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PHOTOACOUSTIC IMAGING OF OPTICALLY THIN FILMS

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In the last few years the study of photoacoustic phenomena has gone through a period of considerable development. The photoacoustic effect is fairly well understood, and photoacoustic spectroscopy is now a practical and useful technique, with commercial equipment available (1). Recently, attention has turned to the possibility of using the photoacoustic effect for imaging applications. A number of experimental studies have been published employing various techniques (2,3,4). The majority of studies have been carried out using front surface illumination, with rear surface detection by piezoelectric transducer. In at least one study, front surface illumination and detection using a conventional gas-microphone PAS cell has been used for imaging cracks and other micro-defects in ceramic materials.

In this paper we report on some preliminary photoacoustic imaging studies carried out using front surface illumination in a gas-microphone cell and an X-Y scanned focussed laser spot. The system is particularly applied to optically thin films attached to opaque substrates, where an analysis of the phase information in the photoacoustic signal adds a depth profiling capability and allows the measurement of film thickness (5).

Fig 1 shows a block diagram of the photoacoustic imaging system. The light source is a 2 mW He-Ne laser (Hughes Corporation). The laser beam is mechanically chopped and then expanded to 5 mm diameter before scanning. The beam is scanned by two orthogonal front surface mirrors mounted on limited rotation galvanometer motors (MFE Ltd) driven from the controlling computer by D-A converters and power amplifiers. The deflected beam is focussed on to the target by a telecentrically mounted biconvex lens. This simple focussing arrangement gives a fairly flat image plane for relatively small deflections. This optical train produces a deflectable spot of approximately 20 μm diameter with a pointability of approximately 40 μm. Optimisation of the optical train would improve these figures considerably. The sample is contained in a commercial gas-microphone cell (EDT Research Ltd). The photoacoustic signal is detected by a two phase lock-in amplifier (Brookdeal 9505 SC) and the in-phase and quadrature components fed to the controlling computer. This is a MINC-23 microcomputer (DEC Ltd) with dual floppy disk drives for the storage of data. A flat bed X-Y plotter and a dot-programmable matrix printer are provided as output devices.

Fig 2 shows a test target and the photoacoustic image obtained from it. The target is a two layer system consisting of a spot and ring separated by a transparent plastic film approximately 70 μm thick, supported on a card substrate. The spot is at the film-substrate interface and the ring is on the film surface. The target is approximately 2.5 mm in diameter. The image was generated by plotting the vector magnitude of the signal as the focussed spot scans across the target. The image consists of 2500 pixels in a 50 x 50 array printed on the matrix printer using a 36 level dot-density grey scale.

Figs 3 and 4 show the two parts of the composite image separated on the basis of the phase shift between surface and sub-surface features. The phase shift between the two images was 63^{o} at a modulation frequency of 22 Hz.

In other calibration experiments, it has been shown that the local thickness of an optically thin film can be measured quantitatively, assuming that the thermal properties of the film are constant and known. In the absence of a knowledge of the thermal diffusivity, qualitative measurements of relative film thickness can be made.

This technique has clear applications for quality control and assurance in materials containing a surface optically thin film which is of interest. The technique could be used to locate and image defects (cracks, pin holes, inclusions, etc) at the film surface, within the film and at the film-substrate interface. Spatial variations in film thickness and the surface quality of the film could also be monitored. Areas of application include polymer films and coatings, corrosion science, printing ink and paint technology, glassy coatings and the microelectronics industry.

