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THREE-DIMENTIONAL IMAGING IN ULTRASONIC MICROSCOPY

Krzysztof DYNOWSKI, Jerzy LITNIEWSKI,
Andrzej NOWICKI

Institute of Fundamental Technological Research
Polish Academy of Sciences
Świętokrzyska 21, 00-049 Warszawa, Poland
e-mail: Krzysztof.Dynowski@ippt.gov.pl

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Advances in modern technology increases requirements for nondestructive characterization of material and biological properties in the μm range.

The acoustic microscope presented in this paper combines C-scan and B-scan modes. The data collected during single XY scan allow to present transversal and horizontal cross-sections of the sample as well as real three-dimensional images of the sample interior.

The system consist of several components: step motor driven mechanical scanner, transmitter/receiver device, ADC 1 GHz board, ultrasonic heads, PC-class computer and image processing and visualization software.

Image processing software is used for initial 3D image analysis of the whole image or its fragments, and for preparing it this way for vectorization. To achieve vectorization we used VTK (Visualization Tool Kit) library from Kitware Inc., which is the open source software, designed for 3D graphics and image processing.

Finally iso-surface is constructed and presented as 3D scene in interactive GUI (Graphical User Interface).

Keywords: 3D visualization, microscope, ultrasound.

1. Introduction

We have built the Acoustic Microscope that operates at the frequency up to 200 MHz and allows to visualize the internal structures of materials. Scanning Acoustic Microscopy (SAM) is a relatively new technique rapidly becoming established as a method for non-destructive evaluation (NDE) of engineering materials using high frequency ultrasound. The acoustic microscope presented in this paper combines C-scan and B-scan modes. The data collected during single XY scan allows to present transversal and horizontal cross-sections of the sample as well as real tree dimensional (3D) images of its interior. Taking an advantage of relatively low attenuation of the ultrasonic waves at very high frequency, acoustic microscope can penetrate materials that are opaque to the light [1, 2] and [3]. The following paper reveals the ability of SAM to visualize unseen internal three-dimensional structures.

2. Components of ultrasonic microscope

Mechanical scanner

Mechanical scanner enables positioning of the ultrasonic lens (lens with transducer) over the investigated sample with a high step precision 0.005 mm. Stepping motors assure movements along XYZ axes. The positioning table with the attached sample can perform scanning in XY plane in the range $50\ \mathrm{mm} \times 50\ \mathrm{mm}$.

Transmitter-receiver

The commercial transmitting-receiving device (Panametrics Inc., model 5900PR) was applied to excite the transducer and to receive high frequency ultrasonic bursts reflected inside the sample. The device operates (transmits and receives) at the frequency up to 200 MHz. The system transmits short excitations (2 ns slope) of energy in the range 1–16 µJ.

Analog/Digital converter board

The A/D converter board (PDA1000) from Signatec, Inc. was applied for sampling and recording echo-signals originating in the sample. The board can operate with signal sampling frequency up to 1 GHz and with 8 bits resolution (256 levels). The card has 1MB RAM memory.

Ultrasonic lens

The system utilizes self-designed ultrasonic lenses that can operate in the frequency range 30–200 MHz. The lenses (transducer with the lens) were optimized for subsurface imaging taking into account geometrical aberration and refraction at the water-sample interface as well as internal spurious reflections within the lens rod [2].

Computer control and imaging software

The heart of the system is the driving computer (PC). The self-designed software is used to control the scanner motion and the sampling board operations. Also, the dedicated software was developed to collect the data and to transmit them into computer memory. In the next step the software processes the signal to remove internal lens reflections, to increase signal-to-noise ratio, detects the amplitude and finally creates two or three-dimensional images using the vector graphics.

3. Acquisition, processing and visualization

The sampling board of the microscope collects ultrasonic echoes – the object responses to the ultrasonic burst send into the sample. Figure 1a shows a typical sequence of R.F. signals recorded with the microscope (“oscilloscope” mode of the microscope). The presented signal consists of the transmitting electric signal, reflections within the sample and multiple ultrasonic reflections in coupling fluid and in the lens.

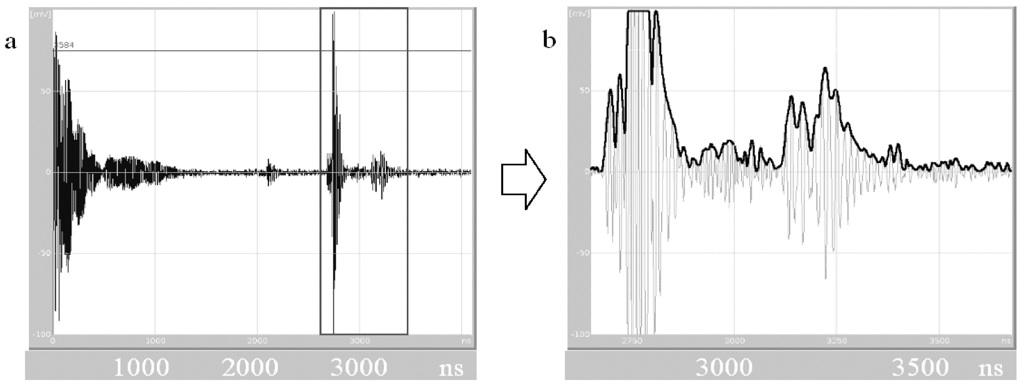

Fig. 1. The signal recorded from a microchip: a) acoustic echoes and b) windowed part of amplified signal is shown together with the amplitude envelope. Frequency 100 MHz.

