4th INTERNATIONAL TOPICAL MEETING ON
PHOTOACOUSTIC, THERMAL AND
RELATED SCIENCES.

4e CONFÉRENCE INTERNATIONALE DE
PHOTOACOUSTIQUE, DE THERMIQUE ET
DE SCIENCES CONNEXES.

TECHNICAL DIGEST

AUGUST 4-8, 1985
HÔTEL DE L'ESTÉREL
VILLE D'ESTÉREL, QUÉBEC
MONDAY, AUGUST 5th, 1985
8:30 AM
Opening by R. Doré, Director of École Polytechnique de Montréal.

PHYSICAL ASPECTS
N.M. Amer, Presider

9:00 AM INVITED PAPER
MA1 Photoacoustic, Photothermal, and Related Techniques: Review and Outlook, F.A. McDonald, Physics Department, Southern Methodist University, Dallas, Texas 75275, U.S.A.

9:35 AM SELECTED ORAL PRESENTATIONS

10:00 AM POSTER VIEWING

MA2 The Photoacoustic Effect: A Method to Study Sorption and Mass Diffusion, P. Korpian, W. Herrmann, A. Kindermann and M. Rothmeyer, Physik-Department, Technische Universität München, D-8046 Garching, FRG. The pressure variation due to sorption, evaporation and diffusion is described. The sorption of water in zeolite and other materials was measured. The effect of gas adsorption at powdered samples is discussed.

MA3 Effect of Gas Viscosity on the Photoacoustic Effect, P. Korpian, B. Buechner, A.C. Tam* and Y.H. Wong**, Physik-Department E13, Technische Universität München, D-8046 Garching, FRG, *IBM Research Laboratory, San Jose, California 95193, USA. **AT & T Bell Laboratories, Murray Hill, New Jersey 07974, USA.

MA4 Analytical Calculation of the Mirage Effect, F. Lepoutre*, B.K. Bein**, and L.J. Inglehart***, *Laboratoire d’Optique, E.S.P.C.I., 10 rue Vauquelin, 75231 Paris Cedex 05, France. **Institut für Experimentalphysik VI, Ruhr-Universität, Bochum, FRG. ***National Bureau of Standards, BLDG 223/A331, Gaithersburg, MD 20899, USA.

Totally analytical expressions for the normal and transverse deflections of the mirage effect can be obtained in the case of a Gaussian excitation. The expressions are easy to use with a personal computer and allow many physical interpretations.


A finite element formulation is developed for the simulation of the PAT effect using the same equations for both solids and fluids. As a first application, the thermoacoustic coupling is studied.
MA6 Separation of Surface Absorption from Bulk Absorption by Using the Phase of the Photoacoustic Signal, B. Mongeau*, G. Rousset and L. Bertrand, Département of Engineering Physics, École Polytechnique, Montréal, Québec, Canada, H3C 3A7. *Department of Physics, College Militaire Royal de Saint-Jean, Saint-Jean, Québec, Canada, J0J 1R0.

Separation of surface absorption from bulk absorption by using the phase of the photoacoustic signal is shown on samples of SiO deposited on ZnSe and CaF$_2$. Spectra of SiO obtained in these two systems are shown and compared.

MA7 The Inverse Optoacoustic Effect, S. Didascalou, R. Stewart and G. Diebold, Brown University, Department of Chemistry, Providence, R.I. 02912, USA.

Sound waves can be produced in a spectrophone cell when an infrared active gas emits radiation to a cold surface. Several properties of this effect are reported.

MA8 The Pressure and Temperature Dependence of Photothermal Deflection Spectroscopic Signals, N. Moore, J.D. Spear, J.B. Benziger, and B.S.H. Royce, School of Engineering and Applied Science, Princeton University, Princeton, NJ 08544, USA.

Gas kinetic theory has been used to predict the pressure and temperature dependence of PDS signals. These predictions have been verified experimentally.

MA9 Digital Simulation of Photoacoustic Impulse Responses, R.M. Miller, Department of Instrumentation and Analytical Science, University of Manchester Institute of Science and Technology, P O Box 88, Manchester M60 1QD, UK.

Photoacoustic impulse responses are simulated using a digital model based on discretization of time and space, and a finite-difference approximation to the governing heat diffusion equations.

MA10 Applicability of Ray Theory to Thermal Wave Analysis, J.A. Burt, Physics Department, York University, 4700 Keele St., Downsview, Ontario, M3J 1P3 Canada.

A simple thermal ray expression is shown to give good agreement with finite difference and variational calculations thus confirming its earlier agreement with experimental measurement.

MA11 Effect of the Thickness of an Air Backing on the Photoacoustic Signal for a Thermally Thin Pb Sample, A. Lachaine and P. Rochon, Physics Department, Royal Military College, Kingston, Ontario, Canada K7L 2W3.

Measurements of the effect of thermally thin air backings on the photoacoustic phase are compared to a simple thermal wave interference model.

10:45 AM QUESTION AND COMMENT PERIOD
MB1 Photoacoustic Resonance Spectroscopy, A. Karbach and P. Hess, Physikalisch-Chemisches Institut, Universität Heidelberg Im Neuenheimer Feld 253, D-6900 Heidelberg, FRG.

Acoustic resonances of a cylinder were recorded with a computer-controlled technique. The pressure dependence of eigenfrequencies, halfwidths, and signal strength was modelled to study different relaxation processes in CH₄.


