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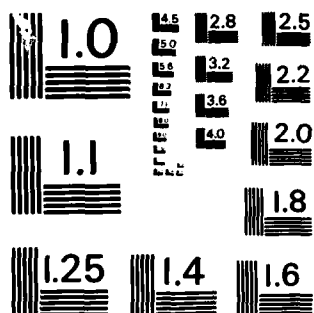
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The scanning photoacoustic microscope has been further developed and experimental results of thermal wave scattering from subsurface flaws have been compared with theoretical predictions.		

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PHOTOACOUSTIC MICROSCOPY

FINAL REPORT

SEPTEMBER 28, 1984

U. S. ARMY RESEARCH OFFICE

CONTRACT NO. DAAG 29-82-K-0152

WAYNE STATE UNIVERSITY

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A. Statement of the Problem Studied

The instrumental technique, Photoacoustic Microscopy, now known generically as Thermal Wave Imaging, was initiated in this laboratory under ARO sponsorship. The overall objective of the research carried out under Contract No. DAAG 29-82-K-0152 was to study the physics of thermal wave scattering from subsurface defects in opaque solids. Another objective was the development of various detection schemes, including both gas-cell and optical probe beam detection and associated instrumentation development.

B. Summary of the Most Important Results

During the course of this study, we have carried out a detailed comparison between theory and experiment for gas-cell detection of thermal wave scattering from closed, slanted cracks in opaque solids. This work was the basis of a 1983 Ph.D. Dissertation by Lt. Col. Kenneth R. Grice, Dept. of Physics, U.S.M.A., West Point, and is detailed technically in the publications cited in Sec. C. Excellent agreement was obtained between theory and experiment. An important finding was the fact that vertical cracks are in principle not observable with gas-cell detection, but are easily detected by thermal wave scattering if optical probe beam (mirage-effect) detection is employed. A detailed study of this detection technique comprised the 1984 Ph.D. Dissertation of Lorretta J. Inglehart, ESPCI, Paris. Again, excellent agreement was obtained between theory and experiment, the details of which are given in the publications cited in Sec. C. Two important findings of that work are: 1) Its extension to the direct and local measurement of thermal diffusivity, and 2) Its applicability for the characterization of opaque coatings.

This laboratory has maintained very useful interactions with Army Scientists at several laboratories, and has participated actively in various

national and international conferences during the Contract period.

C. List of Publications

"Photoacoustic Microscopy", L.D. Favro, L.J. Inglehart, P.K. Kuo, J.J. Pouch, and R.L. Thomas, Proc. 1980 DARPA/AFWAL Review of Progress in Quantitative NDE, Tech. Rep. AFWAL-TR-81-4080, 236-238 (1981).

"Scanning Photoacoustic Microscopy (SPAM) of Si_3N_4 Ceramic Test Bars," L.J. Inglehart, R.L. Thomas, L.D. Favro and P.K. Kuo, Review of Progress in Quantitative Nondestructive Evaluation, D.O. Thompson and D.E. Chimenti, Eds., Vol. 1, pp. 673-675, Plenum (1982).

"Photoacoustic Phase Signatures of Closed Cracks," P.K. Kuo, L.D. Favro, L.J. Inglehart, R.L. Thomas, and M. Srinivasan, J. Appl. Phys. 53, 1258 (1982).

"Experimental and Theoretical Characterization of Near Surface Cracks in Solids by Photoacoustic Microscopy", P.K. Kuo, L.J. Inglehart, L.D. Favro, and R.L. Thomas, Proc. 1981 IEEE Ultrasonics Symposium, B.R. McAvoy, Ed., pp.837-839, Publishing Services IEEE, New York (1981).

"A General Theorem for Simplifying Calculations of Photoacoustic Signals in Gas Filled Cells", P.K. Kuo, L.J. Inglehart, L.D. Favro, and R.L. Thomas, Proc. 1981 IEEE Ultrasonics Symposium, B.R. McAvoy, Ed., pp.788-791, Publishing Services IEEE, New York (1981).