The echo-signal is sampled so assuming the wave speed in the probe to be constant, the relationship between time (Δt) and penetration depth (Δz) is linear and can be described as:

$$\Delta z = 1/2 \times \Delta t \times V, \tag{1}$$

where V stands for the longitudinal wave velocity in the sample.

The proper selection of a limited-duration time period (Δt) that contains echoes from the chosen internal structures and excludes the disturbing reflections, assures a good quality of images and reasonable time of data processing. In Fig. 1a a window is presented which is used to select a part of the signal that is next subjected to amplitude detection (Fig. 1b).

The analysis software supports several image processing procedures which allow remove background and noise and are used to enhance intensity of the chosen regions of the volume. Digital data processing are based on the following filters [4]:

- **threshold value** – leave in the image only the points that intensity exceed some threshold value while the other points are set to zero (black);
- **boundary cutting** – select the part of the image of the investigated object that is assumed to process;
- **smoothing** – remove isolated peaks of intensity that often are met in the measured data;
- **intensity coefficient** – increase or reduce image brightness.

The proper applying of these filters can result in “cleaning” the data from disturbing components and prepare volume data for vectorization procedure.

To achieve vectorization we used VTK (Visualization Tool Kit) software from Kitware Inc., which is the open source library, designed for 3D graphics and image processing [5].

The imaging abilities of the microscope were tested using a custom-designed phantom. The phantom consisted of two copper wires (diameter of 0.25 mm and 0.5 mm) and a steel ball (diameter of 1 mm) embedded in the epoxy resin (longitudinal wave velocity $= 2800$ m/s). The waves of 100 MHz frequency were focused inside the sample, approximately 1.0 mm under the surface. The selected projections of 3D image of this sample are presented in Fig. 2.

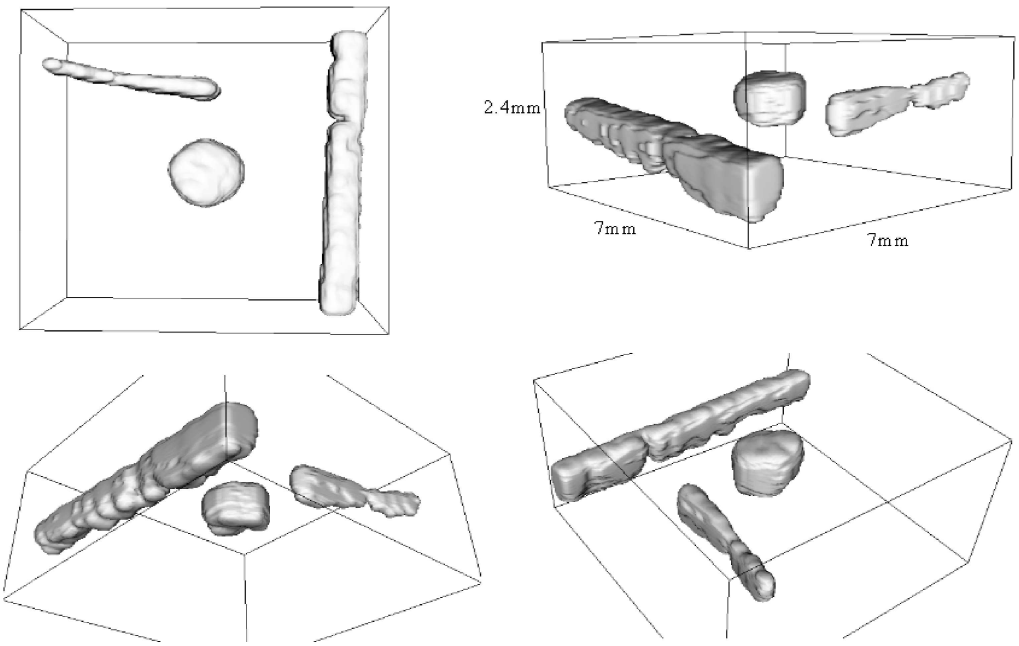

Fig. 2. Projections of 3D image of the test sample. Distortions of geometrical dimensions introduced due to the different velocity of waves propagating in the objects and epoxy are clearly visible.

4. Conclusions

The scanning acoustic microscope described in this paper can be used for imaging internal structures embedded in the materials that are opaque for the light. The scene rendering GUI (graphical user interface) was used what allows for rotation of visualized objects and movements of observation point (camera). That significantly increases human perception and image recognition. The microscope can be used in material studies and microelectronics as well as for biological investigations.

The imaging resolution of the microscope, lateral and longitudinal, depends on material properties of the samples as these define the focused ultrasonic field properties and the length of the probing pulses.

The microscope collects the RF data what allows for utilization of amplitude and phase information. This information will be used in the further study that will focus on resolution enhancement and compensation of geometrical distortions in 3D images obtained with the microscope.

References

[1] BRIGGS A., *Advances in Acoustic Microscopy*, Vol. I, II of Plenum Press, New York 1995, 1996.

[2] LITNIEWSKI J., *Subsurface imaging of samples by SAM*, Archives of Acoustics, **19**, 4, 487–493 (1994).

[3] LITNIEWSKI J., *An acoustic microscope for microflaw inspection and subsurface imaging*, Archives of Acoustics, **26**, 1, 25–36 (2001).

[4] NIKOLAIDIS N., PITAS I., *3-D Image Processing Algorithms*, Wiley-Interscience Pub., New York 2001.

[5] SCHROEDER W. J., GEVECI B., MALATERRE M., *Compatible Triangulations of Spatial Decompositions*, [in:] Proceedings of Visualization 2004, IEEE Press October 2004.