References

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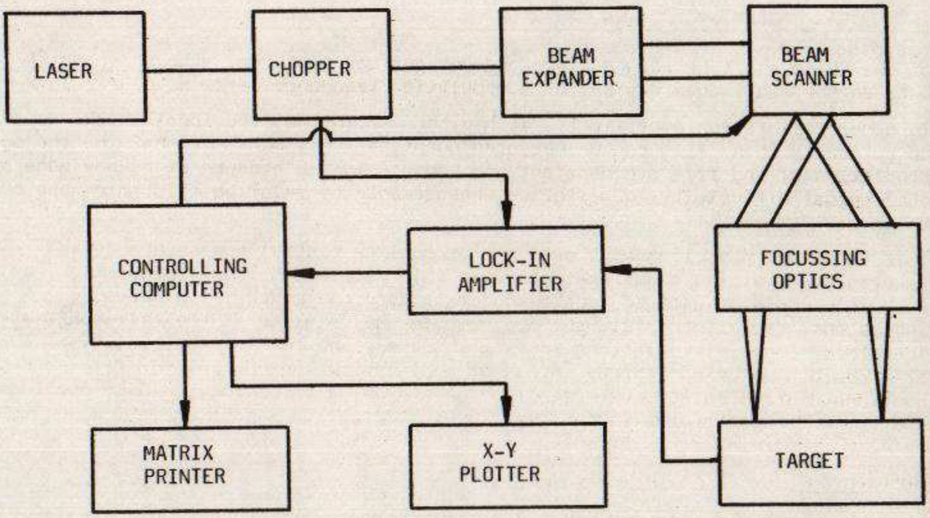


FIGURE 1 BLOCK DIAGRAM OF PHOTOACOUSTIC IMAGING SYSTEM

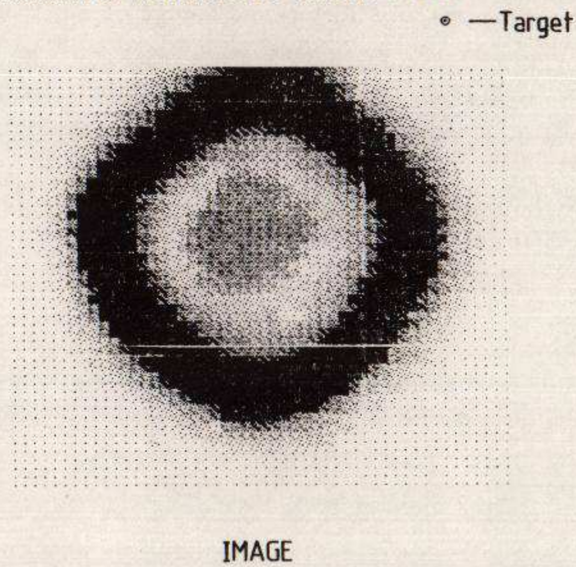
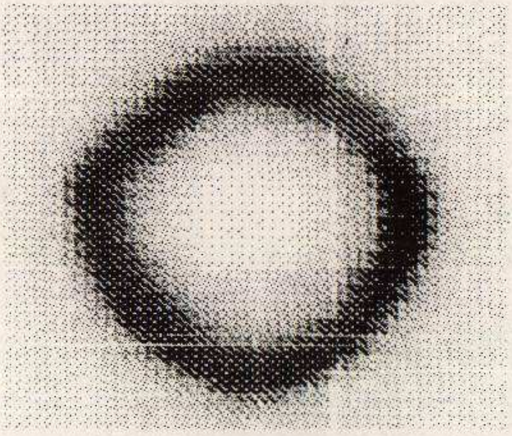
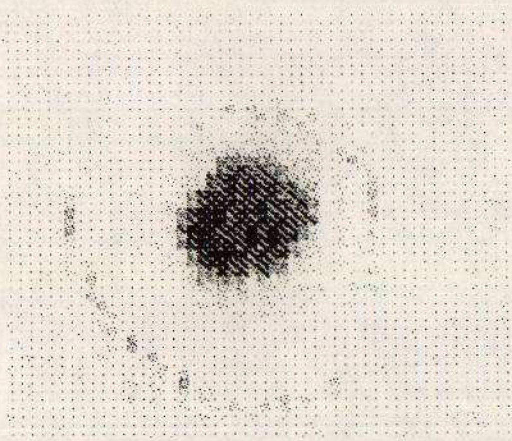


FIGURE 2 TWO-LAYER TARGET AND PHOTOACOUSTIC IMAGE



SURFACE IMAGE

FIGURE 3 PHOTOACOUSTIC IMAGE OF FILM SURFACE



SUB-SURFACE IMAGE

FIGURE 4 PHOTOACOUSTIC IMAGE OF FILM-SUBSTRATE INTERFACE
(63^{o} PHASE SHIFT RELATIVE TO FIGURE 3)