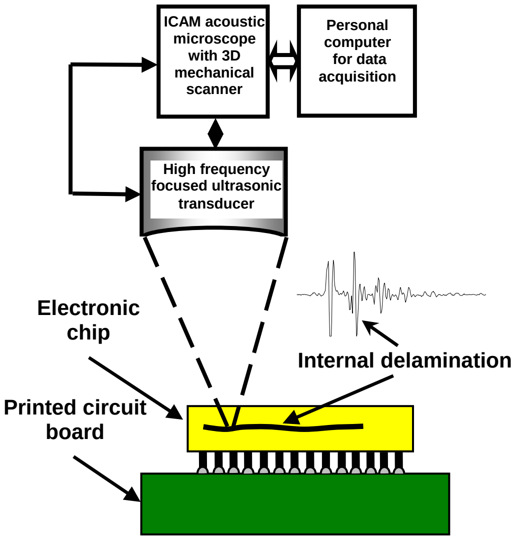
Introduction

The ultrasonic immersion technique enables to detect very thin internal delaminations in PCB and electronic components, detection of which is more problematic or impossible using other techniques. Due to requirements of a very high spatial resolution of the internal defects the ultrasonic technique usually is used only for laboratory investigations, but not for on-line testing. The increase of a scanning speed leads to loss of the accuracy. To improve detection and characterization of internal defects inside electronic components, various testing methods and signal processing procedures have been used, including phase imaging, the Wiener filtering, the wavelet transform, deconvolution and etc. [1-5].

The objective of the presented work was to investigate the methods of signal processing, which enables to enhance quality of ultrasonic images.

Experimental set-up

The experimental testing of the PCB was performed using the scanning acoustic microscope (SAM) produced by Ultrasonic Science Ltd. The measurements were carried out using a focused transducer with the central frequency 50 MHz, the diameter 6 mm and the focal distance 13 mm. The used experimental set-up and photography of the tested electronic chip is presented in Fig.1. The scanning of the ultrasonic transducer has been performed in the region with dimensions 35 mm along *x* and *y* axis. The scanning step was 0.035 mm along *x* axis and 0.034 mm along *y* axis. Conventional C-scan images were created using the maximal amplitude of the signal in the rectangularly shaped time window. The analysed C-scan image of the tested electronic chip (Fig.1, b) is presented in Fig.2. The image shows two regions of delaminations insight the chip. In order to improve the spatial resolution of a conventional C-scan image, the two different signal processing methods have been proposed.



a

b

Fig.1. **Experimental set-up for on-line immersion pulse-echo testing of the electronic component structure (a) and the photo of the electronic chip housing under the test (b)**

Signal processing in time domain

The signals reflected by an internal structure of electronic microchips usually possess complicated

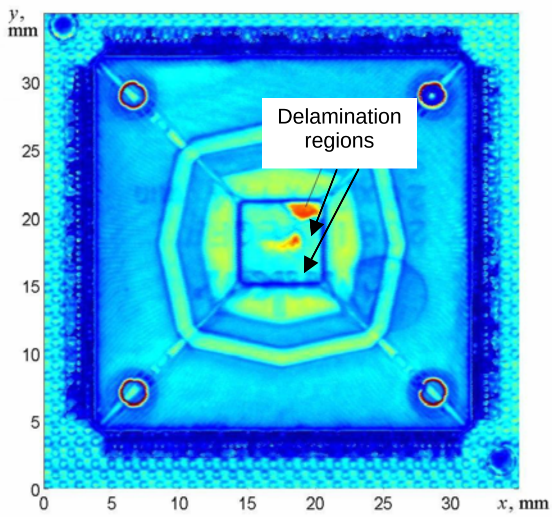


Fig.2. **The conventional C-scan image of the detected delaminations in tested electronic chip**

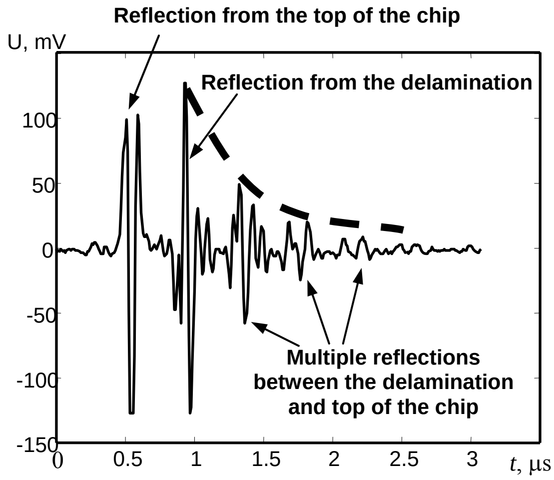


Fig. 3. **The multiple reflections in the signal measured at the position over the delamination type defect**

waveforms and as a consequence the simple amplitude imaging technique does not give the desirable results. On the other hand it is known that the delay time measurements are usually more accurate comparing to the amplitude measurements. So, for more accurate imaging of the internal defects, the separate signal segments can be exploited, positions of which are determined from the time of flight measurements.