The photoacoustic signal generated in a photoacoustic gas cell with rigid wall boundaries is calculated by solving the coupled equations for sound propagation and thermal diffusion in a viscous and relaxing gas. When a condition of zero heat flow through the lateral walls of the cell is verified, a general expression is found which can be applied whatever the deactivation path is for collisional relaxation in the gas. Both resonant and non-resonant modes of operation in photoacoustics are considered.

MB3 Heat Diffusion Solutions for the Nonresonant Spectrophone, R. Gerlach and N.M. Amer, Applied Physics and Laser Spectroscopy Group, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, U.S.A.

Analytic heat diffusion solutions for compressible gas in cylindrical cells for Gaussian and arbitrary beam profiles are compared to standard (neglecting compressibility) heat diffusion equation solutions.

MB4 New Theoretical Aspects of Resonant Photoacoustic Spectroscopy, R. Gerlach, R.H. Johnson* and N.M. Amer, Applied Physics and Laser Spectroscopy Group, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, U.S.A. *Present address: Electrical Engineering Dept., Texas A & M University, College Station, Texas 77843, U.S.A.

We derive surface Q for arbitrary mode, show that first azimuthal mode gives higher signal than radial, discuss size considerations, and compare to nonresonant PAS.

We describe a low-pressure photoacoustic spectrometer based on a radio-frequency discharge/laser optogalvanic (PARFLOG) detector. Magnetic predissociation of the $I_2$ B-state is discussed.

MB6 Overtone Stimulated Raman Pumping of $H_2$ from $V = 0$ to $V = 2$ and Subsequent Time Domain Photoacoustic Detection of Vibrational Relaxation, T.G. Kreutz*, J. Gelfand and R.B. Miles, *Department of Chemistry, Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ 08544, USA.

We have excited $H_2$ into the $V = 2$ vibrational state using stimulated overtone Raman pumping. This was followed by time domain photoacoustic detection of vibrational relaxation.

MB7 Influence of Condenser Microphones on Phase Measurements in Photoacoustics at Low Pressure, G. Louis, F. Lepoutre and J.P. Monchalin, 1- Département de Recherches Physiques, (Laboratoire associé au CNRS n° 71), Université Pierre et Marie Curie, 4 Place Jussieu 75230 Paris Cedex 05, France. 2- E.S.P.C.I. Laboratoire d’Optique, 10 rue Vauquelin, 75231 Paris Cedex 05, France. 3- Département de génie physique, École Polytechnique, C.P. 6079, Succ. A, Montréal, Québec, Canada, H3C 3A7. Present address: Physical Metallurgy Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Canada.

The photoacoustic cells using condenser microphones exhibit phase shifts which cannot be explained by photoacoustic theories. A very simple model of the microphone damping agrees with the experimental results.

MB8 Photorefractive Deflection Technique Using Parallel and Overlapping Probe and Pump Beams, M.-C. Gagné, P. Galarneau and S.L. Chin, Laboratoire de recherches en optique et Laser (LROL), Département de physique, Université Laval, Québec, Canada, G1K 7P4.

The behaviour of a probe beam parallel to and inside the pump beam was studied. Application to collinearly align several laser beams are discussed.
MC1 High-Sensitivity Photoacoustic and Photothermal Detections, A.C. Tam, IBM Research Laboratory, San Jose, CA 95193, U.S.A.

4:05 PM SELECTED ORAL PRESENTATIONS

MC2 Application of Photothermal and Photoacoustic Deflection Spectroscopy to Flame Diagnostics, A. Rose and R. Gupta, Department of Physics, University of Arkansas, Fayetteville, AR 72701 U.S.A.

We have applied photoacoustic deflection spectroscopy and photothermal deflection spectroscopy to a measurement of several flame parameters with a high degree of temporal and spatial resolution. The measured parameters include minority species concentrations, flow velocities, and local temperatures.

MC3 Characterization of Vapor and Aerosol Flows by Photothermal Methods, H. Sontag and A.C. Tam, IBM Research Laboratories K06-282, 5600 Cottle Road, San Jose, CA 95193, U.S.A.

Pulsed laser heating is used to label aerosols or absorbing vapors which can be detected by optical means yielding flow and spectroscopic information.

MC4 Laser-Photoacoustic Study of the Water-Vapor Absorption, M.W. Sigrist and J. Hinderling, Physics Department, ETH, Hoenggerberg, CH-8093 Zurich, Switzerland.

New results on the temperature dependence of both line and continuum absorption of water vapor obtained by CO2 laser photoacoustic spectroscopy are discussed.

MC5 Trace Gas Detection by Intra-Cavity Laser Photothermal Deflection, K.H. Fung and H.-B. Lin, Brookhaven National Laboratory, Environmental Chemistry Division, Department of Applied Science, Upton, NY 11973, U.S.A.

An improved thermal lens detector in which the output of the probe laser is modulated by the photothermal process taking place within its cavity is presented.

MC6 Photoacoustic Spectroscopy Applied to Low Level Hydrazine Vapor Monitoring, S.M. Beck, G.L. Loper and J.A. Gelbwachs, Chemistry and Physics Laboratory, The Aerospace Corporation, P. O. Box 92957, Los Angeles, California 90009, U.S.A.

We are developing a low level rocket fuel photoacoustic detector. We present sample and interference spectra, flowing sampler cell design, and cell wall coating measurements.
MC7 Quantitative Detection of Atmospheric Pollutants by Pulsed Laser Photoacoustic Spectroscopy, D.A. Gilmore and G.H. Atkinson, Department of Chemistry, University of Arizona, Tuscon, Arizona, U.S.A.

