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DEPTH RESOLVED THERMAL WAVE IMAGING OF LAYER-STRUCTURED SAMPLE BY CORRELATION PHOTOACOUSTICS

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A new photoacoustic method, correlation photoacoustic imaging, has been developed combining two independently developed techniques, thermal wave imaging and correlation photoacoustic spectroscopy. This method can be used for surface and/or depth analysis of solid samples and was demonstrated on a layer-structured model sample.

Thermal wave imaging[1-3] is a technique which presents the microscopic thermal features on or beneath the surface of a sample. The thermal features are reflected on the variations of the specific heat, on the ability of absorbing the light irradiated, and on the spacial distribution of the chemical composition of the solid materials concerned.

Correlation photoacoustic spectroscopy[4-7] gives the information concerning the delay time of the photoacoustic signal with respect to an exciting signal. This technique can be used for the study of non-radiative relaxation processes, and for measuring the photoacoustic spectra of a layer lying at a deep level below the surface.[4-8] The measurement may thus be considered as the depth profiling of a sample. The combination of the thermal wave imaging and the correlation photoacoustic spectroscopy will consequently enable the three-dimensional analysis of surface and subsurface region of a solid material in non-destructive way.

A blockdiagram of the apparatus employed is shown in Fig. 1. The system of correlation photoacoustics was of the same general form as that described previously.[4,5] The light source was He-Ne laser (NEC GLG-108 50 mW) operated at 632.8 nm with an output power ranging from 20 mW to 40 mW. The thermal wave imaging system was designed and constructed in our laboratory and combined to the correlation photoacoustic system. The laser beam was amplitude modulated using a mechanical chopper which produced an M-series pseudo-random binary sequence with 255 zeros and ones in length.[8,9] The beam was focused downward on to an image plane using a biconvex lens with focal length 100 mm. The beam diameter on the image plane was approximately 100 μm. The sample cell was fixed on an X-Y stage which was translated within the range 15 mm x 15 mm by programmed control using a microcomputer(SORD M-223). The structure of the model sample is shown in Fig. 2. A circle having the diameter 2500 μm was drawn on a substrate sheet of poly(vinyliden chloride) of 200 μm thick. This substrate with the circle pattern on it was tightly covered by two sheets of poly(vinyliden chloride) of 15 μm thick/each, and then a Y pattern was drawn on the upper sheet of poly(vinyliden chloride). Consequently these two patterns were separated by two sheets of polyvinyliden chloride from each other. The lines of the patterns were drawn with 200 μm in width. The photoacoustic signal coming back from the sample was detected, while that going through the substrate layer was neglected.

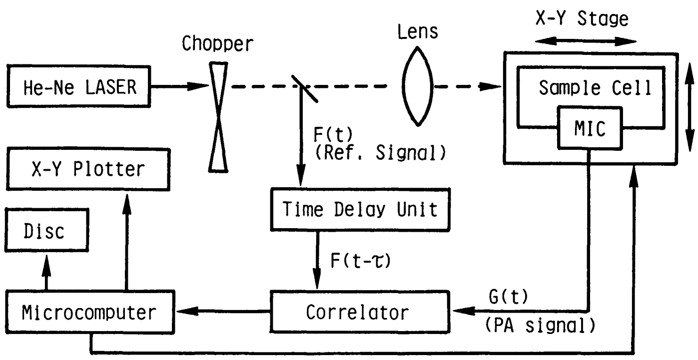


Fig.1. Blockdiagram showing the experimental system for correlation photoacoustic imaging. Scanning of the laser beam is conducted by translating the XY stage under the programmed control by a microcomputer.