As it is known, the reflection coefficient of a longitudinal ultrasonic wave strongly depends on the difference of acoustic impedances between neighboring layers having different material properties. So, at the each boundary between the neighboring layers the reflection occurs. Such signals are reflected by the other boundaries also. This leads to signals containing a non regular number of reflections and are different for different chips. On the other hand, in al cases the reflection from the delaminated areas is much stronger due to a big difference between the acoustic properties of the materials used in a chip structure and air (it is assumed that the delamination is filled with air). This feature usually is exploited by the conventional defect detection algorithm, based on the maximal amplitude of the reflected ultrasonic signal. Another feature of the signal in the case of the delamination type defect in a chip structure is that the multiple reflections occur between the delamination and the chip housing. This can be observed in the signal presented in Fig.3.

The main idea of the proposed algorithm is to compress the information contained in the whole multiple reflected signal using an advanced processing technique and to exploit this integral parameter for the determination of the presence of internal defects. The developed algorithm consists of the following steps:

- the arrival time t_{surf} of the signal reflected by the chip upper surface is determined ;
- the cross-correlation of the signal part below the surface is calculated $y_c(t)$. As the reference signal, the signal reflected by a flat surface is used;
- the delay time Δt_1 between the maximum of the cross correlation function and the surface reflection is calculated;
- the positions of the next multiple reflections in the time domain are estimated ($2\Delta t_1$, $3\Delta t_1$ …);
- the cross-correlation function is calculated at these positions within the selected rectangularly shaped time window. The maximal amplitude in the cross correlation function is estimated ($A_{c2,max}$, $A_{c2,max}$);
- the deviations of these values from the known amplitude decay dependency are calculated ($\Delta A_{c1,\,max}$, $\Delta A_{c2,\,max}$, …),

  where $\Delta A_{c1,\max} = \sqrt{\left(A_{c1,\max} - A_{ref}\right)^2}$.
- all calculated deviations are integrated

$$A_{\text{int}} = \sum_{k=1}^{N} \Delta A_{ck,\max} ,$$

where N is the number of reflections which should be taken into account.

The values A_{int} are used to create the C-scan image.

The C-scan image created using the developed signal processing algorithm is presented in Fig.4. As can be seen there are no problems for spatial localization of the defect.

Signal processing in frequency domain

The algorithm of signal processing in the frequency domain has been performed in such steps:

- selection of appropriate reflection in a time domain using *a priori* information obtained by numerical simulation:

  $u_{\inf}(t) = u_{ref}(t_1 : t_2)$,

  where $u_{\inf}(t)$ is the informative part of the reflected signal u_{ref}, the boundaries of the rectangularly shaped window have been denoted by t_1 and t_2;
- calculation of the frequency response of the multi-layered electronic component in the case of ultrasonic wave incidence and reflection back from an internal multilayered structure;
- calculation of the spectrum of the informative part of the reflected signal at each scanning point:

  $U(f, x, y) = \left|FFT\left(u_{\inf}(t, x, y)\right)\right|$;

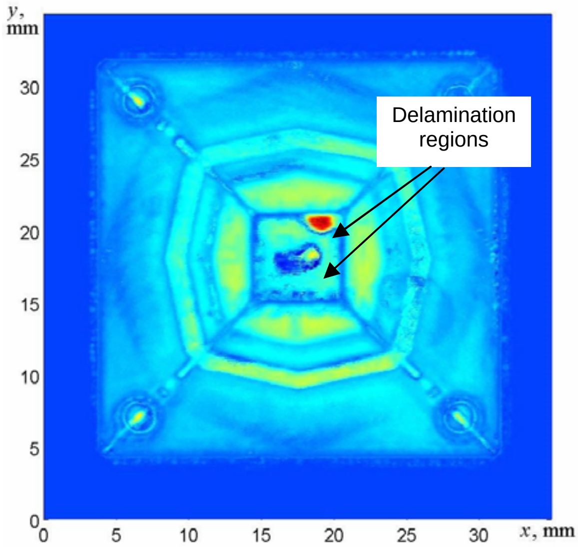


Fig.4. **The ultrasonic C-scan image of the delaminations in the chip created using the first signal processing method (time domain)**

- comparison of the calculated frequency response of the component and the spectrum of the real reflected signal at critical frequencies (f_1,f_2), which represent increase or decrease of the magnitude. The selection of the appropriate spectrum parts have been performed in such way:

$$A(f,x,y) = \max(u(f_1 : f_2, x, y)),$$

where x, y denote the scanning directions, the informative part of the magnitude spectrum has been denoted by f_1 and f_2.