Pulsed laser photoacoustic spectroscopy in the visible and ultraviolet was utilized to quantitatively determine the concentrations of atmospheric pollutants at the ppbv level. Pollutants under study include NO$_2$, SO$_2$, H$_2$CO, and CH$_3$CHO.

MC8 Laser-Photoacoustic Spectroscopy of Air Pollutants, M.W. Sigrist, St. Bernegger and P.L Meyer, Physics Department, ETH, Hoenggerberg, CH-8093, Zurich, Switzerland.

Two laser-photoacoustic systems that are used for the sensitive detection of various gaseous air pollutants are presented. First results from different air samples are discussed.


Possible application of laser photoacoustic spectroscopy aimed to measure the concentration of volatile odorant in the air is being described.

5:15 PM QUESTION AND COMMENT PERIOD

SURFACES AND INTERFACES
J. Pelzl, Presider

5:35 PM SELECTED ORAL PRESENTATIONS

MD1 Study of the Liquid-Gas Boundary of Water and Alcohols by Photoacoustic Spectroscopy, U. Haas, Institut für Physik, Universität Hohenheim, D7000 Stuttgart 70, FRG.

The PA-amplitudes of free and H-bonded hydroxyl absorptions show different dependence of modulation frequency, revealing a structural modification from inside the liquid towards its surface.

MD2 Rough Surfaces Characterization by Photothermal Analysis, J.P. Roger, D. Fournier, A.C. Boccara, F. Chao* and M. Costa*, Laboratoire d’Optique Physique, ESPCI, 10 rue Vauquelin, 75231 Paris Cedex 05, France. *Laboratoire d’Electrochimie Interfaciale du CNRS, 1 place A. Briand, 92190 Meudon Bellevue France.

A theoretical model is developed for a quantitative evaluation of the photothermal signal exhibited by rough surfaces. Experiments performed by ellipsometry, specular reflection and mirage detection are presented and analyzed.
MD3 Photothermal Detection of Plasmon Surface Polariton on Periodic Silver Gratings with Adsorbed Monolayer Coverages, R.K. Grygier, W. Knoll* and H. Coufal, IBM Research Laboratory, San Jose, California 95193, U.S.A. *Permanent Address: Physik Department E22, Technische Universität München, D-8046 Garching, FRG.

Surface plasmon resonances of periodic silver surfaces are studied with photothermal calorimetry. Shifts due to adsorbed monolayers of hexane and arachidates are observed.

MD4 Surface Temperature Measurement During Pulsed Laser-Induced Thermal Desorption of Xenon from a Copper Film, I. Hussla, H. Coufal, F. Trager* and T.J. Chuang, IBM Research Laboratory, San Jose, California 95193, U.S.A. *Permanent address: Department of Physics, University of Heidelberg, Heidelberg, FRG.

Surface temperatures during laser-induced thermal desorption, determined directly with a pyroelectric calorimeter, are correlated with temperatures derived from time-of-flight data of desorbed xenon.

MD5 Coupling of Pulsed Voltametry with Photothermal Mirage Spectroscopy for In-Situ Observation of Electrode - Electrolyte Interface, A.-M. Dorthe-Merle, J.P. Morand* and E. Maurin**, Laboratoire de Photophysique Photochimie Moleculaire, UA 348 CNRS Université de Bordeaux 1 F 33405 Talence France. *E.N.S.C.P.B. Université de Bordeaux 1 F 33405 Talence. **UA 348 CNRS 33405 Talence France.

Photothermal mirage spectroscopy coupled with pulsed voltametry has been used to observe in-situ the absorption spectrum of non equilibrium electrochemical species formed at the surface of a platinum electrode.


The nature and width of the optical bandgap and near bandgap absorption coefficients for polycrystalline films of p-CulnSe₂ on Al₂O₃ or on Mo/Al₂O₃, similar to those used in CdS/CulnSe₂ solar cells, are determined.


Photocalorimetric Spectroscopy and AC Calorimetry will be discussed as methods for the study of the spectra, growth and heat-of-adsorption of thin films on surfaces.
MD8 Photothermal Deflection Spectroscopy and Photoconductivity Studies of Photoprocesses at Single Crystal CdS Electrolyte Interfaces, R.E. Wagner, V.K.T. Wong and A. Mandelis, Photoacoustics Laboratory, Department of Mechanical Engineering, University of Toronto, Toronto, Ontario, M5S 1A4.

We have used photothermal deflection spectroscopy (PDS) to examine how the degree of band bending in a photoelectrochemical (PEC) cell, consisting of an n-CdS single crystal and a polysulfide electrolyte, affects the rate of non-radiative recombination in the CdS; at the same time, the photocurrent was monitored as a complementary information channel. Our results are indicative of the strong potential of PDS to facilitate the understanding and interpretation of photophysical and photochemical processes at the photoelectrode-electrolyte interface.


A combined photoacoustic attenuated total reflection method is used to detect the non-radiative decay of plasmons surface polariton in heavily doped polyacetylene films, and to determine the optical dielectric constant of the film.

6:45 PM QUESTION AND COMMENT PERIOD

9:00 PM TUTORIAL PRESENTATION

MW1 Noise Problems in Photoacoustic and Photothermal Detection, D. Fournier, Laboratoire d’Optique Physique, ESPCI, 10 rue Vauquelin, 75231 Paris CEDEX 05, France.
TUESDAY, AUGUST 6th, 1985
PHOTOACOUSTIC SPECTROSCOPY
G.F. KIRKBRIGHT MEMORIAL SESSION
B.S.H. Royce, Presider

8:30 AM
G.F. Kirkbright Contributions to Photoacoustic,
J.F. McClelland

9:00 AM INVITED PAPER
TuA1 Quantitative Capabilities of Photoacoustic Spec-
troscopy for Analysis of Solid Materials, J.F. McClelland,
Ames Laboratory-U.S.D.O.E., Iowa State University, Ames,
Iowa 50011, U.S.A.

