ADVANTEST Photoacoustic Microscope Hadatomo™ Z

Application for Non-Destructive Inspection

IC chip internal measurement

We attempted to apply the Hadatomo™ Z photoacoustic microscope for non-destructive inspection. One of the features of the Hadatomo™ Z is simultaneous measurement using photoacoustic imaging and ultrasound imaging. By using an ultrasonic sensor with center frequency of 60 MHz, high-resolution imaging is possible. Photoacoustic imaging is a method to receive and visualize thermoelastic waves (ultrasonic waves) generated from materials absorbing specific wavelength laser light energy. By using this method for organism imaging, information inside the organism is obtained. For non-destructive inspection, laser light cannot reach inside of a measurement subject, so a method to visualize images using ultrasonic waves, generated on the surface of the substance, is used. Thermoelastic waves generated by laser light have different frequency characteristics and wavelength, compared to ultrasonic waves generated from the piezoelectric element of an ultrasonic sensor, so images not available in previous ultrasound imaging may be obtained.

We visualized the interior of an IC using the Hadatomo™ Z. We used a DRAM chip (K4B1G1646G-BCH9, Samsung) for measurement. Fig. 1 shows principles of measurement and setup procedure. As shown in Fig. 1 (a), we fixed the IC to a position inside the spacer of the Hadatomo™ Z. Laser light, irradiated from the ultrasonic sensor, was absorbed by the mold of the IC chip to generate ultrasonic waves. The ultrasonic waves propagated within the IC chip, then we measured the reflected waves with the Hadatomo™ Z to visualize images. The measurement area is 9 mm square, and the scan step is 15 µm.

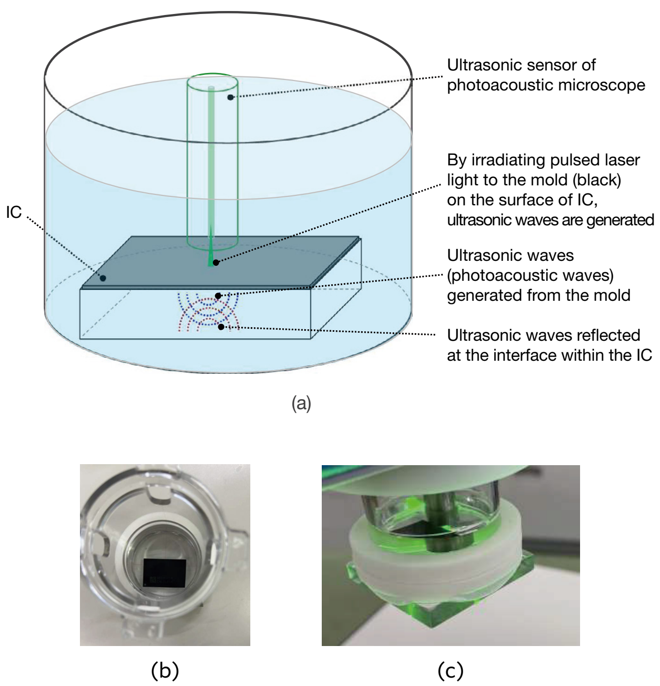

Fig. 1 Principles of measurement and setup photo
(a) Principles of measurement, (b) Photo of IC chip setup, (c) Photo during measurement

Fig. 2 shows an external view of the IC and an ultrasound image and photoacoustic image obtained by measurement. In both the ultrasound image and photoacoustic image, wiring inside the IC chip can be observed in the picture.

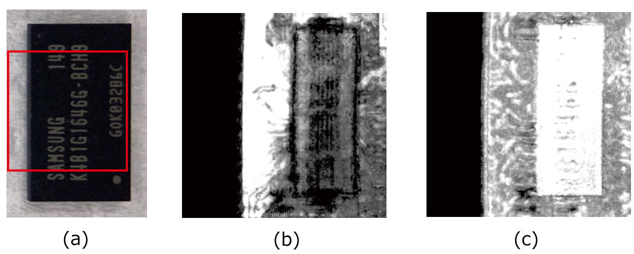

Fig. 2 Measurement results (a) External photo of IC, (b) Ultrasound image, (c) Photoacoustic image

Next, we conducted frequency analysis on the measured images. Fig. 3 shows the results. Among the ultrasound images, almost no image is obtained with the band pass filter (BPF) 1 to 20 MHz. In contrast, with the BPF 20 to 40 MHz (a2) or BPF 40 to 60 MHz (a3), wiring patterns are clearly visualized. With the BPF 40 to 60 MHz, the image of the highest contrast is obtained. On the other hand, among the photoacoustic images, in the image with BPF 1 to 20 MHz, we cannot observe the wiring, though brightness of the image is high (b1). It is assumed that the resolution is not high enough in the low frequency ultrasonic waves. With the BPF 20 to 40 MHz, wiring is clearly visualized (b2). In contrast, with the BPF 40 to 60 MHz, internal structures of the chip are visible, but almost no wiring is visible (b3). The above results suggests that in the photoacoustic imaging, almost no high-frequency reflection waves are generated inside the IC. As described above, the clearest ultrasound image is with BPF 40 to 60 MHz (a3), and the clearest photoacoustic image is with BPF 20 to 40 MHz (b2). When we compare each image, we find slightly different illumination or contrast of the wiring. Therefore, we can assume that characteristics of the received ultrasound signals are different. This means there is a large difference in variations by frequency between the ultrasonic waves and the photoacoustic waves.

