Photoacoustic Microscopy

L. D. Favro  
Wayne State University

L. I. Inglehart  
Wayne State University

P. K. Kuo  
Wayne State University

J. J. Pouch  
Wayne State University

R. L. Thomas  
Wayne State University

Follow this and additional works at: http://lib.dr.iastate.edu/cnde_yellowjackets_1981

Part of the Materials Science and Engineering Commons

Recommended Citation
http://lib.dr.iastate.edu/cnde_yellowjackets_1981/34
Photoacoustic Microscopy

Abstract
Recent advances in scanning photoacoustic microscopy (SPAM) for NDE are described. Conventional and phase-contrast modes are used to detect a well-characterized subsurface flaw in Al, and the results are shown to be in good agreement with calculations based upon a three-dimensional thermal diffusion model.
Applications of the technique are given which demonstrate surface and subsurface flaw detection in complex-shaped ceramic turbine parts. Photoacoustic pictures are presented of an integrated circuit semiconductor chip and show 6 μm resolution.

Keywords
Nondestructive Evaluation

Disciplines
Materials Science and Engineering
PHOTOACOUSTIC MICROSCOPY

L. D. Favro, L. I. Inglehart, P. K. Kuo, J. J. Pouch, and R. L. Thomas
Department of Physics, Wayne State University
Detroit, Michigan 48202

ABSTRACT

Recent advances in scanning photoacoustic microscopy (SPAM) for NDE are described. Conventional and phase-contrast modes are used to detect a well-characterized subsurface flaw in Al, and the results are shown to be in good agreement with calculations based upon a three-dimensional thermal diffusion model. Applications of the technique are given which demonstrate surface and subsurface flaw detection in complex-shaped ceramic turbine parts. Photoacoustic pictures are presented of an integrated circuit semiconductor chip and show 6 μm resolution.

INTRODUCTION

Scanning photoacoustic microscopy (SPAM) is developing into a valuable NDE technique which is particularly applicable for the detection of very small (<10 μm) surface flaws and somewhat larger flaws located in the near subsurface region (within 1 mm). The technique also has the advantage of being applicable to samples of complex shape. In this paper we first review the essential features of the theory and point out several important parameters by considering the simple case of an opaque solid slab containing a back surface step. We next describe an experimental verification of this theory from measurements of the magnitude and phase of the photoacoustic signal for a rectangular aluminum slab with a variable thickness back surface slot. NDE applications are illustrated by SPAM measurements on ceramics with surface and subsurface flaws (including a turbine stator vane) and on a semiconductor I/C chip.

EXPERIMENTAL TECHNIQUE

A block diagram of the apparatus is given in Fig. 1. The intensity of the laser is chopped at a frequency f_c, and focused onto the surface of the sample. The resulting ac temperature profile of the surface periodically heats the layer of gas within a thermal diffusion length of the surface, and the resulting pressure variation couples through the gas to the microphone. The output of the microphone is monitored in magnitude and phase by means of a lock-in amplifier which is referenced to the chopping frequency.

THEORY

Consider an opaque solid slab with a back surface step, varying in thickness from Δ≫τ to 8, where τ = (2σ/α)½, w = 2πf_c, and α is the thermal diffusivity of the sample. We have carried out a Green's function calculation of the resulting ac temperature profile at the surface of the sample and find that the normalized magnitude and phase of the resulting photoacoustic signal is given in Figs. 2 and 3, respectively. Excellent agreement is found with experimental measurements on an aluminum slab containing an 850 μm wide, back surface slot (see Fig. 4). These experiments show that the back surface is detectable in the phase at a depth > 1.82 μg, or nearly 1.5 mm for our lowest values of f_c.

APPLICATIONS

In order to illustrate the technique for NDE applications, we show a Si₃N₄ ceramic with a 200 μm Fe inclusion and a Knoop indentation (Fig. 5); slip cast Si₃N₄ ceramic stator vanes with surface and subsurface defects (Figs. 6, 7), and a semiconductor IC chip (Fig. 8) with 6 μm resolution.
Fig. 3 Phase of the complex SPAM signal for an opaque slab with a back surface slab.

Fig. 4 Aluminum slab with a subsurface rectangular slot.

Fig. 5 Magnitude and phase of the observed SPAM signal for the sample described in Fig. 4.

Fig. 6 SPAM traces of the fillet region of the trailing edge of a slip cast Si$_3$N$_4$ turbine stator vane.

Fig. 7 SPAM traces of a Si$_3$N$_4$ stator vane with subsurface defects.
ACKNOWLEDGEMENTS

This research was supported by ARO under Contract No. DAAG 29-C-0151, and by AFML/APL under contract No. F33615-77-C-5171, as a subcontract from AirResearch Manufacturing Company of Arizona. The authors wish to acknowledge with thanks the collaboration of J. Schuldies of AirResearch and J. Srinivasan of Carborundum on the ceramic studies, and Y.H. Wong of Bell Labs on many phases of this work.

REFERENCES