9:35 AM SELECTED ORAL PRESENTATIONS

10:00 AM POSTER VIEWING

TuA2 An In-Situ Method for Studying Photochemical Reactions Involving Organics Adsorbed on Particulate Surfaces Using Fourier Transform-Infrared Photoacous-
tic Spectroscopy, S.-Q. Luo and J.F. McClelland, Ames
Laboratory-U.S. DOE, Iowa State University, Ames, Iowa
50011, U.S.A.
A method has been developed that simulates the atmos-
pheric irradiation geometry experienced by airborne partic-
ulates and allows in-situ IR analysis of surface adsor-
bed photochemical reactants and products as a function of irradiation time and intensity.

TuA3 New Method for Quantitative Fourier Transform Photoacoustic Spectroscopy, M. Choquet, G. Rousset
A phase analysis of the FTPAS interferogram is proposed to obtain quantitative spectrum while correcting exper-
imental phase errors and wavenumber dependency problem.

Chemical Laboratory, Duke University, Durham, NC 27706,
U.S.A.
Mirage effect detection in the mid-infrared with a deflec-
tion amplifying liquid has been used with a commercial scanning FT-IR spectrometer to characterize cyanome-
tallates and metal carbonyls on solid surfaces.

TuA5 Experimental and Theoretical Spectroscopic Investiga-
tions of Condensed Phases Using Correlation Photo-
acoustic Spectroscopy, J.T. Dodgson and A. Mandelis,
Photoacoustics Laboratory, Department of Mechanical
Engineering, University of Toronto, Toronto, Ontario,
Canada, M5S 1A4.
Correlation Photoacoustic Spectroscopy has been used to determine its sensitivity to material optical absorption coefficient spectra, utilizing Holmium Oxide powders and India inks of various concentrations as exploratory samples. A theoretical model of the method was developed and the theoretical results were found to be in general agreement with the experimental data. Both theory and experiment indicate that Correlation Photoacoustic Spectroscopy can be effectively used to monitor optical absorption phenomena in condensed phases.

TuA6 A Photoacoustic Technique for the Measurement of Multiphoton Absorption Cross Sections in Solids, S.C. Jones, A. Fischer and P. Braunlich, Department of Physics, Washington State University, Pullman, WA 99164-2814, U.S.A.

The first photoacoustic observation of four photon absorption in a transparent optical material is reported. The experimental facility and the calibration procedures employed for absolute cross section measurements are described in detail, and initial results obtained in single-crystalline NaCl with 100 ps laser pulses of 532 nm wavelength are presented.


Thin sample geometry FT-IR/PAS revealed unidentate coordinated carbonate associated with Y(OH)_3 and Y_2O_3 as a function of dewatering method employed in the sol-gel processing of yttria.

TuA8 Influence of Wavelength Modulation by a Mechanical Chopper on the Photoacoustic Spectrum, K.W. Mo*, K.W. Klossok and J. Pelzl, Institut für Experimentalphysik AGVI, Ruhr-Universitat, D-4630 Bochum 1, FRG.


Modifications of the optical PA-spectrum resulting from the wavelength modulation due to a mechanical light chopper are investigated experimentally and theoretically.

TuA9 Photoacoustic Spectroscopy of Lanthanide and Actinide Oxides, G. Heinrich and H.-J. Ache, Kernforschungszentrum Karlsruhe GmbH, Institut für Radiochemie, Postfach 3640, D-7500 Karlsruhe 1, FRG.

The photoacoustic spectra in the ultraviolet, visible and near infrared region of solid state lanthanide oxides are compared with those of the actinide oxides.

TuA10 High Resolution Ultraviolet Photoacoustic Spectroscopy, D.A. Gilmore and G.H. Atkinson, Department of Chemistry, University of Arizona, Tucson, Arizona, U.S.A.

Ultraviolet photoacoustic spectroscopy (PAS) obtained
ENERGY TRANSFER IN GASES
N.M. Amer, Presider

11:05 AM SELECTED ORAL PRESENTATIONS

11:30 AM POSTER VIEWING

MB1 Photoacoustic Resonance Spectroscopy, A. Karbach and P. Hess, Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 253, D-6900 Heidelberg, FRG.

Acoustic resonances of a cylinder were recorded with a computer-controlled technique. The pressure dependence of eigenfrequencies, halfwidths, and signal strength was modeled to study different relaxation processes in CH₄.


The photoacoustic signal generated in a photoacoustic gas cell with rigid wall boundaries is calculated by solving the coupled equations for sound propagation and thermal diffusion in a viscous and relaxing gas. When a condition of zero heat flow through the lateral walls of the cell is verified, a general expression is found which can be applied whatever the deactivation path is for collisional relaxation in the gas. Both resonant and non-resonant modes of operation in photoacoustics are considered.

MB3 Heat Diffusion Solutions for the Nonresonant Spectrophone, R. Gerlach and N.M. Amer, Applied Physics and Laser Spectroscopy Group, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, U.S.A.

Analytic heat diffusion solutions for compressible gas in cylindrical cells for Gaussian and arbitrary beam profiles are compared to standard (neglecting compressibility) heat diffusion equation solutions.