"Photoacoustic Microscopy for NDE of Opaque Solids", R.L. Thomas, L.J. Inglehart, L.D. Favro, and P.K. Kuo, in "Novel NDE Methods for Materials", Ed. B.B. Rath, Conf. Proc. Metall. Soc. of AIME, Warrendale, PA, pp. 83-90 (1983).

"Thermal Wave Imaging for Nondestructive Evaluation", R.L. Thomas, L.D. Favro, K.R. Grice, L.J. Inglehart, P.K. Kuo, and Gerd Busse, Proc. 1982 IEEE Ultrasonics Symposium, B.R. McAvoy, Ed., pp. 586-590, Publishing Services, IEEE, New York (1982).

"Photoacoustic Microscopy", Proc. First Workshop on Nondestructive Evaluation (NDE) of Titanium Alloys", O.P. Arora, H.H. Chaskelis and N.K. Batra, Eds., ONR Rept. DTNSRDC-SME-CR-14-82, pp. 149-159, Washington (1982).

"Spatial Resolution of Thermal Wave Microscopes", L.J. Inglehart, K.R. Grice, L.D. Favro, P.K. Kuo and R.L. Thomas, Appl. Phys. Lett. 43, 446 (1983).

"Thermal Wave Imaging of Closed Cracks in Opaque Solids", K.R. Grice, L.J. Inglehart, L.D. Favro, P.K. Kuo, and R.L. Thomas J. Appl. Phys. 54, 6245-6255 (1983).

"Thermal Wave Imaging of Cracks in Metals", K.R. Grice, L.J. Inglehart, L.D. Favro, P.K. Kuo and R.L. Thomas, Proc. 3rd International Conf. on Photoacoustic and Photothermal Spectroscopy, Supplement au Journal de Physique, Tome 44, FASC. 10, Colloque No. 6, C6-519-C6-524 (1983).

"Spatial Resolution of Thermal Wave Microscopes", L.J. Inglehart, M.J. Lin, L.D. Favro, P.K. Kuo, and R.L. Thomas, Proc. 1983 IEEE Ultrasonics Symposium, edited by B.R. McAvoy (IEEE, New York, 1983), pp. 668-671.

"Thermal Wave Imaging for NDE of Electronic Components", R.L. Thomas, A. Rosencwaig and J. Opsal, to be published in Review of Progress in Quantitative Nondestructive Evaluation, Vol. 4, D.O. Thompson and D.E. Chimenti, Eds., Plenum.

"Theory of Mirage Effect Detection of Thermal Waves in Solids", P.K. Kuo, L.J. Inglehart, E.D. Sandler, M.J. Lin, L.D. Favro and R.L. Thomas, to be published in Review of Progress in Quantitative Nondestructive Evaluation, Vol. 4, D.O. Thompson and D.E. Chimenti, Eds., Plenum.

"Resolution Studies for Thermal Wave Imaging", L.J. Inglehart, D.J. Thomas, M.J. Lin, L.D. Favro, P.K. Kuo and R.L. Thomas, to be published in Review of Progress in Quantitative Nondestructive Evaluation, Vol. 4, D.O. Thompson and D.E. Chimenti, Eds., Plenum.

"Thermal Wave Imaging for NDE of Metals", Proc. 1984 Metals Congress Session on In-Process Nondestructive Characterization and Process Control, to be published in the ASM Metals/Materials Technology Series.

D. Scientific Personnel Supported and Degrees Awarded

R.L. Thomas, Professor

L.D. Favro, Professor

P.K. Kuo, Professor

L.J. Inglehart, M.Sc. (1982), Ph.D. (1984)

Other Participants at no cost to the contract:

Lt. Col. K.R. Grice, Ph.D (1983)

Dr. M.J. Lin, Visiting Professor, 1983-84, National Taiwan Normal University

I. Bergel, M.Sc. Thesis in preparation

C. Reyes, Ph.D. Candidate

W. Shen, Ph.D. Candidate

E. Sandler, High School Apprentice, 1983, Undergraduate Assistant, 83-84

M. Johnson, Undergraduate Assistant

J. Jacobs, Undergraduate Assistant

S. Fradkin, A. Boyer, J. Cancelosa, C. Drain, A. Williams, J. Stein, High School Apprentices

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