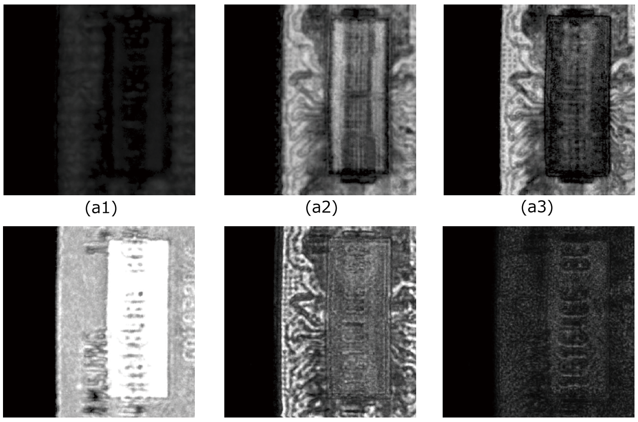

Fig. 3 Results of frequency analysis
(a1-a3) Ultrasound images, (b1-b3) Photoacoustic images,
(a1, b1) BPF 1 to 20 MHz, (a2, b2) BPF 20 to 40 MHz,
(a3, b3) BPF 40 to 60 MHz

Fig. 4 shows the results of displaying frequency as colors on the ultrasound images and photoacoustic images. As shown in the results of Fig. 3, we can see that the ultrasound images contain more high-frequency components compared to the photoacoustic images. In the ultrasound image of Fig. 4 (a2), we can observe the difference of frequency characteristics between the chip in the center, and other areas. In contrast, in the photoacoustic image of Fig. 4 (b2), we can observe the difference of frequency on wiring, so the results are different from the ultrasound image. In the tomographic images, similar results are observed. In the ultrasound image, frequency difference between the IC chip and other areas is clearly visible. In contrast, in the photoacoustic image, frequency difference is visible in the wiring part. Note, that in the tomographic image, display resolution in the depth direction is different between the ultrasound image and the photoacoustic image.

In the photoacoustic image, the system is only detecting the receiving time of the ultrasound waves, so the display depth on the depth direction is 2x that of the ultrasound image.

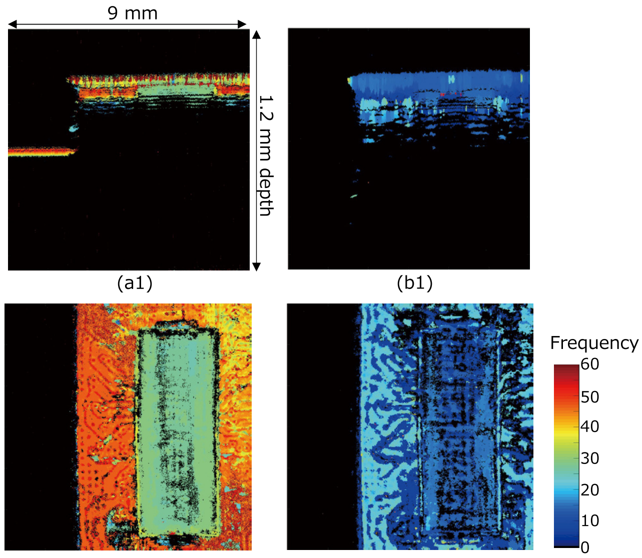

Fig. 4 Images colored with frequency (a1, a2) Ultrasound images,
(b1, b2) Photoacoustic images, (a1, b1) Tomographic images
(a2, b2) Top view images

With the results of this experiment, we could confirm the possibility of applying the Hadatomo™ Z photoacoustic microscope for non-destructive inspection. When we can get frequency characteristic signals from defects (voids) inside of ICs, as was not possible with conventional ultrasound imaging, there are possibilities for analysis approaches differing from previous methods. The Hadatomo™ Z is equipped with lasers of two wavelengths for organism measurement applications. However, for non-destructive inspection, the purpose is to irradiate laser light to the substance absorbing laser light, so a single wavelength laser is enough. Note that the amount of generated photoacoustic waves is proportional to the energy of light. When we set the upper limit of the light irradiation energy of the Hadatomo™ Z, we calibrated it to Maximum Permissible Exposure (MPE) to ensure the safety of subjects. For non-destructive inspection, higher levels of light irradiation energy can be used, so we can generate stronger photoacoustic waves. As shown above, we may expect a new method for non-destructive inspection by applying photoacoustic imaging, which has different characteristics from ultrasound imaging.