MB4 New Theoretical Aspects of Resonant Photoacoustic Spectroscopy, R. Gerlach, R.H. Johnson* and N.M. Amer, Applied Physics and Laser Spectroscopy Group, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, U.S.A. *Present address: Electrical Engineering Dept., Texas A & M University, College Station, Texas 77843, U.S.A.

We derive surface Q for arbitrary mode, show that first azimuthal mode gives higher signal than radial, discuss size considerations, and compare to nonresonant PAS.

We describe a low-pressure photoacoustic spectrometer based on a radio-frequency discharge/laser optogalvanic (PARFLOG) detector. Magnetic predissociation of the I\textsubscript{2} B-state is discussed.

MB6 Overtone Stimulated Raman Pumping of H\textsubscript{2} from V = 0 to V = 2 and Subsequent Time Domain Photoacoustic Detection of Vibrational Relaxation, T.G. Kreutz*, J. Gelfeld and R.B. Miles, *Department of Chemistry, Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ 08544, USA.

We have excited H\textsubscript{2} into the V = 2 vibrational state using stimulated overtone Raman pumping. This was followed by time domain photoacoustic detection of vibrational relaxation.

MB7 Influence of Condenser Microphones on Phase Measurements in Photoacoustics at Low Pressure, G. Louis\textsuperscript{1}, F. Lepoutre\textsuperscript{2} and J.P. Monchalin\textsuperscript{3}, 1- Département de Recherches Physiques, (Laboratoire associé au CNRS n° 71). Université Pierre et Marie Curie, 4 Place Jussieu 75230 Paris Cedex 05, France. 2- E.S.P.C.I. Laboratoire d'Optique, 10 rue Vauquelin, 75231 Paris Cedex 05, France. 3- Département de génie physique, École Polytechnique, C.P. 6079, Succ. A, Montréal, Québec, Canada, H3C 3A7. Present address: Physical Metallurgy Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Canada.

The photoacoustic cells using condenser microphones exhibit phase shifts which cannot be explained by photoacoustic theories. A very simple model of the microphone damping agrees with the experimental results.

MB8 Photorefractive Deflection Technique Using Parallel and Overlapping Probe and Pump Beams, M.-C. Gagné, P. Galarneau and S.L. Chin, Laboratoire de recherches en optique et Laser (LROL), Département de physique, Université Laval, Québec, Canada, G1K 7P4,

The behaviour of a probe beam parallel to and inside the pump beam was studied. Application to collinearly align several laser beams are discussed.

12:15 PM QUESTION AND COMMENT PERIOD

DETECTION IN GASES

J. Pelzl, Presider

3:30 PM INVITED PAPER
MC1 High-Sensitivity Photoacoustic and Photothermal Detections, A.C. Tam. IBM Research Laboratory, San Jose, CA 95193, U.S.A.

4:05 PM SELECTED ORAL PRESENTATIONS

4:30 PM POSTER VIEWING

MC2 Application of Photothermal and Photoacoustic Deflection Spectroscopy to Flame Diagnostics, A. Rose and R. Gupta, Department of Physics, University of Arkansas, Fayetteville, AR 72701 U.S.A.

We have applied photoacoustic deflection spectroscopy and photothermal deflection spectroscopy to a measurement of several flame parameters with a high degree of temporal and spatial resolution. The measured parameters include minority species concentrations, flow velocities, and local temperatures.

MC3 Characterization of Vapor and Aerosol Flows by Photothermal Methods, H. Sontag and A.C. Tam, IBM Research Laboratories K06-282, 5600 Cottle Road, San Jose, CA 95193, U.S.A.

Pulsed laser heating is used to label aerosols or absorbing vapors which can be detected by optical means yielding flow and spectroscopic information.

MC4 Laser-Photoacoustic Study of the Water-Vapor Absorption, M.W. Sigrist and J. Hinderling, Physics Department, ETH, Hoenggerberg, CH-8093 Zurich, Switzerland.

New results on the temperature dependence of both line and continuum absorption of water vapor obtained by CO₂ laser photoacoustic spectroscopy are discussed.

MC5 Trace Gas Detection by Intra-Cavity Laser Photothermal Deflection, K.H. Fung and H.-B. Lin, Brookhaven National Laboratory, Environmental Chemistry Division, Department of Applied Science, Upton, NY 11973, U.S.A.

An improved thermal lens detector in which the output of the probe laser is modulated by the photothermal process taking place within its cavity is presented.

MC6 Photoacoustic Spectroscopy Applied to Low Level Hydrazine Vapor Monitoring, S.M. Beck, G.L. Loper and J.A. Gelbwachs, Chemistry and Physics Laboratory, The Aerospace Corporation, P. O. Box 92957, Los Angeles, California 90009, U.S.A.

We are developing a low level rocket fuel photoacoustic detector. We present sample and interference spectra, flowing sampler cell design, and cell wall coating measurements.
MC7 Quantitative Detection of Atmospheric Pollutants by Pulsed Laser Photoacoustic Spectroscopy, D.A. Gilmore and G.H. Atkinson, Department of Chemistry, University of Arizona, Tucson, Arizona, U.S.A.

Pulsed laser photoacoustic spectroscopy in the visible and ultraviolet was utilized to quantitatively determine the concentrations of atmospheric pollutants at the ppbv level. Pollutants under study include NO₂, SO₂, H₂CO, and CH₃CHO.

MC8 Laser-Photoacoustic Spectroscopy of Air Pollutants, M.W. Sigrist, St. Bernegger and P.L. Meyer, Physics Department, ETH, Hoenggerberg, CH-8093, Zurich, Switzerland.