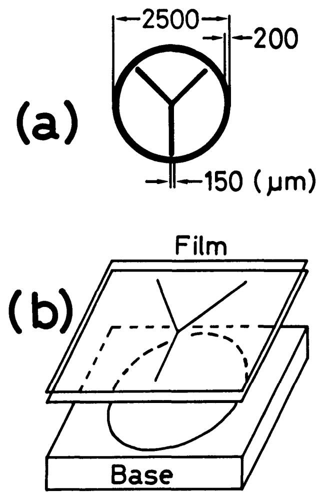
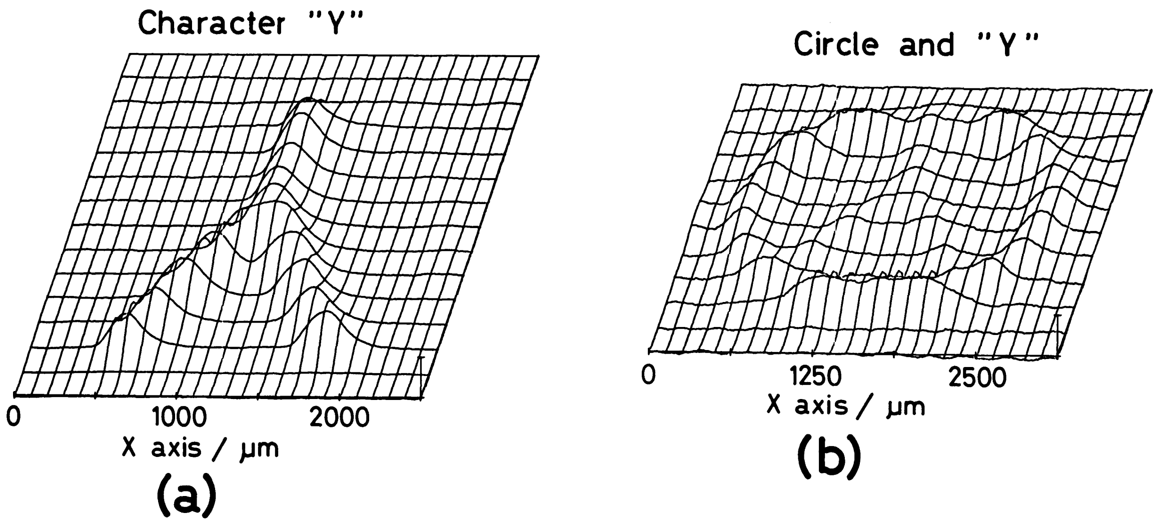


Fig.2. Diagram showing the structure of the model sample. Figure 2(a) shows the patterns drawn on the polymer sheets viewed along the direction normal to the sheet plane. Figure 2(b) schematically shows the way of constructing the model sample.

Prior to the imaging experiments, the impulse response curves (the spectra of the first kind of correlation photoacoustics) had been recorded with the beam spot focused on the character Y on the surface sheet and next focused on the circle on the sheet of vinyl chloride. From the peak position of the impulse response curves, the delay time of the photoacoustic signal from each depth was found to be 0.5 ms and 4.3 ms for the character Y and for the circle, respectively.

Figure 3(a) shows the correlation photoacoustic imaging obtained with the delay time fixed at 0.5 ms. The thermal wave imaging of the surface layer are clearly seen without any trace of signals from the deeper layers. Since the amplitude response is dominated by the relative absorption coefficients of the different part in the image plane, only the character Y on the surface layer emerges. The correlation photoacoustic imagings for the deeper levels are



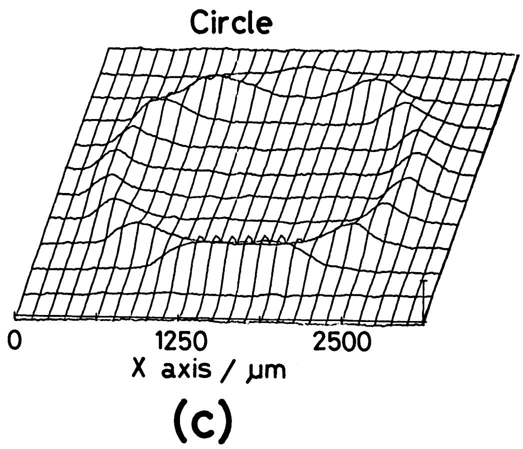


Fig.3. Results of the correlation photoacoustic imaging of the model sample, obtained with the delay times fixed at 0.5 ms (a), 3.8 ms (b), and 4.3 ms (c).

shown in Figs. 3(b) and 3(c). These images were obtained with the delay times fixed at 3.8 ms and at 4.3 ms, respectively. In Fig. 3(c) the image of the circle is seen without any signals from upper layers, while in Fig. 3(b) the both images of the character Y and the circle are seen on the same imaging plane.

The combined technique of photoacoustic imaging and the correlation photoacoustics was thus demonstrated to enable the three-dimensional analysis of surface and subsurface region in non-destructive way. The improvements of resolution both in area and in depth are now in progress.

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