The estimated $A(f, x, y)$ is presented in C-scan image (Fig.5.), taking into account information provided by reflected ultrasonic waves from delamination regions and “shadowing” effect of the dye layer also (Fig.5, a, b).

Conclusions

The investigation results of the printed circuit boards by the pulse-echo ultrasonic technique were presented. In order to improve the spatial resolution of a conventional C-scan image, the two signal processing methods have been proposed and compared.

The first method is based on compressing of the information provided by amplitude and time-of-flight measurements. The second method is based on the adaptive ultrasonic numerical model of the electronic device, which enables to optimize the selection of ultrasonic signal segments possessing the information about internal defects. Such selection has been applied for appropriate parts in the reflected signal waveform in the time and the frequency domains.

The proposed both signal processing techniques enable to perform a reliable detection of internal defects in electronic components. The comparison of such methods shows that the better results provide the second method using time and frequency domain selection.

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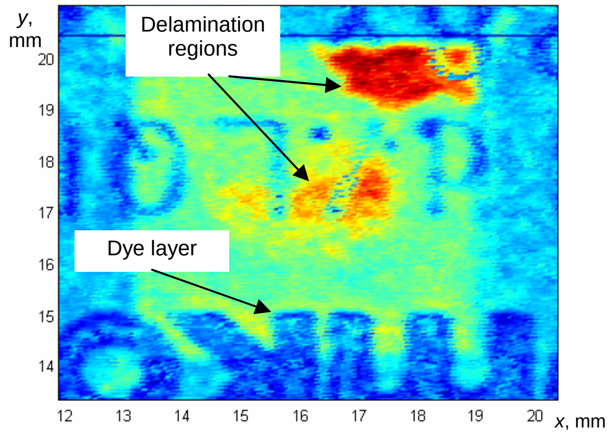

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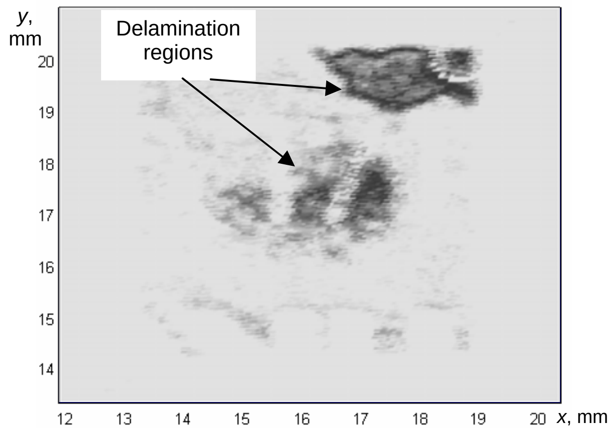

b

Fig.5. **The zoomed region of the ultrasonic C-scan image of the delamination type defect in the chip structure created using the second signal processing method (frequency domain): a – extraction information provided by reflected ultrasonic waves from delamination and “shadowing” effect of the dye layer, b – extraction of information only provided by reflected ultrasonic waves from delamination**

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Signalų apdorojimo metodų taikymas ultragarsiniams spausdinto montažo plokščių tyrimams

Reziumė

Atlikta spausdinto montažo plokščių elektroninių komponentų vidinių defektų aptikimo būdų lyginamoji analizė. Pasiūlyti du skaitmeninio signalų apdorojimo metodai. Jie sukurti tiriant realius ultragarsinius signalus, atsispindėjusius nuo elektroninių komponentų vidinių defektų. Eksperimentiniams tyrimams naudotas firmos „Ultrasonic Science Ltd.“ akustinis mikroskopas su 50 MHz dažnio fokusuotuoju keitikliu. *C* tipo vaizdai vienu metodu apdoroti laiko ašyje, kitu – dažnio ašyje. Palyginus gautus vaizdus nustatyta, kad dažnio ašyje apdorotų defektų vaizdų skiriamumas didesnis nei apdorotųjų laiko ašyje.

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