Two laser-photoacoustic systems that are used for the sensitive detection of various gaseous air pollutants are presented. First results from different air samples are discussed.


Possible application of laser photoacoustic spectroscopy aimed to measure the concentration of volatile odorant in the air is being described.

5:15 PM QUESTION AND COMMENT PERIOD

SURFACES AND INTERFACES
J. Pelzl, Presider

5:35 PM SELECTED ORAL PRESENTATIONS
6:00 PM POSTER VIEWING

MD1 Study of the Liquid-Gas Boundary of Water and Alcohols by Photoacoustic Spectroscopy, U. Haas, Institut für Physik, Universität Hohenheim, D7000 Stuttgart 70, FRG.

The PA-amplitudes of free and H-bonded hydroxyl absorptions show different dependence of modulation frequency, revealing a structural modification from inside the liquid towards its surface.

MD2 Rough Surfaces Characterization by Photothermal Analysis, J.P. Roger, D. Fournier, A.C. Boccara, F. Chao* and M. Costa*, Laboratoire d’Optique Physique, ESPCI, 10 rue Vauquelin, 75231 Paris Cedex 05, France. *Laboratoire d’Electrochimie Interfaciale du CNRS, 1 place A. Briand, 92190 Meudon Bellevue France.

A theoretical model is developed for a quantitative evaluation of the photothermal signal exhibited by rough surfaces. Experiments performed by ellipsometry, specular reflection and mirage detection are presented and analyzed.
with pulsed lasers and nonlinear optics was used to record spectra of formaldehyde, acetaldehyde, SO$_2$ and NO$_2$ with 0.3 to 0.05 cm$^{-1}$ resolution.

**TuA11 Research of Photoacoustic Measurement and Absolute Calibration of Absorption in Optical Thin Films, G. Jian, C. Wen-bin and S. Bai-xuan, Optical Engineering Department of Zhejiang University, Hangzhou, R.P. China.**

A calibration method has been realized by the curve-fit method for photoacoustic measurement in optical thin films which are illuminated in the rear and front, respectively.

**10:45 AM QUESTION AND COMMENT PERIOD**

INTERDISCIPLINARY SESSION

**11:05 AM SELECTED ORAL PRESENTATIONS**

**11:30 AM POSTER VIEWING**

**TuB1 Non Destructive Evaluation of Magnetic Materials by the FMR-Photothermal Deflection Spectroscopy, U. Netzelmann, J. Pelzl, D. Fournier* and A.C. Boccara*, Institut für Experimentalphysik AG VI, Ruhr-Universität, D-4630 Bochum, FRG. *Laboratoire Optique Physique, ESPCI, 10 rue Vauquelin, 75231 Paris Cedex 05, France.**

Detection of the ferromagnetic resonance (FMR) by photothermal beam deflection has been used to measure locally magnetic depth profiles of recorder tapes and to determine the non-uniform in-plane magnetisation of metglass ribbons.


Absorption by a polycrystalline metal of a chopped CW ultrasonic beam is measured by infrared detection.

**TuB3 Gas Velocity Measurements by Photothermal Deflection Spectroscopy, J.A. Sell, Physics Department, General Motors Research Laboratories, Warren, Michigan 480909055, U.S.A.**

Gas velocities are measured by two different methods using photothermal deflection spectroscopy with 1 ms temporal resolution and spatial resolution less than $10^{-4}$ cm$^3$.

**TuB4 Electrocapillarity vs. Optocapillarity, H.L. Fang, The Standard Oil Company (Ohio), Corporate Research Center, 4440 Warrensville Center Road, Warrensville Heights, Ohio 44128, U.S.A.**

A capillary wave is generated by the modulation of either an electric field or a heating laser. Comparison is made with experimental data.

Water content in polyethylene and silicone oil is studied by I.R. photoacoustic spectroscopy. An absorption corresponding to the OH vibration of associated water molecules is observed from both the surface and bulk of the dielectric sample.

TuB6 Deformation of Liquid Surface by Laser Heating: Laser Beam Self-Focusing and Generation of Capillary Waves, J. Hartikainen, J. Jaarinen, M. Luukkala, Department of Physics, University of Helsinki, Siltavuorenpenker 20 D, SF-00170 Helsinki, Finland.

The surface deformation of oil by laser heating is presented. The self-focusing of the reflected beam and the generation of capillary waves are observed.

TuB7 Orientation Study of Piezoelectric Coatings on Optical Fibers Using Fourier Transform IR Photoacoustic Spectroscopy, H. Talaat, Physics Department, Catholic University of America, Washington D.C. 20064, U.S.A. and Physics Department, Faculty of Science, Ain Shams University, Cairo, Egypt.

Fourier transform IR-photoacoustic dichroism investigations of optical fibers coated with piezactive PVF2 polymer are applied to study the molecular orientation associated with the piezoactivity of the coatings to estimate their performance.

TuB8 Photopyroelectric Spectroscopy of Solids and Liquids (PPES), A. Mandelis, Photoacoustics Laboratory, Department of Mechanical Engineering, University of Toronto, Toronto, Ontario, Canada, M5S 1A4.

A new photothermal technique, photopyroelectric spectroscopy, is described. A few applications demonstrate its potential in measuring physicochemical properties of solid and liquid materials.

TuB9 Pulsed Photothermal Deflection Spectroscopy in Flowing Media, V. Zharov* and N.M. Amer, Applied Physics and Laser Spectroscopy Group, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720, U.S.A. *Permanent address: Department of Biomedical Instruments, Moscow High Technical School, Moscow, USSR, 107005.

