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 IC 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.

Fig. 1 Block diagram of the apparatus.

APPLICATIONS

In order to illustrate the technique for NDE applications, we show a \( \text{Si}_3\text{N}_4 \) ceramic with a 200 μm Fe inclusion and a Knoop indentation (Fig. 5); slip cast \( \text{Si}_3\text{N}_4 \) ceramic stator vanes\(^3\) with surface and subsurface defects (Figs. 6, 7), and a semiconductor IC chip\(^4\) (Fig. 8) with 6 μm resolution.

Fig. 2 Magnitude of the complex SPAM signal for an opaque slab with a back surface step.
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. 5 SPAM signal for a Si₃N₄ ceramic with a 200 μm Fe inclusion. Inset shows the SPAM signal for a Knoop indentation in a Si₃N₄ ceramic.

Fig. 6 SPAM traces of the fillet region of the trailing edge of a slip cast Si₃N₄ turbine stator vane.

Fig. 7 SPAM traces of a Si₃N₄ stator vane with subsurface defects.
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