Pulsed photothermal deflection was used to spatially map out flow velocity profile and to determine absolute flow velocities.

A new mass air flow sensor that measures time of flight of temperature oscillations along the air-solid interface is reported. Theory and experiment are discussed.

12:15 PM QUESTION AND COMMENT PERIOD
NONDESTRUCTIVE EVALUATION NDE 1
K. Wickramasinghe, Presider

3:30 PM INVITED PAPER
TuC1 Thermal Wave Imaging for NDE, R.L. Thomas, L.D. Favro and P.K. Kuo, Department of Physics, Wayne State University, Detroit, MI 48202, U.S.A.

4:05 PM SELECTED ORAL PRESENTATIONS
4:30 PM POSTER VIEWING
TuC2 Optical Beam Deflection Imaging of Vertical Cracks in Solids, F.A. McDonald, G.C. Wetsel Jr. and G.E. Jamieson, Department of Physics, Southern Methodist University, Dallas, Texas 75275, U.S.A.

A method of calculation of optical beam deflection imaging signals is presented and applied to the case of closed vertical cracks in opaque solids.

TuC3 Nonlinear Photothermal Imaging, G.C. Wetsel Jr., The Johns Hopkins University, Applied Physics Laboratory, Laurel, MD 20707, U.S.A.

Nonlinear photothermal optical-beam-deflection signals have been observed. Theoretical models of the phenomena have been developed for comparison with the experimental results.

TuC4 Theory of Real-Time Photoacoustic Microscopy, R.S. Quimby and Z.M. Liu, Department of Physics, Worcester Polytechnic Institute, Worcester, Massachusetts 01609, U.S.A.

A photoacoustic theory is developed for a moving heat source. The theory is applied to real-time photoacoustic microscopy, in which the beam position is ramp modulated.

TuC5 Resolution and Contrast in the Thermoacoustic Microscope, J. Opsal and A. Rosencwaig, Thermo-Wave, Inc., Fremont, CA 94539, U.S.A.

A 3-dimensional analysis of thermoelastic effects is presented to explain the resolution and contrast observed in the thermoacoustic microscope.

Characterization of metallic samples in the neighborhood of interfaces using laser excitation with optical-beam-deflection and attached-transducer detection are compared.


Grain boundaries in high purity aluminum are examined using electron beam generation and piezoelectric detection. The relative importance of thermal, elastic and acoustic contributions to contrast is discussed.

TuC8 Ion-Acoustic Imaging of Subsurface Flaws in Aluminum, F.G. Satikewicz, J.C. Murphy and L.C. Aamodt, Applied Physics Laboratory, The Johns Hopkins University, Johns Hopkins Road, Laurel, MD 20707, U.S.A.

Ion-acoustic imaging has been demonstrated. Studies of subsurface flaws in aluminum have identified two contrast processes. Non-thermal acoustic generation has been studied experimentally and theoretically.


Thermal wave transmission of a rotating sample shows structures where one part depends on rotational frequency while the other depends on detector offset and wheel velocity.

TuC10 A Theoretical Study of the Thermoacoustic Microscope, L.D. Favro, P.K. Kuo and R.L. Thomas, Department of Physics, Wayne State University, Detroit, MI 48202, U.S.A.

We present a theoretical analysis of four different mechanisms by which acoustic waves are generated in the thermoacoustic microscope.

The use of a chopped ion beam to generate acoustic signals during the implantation process and can be used to monitor the progress of implantation.

TuC12 Corroded Needles Examined by Mirage Effect, L.J. Inglehart*, F. Lepoutre and E. Legal Lasalle, Laboratoire d’Optique Physique, ESPCI, 10 rue Vauquelin, 75231 Paris Cedex 05, France. *Permanent address: National Bureau of Standards, BLDG 223/A331, Gaithersburg, MD 20899, U.S.A.

Photothermal images of tubes made of a special stainless steel are reported. Very thin surface damages have been detected and related to variations in the thermal properties. Inner defects have been also quantitatively discussed. Corrosion effects will be discussed.

5:15 PM QUESTION AND COMMENT PERIOD

NDE 2: THERMAL WAVE IMAGING
K. Wickramasinghe, Presider

5:35 PM SELECTED ORAL PRESENTATIONS

6:00 PM POSTER VIEWING

TuD1 Nondestructive Evaluation of a Carbon Fiber Composite Using the Mirage Effect, L.J. Inglehart*, F. Lepoutre, F. Charbonnier and D. Fournier, Laboratoire d’Optique Physique, ESPCI, 10 rue Vauquelin, 75231 Paris Cedex 05, France. *Permanent address: National Bureau of Standards, BLDG 223/A331, Gaithersburg, MD 20899, U.S.A.

For the first time, thermal images of a composite material have been obtained and quantitatively analyzed from mirage effect experiments. The method allows the determination of local thermal properties geometric features and fiber ruptures.

TuD2 Depth Resolved Thermal Wave Imaging of Layered Samples by Correlation Photoacoustics, Y. Sugitani and A. Uejima, Institute of Chemistry, The University of Tsukuba, Sakura-mura, Ibaraki 305, Japan.

A new photoacoustic method, correlation photoacoustic imaging, has been developed combining two independently developed techniques, thermal wave imaging and correlation photoacoustic spectroscopy. This method was demonstrated on a layer-structured model sample.
TuD3 On the Influence of Thin Absorber Layers in Thermal Wave Applications, R. Tilgner, J. Baumann and M. Beytus, Siemens AG, ZFA, Munich, FRG.

We investigate the influence on surface temperature caused by thermally thin light absorbing layers deposited on the sample under observation in photoacoustic or photothermal experiments.

TuD4 Photothermal Examination of Buried Layers, J. Baumann and R. Tilgner, Siemens AG, ZFA, Munich, FRG.

Based on the conventional thermal-wave approach we analyze the influence of buried layers on the complex surface temperature of a sample. First experimental results confirm the calculations.


A pulsed photothermal technique is described for the non-destructive evaluation of layered materials. A FFT analysis of the thermoelastic signal allows defect sizing by comparison with a numerical simulation.

TuD6 Data Analysis in Opto-Thermal Transient Emission Radiometry, R.E. Imhof, F.R. Thornley, J.R. Gilchrist and D.J.S. Birch, Department of Applied Physics, Strathclyde University, Glasgow G4 ONG, Scotland.

Least-squares methods of extracting physical parameters from opto-thermal decay curves in the presence of distortion, RF pick-up and noise will be described.


Degradation in paint films caused by accelerated weathering has been characterised using Opto-Thermal Transient Emission Radiometry (OTTER). The measured opto-thermal decay-times decrease with weathering exposure.


The principle of the pulsed photothermal technique and the general form of the analytical solutions related to the
application of the technique to layered materials are recalled. Two examples of application are given: characterization of the adhesion of a coating on a substrate and of a delamination in a carbon/epoxy composite material.

TuD9 Flexural Resonance Measurements of Clamped and Partially Clamped Discs Excited by Laser-Induced PhotoAcoustics, R.A. Crosbie, R.J. Dewhurst and S.B. Palmer, Departement of Applied Physics, University of Hull, Cottingham Road, Hull, England, HU6 7RX.

Nanosecond laser pulses have been used to excite clamped or partially clamped discs to resonance. Measurements show that circular-like flaws in laminations may be characterised.


Several enamel coatings exhibiting different adherence properties have been experimentally studied and the results are compared to an analytical model with an interface thermal resistance.


Thermal wave detection by a simple phase sensitive interferometric arrangement is used for remote nondestructive detection of material subsurface structure in metal.

TuD12 Thermal Wave Transient Behaviour, B. Rief, Institut für Kunststoffprüfung und Kunststoffkunde, Universität Stuttgart, D-7000 Stuttgart 80, G.F.R.

When a thermal wave is switched on, it takes some time until phase and magnitude have reached their final value. The intention of this paper is to determine how this time depends on sample depth.

6:45 PM QUESTION AND COMMENT PERIOD

9:00 PM TUTORIAL PRESENTATION

TuWi Experimental Aspects of Photothermal Radiometry, P.-E. Nordal and S.O. Kanstad*, Applied Optics Laboratory, P.O. Box 303 Blindern, 0314 Oslo 3, Norway.

*LASERLAB P.O. Box 2787 Elverhøy, 9001 Tromsø, Norway.
WA1 Photoacoustic and Photothermal Techniques for Thermal Characterization, A.C. Boccara, Laboratoire d'Optique Physique, ESPCI, 10 rue Vauquelin, 75231 Paris CEDEX 05, France.

9:05 AM SELECTED ORAL PRESENTATIONS

WA2 Thermal Diffusivity Measurements of 1 µm Thick Polymer Films by Time Resolved Photocalorimetry, P. Hefferle* and H. Coutal, IBM Research Laboratory, San Jose, California 95193, U.S.A. *Permanent address: Fachbereich Chemie, Technische Universität München, D-8046 Garching, FRG.

Thermal Diffusivities of polymer films with thickness in the 1 µm range are determined by a pulsed method using time resolved calorimetry.

WA3 Photoacoustic Study of the Thermal Diffusivity of Metglass Ribbons, R. Kordecki, B. Bein and J. Pelzl, Institut für Experimentalphysik AGVI, Ruhr-Universität, D-4630 Bochum 1, FRG.

Thermal diffusivities of freely supported metallic ribbons are measured at different annealing stages using a gas coupled microphone and a symmetrized heat wave excitation.

WA4 Effective Thermal Properties of Rough and Porous Limiter Graphite, B.K. Bein, S. Krueger and J. Pelzl Ruhr-Universität Bochum, Institut für Experimentalphysik VI, D-4630 Bochum 1, FRG.

PA phase lag and amplitude of rough and porous graphite limiter plates were measured and interpreted in order to obtain a quantitative description of the effective thermal depth structure.


A method is described for the absolute measurement of thermal inertia by the one-side photothermal technique. Ceramic materials have been characterized by this method.

WA6 Compared Photothermal Measurements of Thermal Diffusivity in Composites, D.L. Balageas, R.M. Pujolà,
Experimental measurements of the thermal diffusivity obtained by pulsed and modulated photothermal techniques are compared in the case of directional reinforced (3-D) carbon/carbon composites.

WA7 A Thermal Wave Approach for Heterogeneous Materials with Continuously Varying Thermal and Optical Properties in one Dimension, L.C. Aamodt and J.C. Murphy, Applied Physics Laboratory, Johns Hopkins University, Johns Hopkins Road, Laurel, MD 20707, U.S.A.

Heat obstructions created in heterogeneous materials with continuously varying thermal and optical properties in one dimension are analyzed using a thermal wave approach.

WA8 Phase Transitions and Thermal Diffusivity Measurements of Thin Liquid Crystal Samples by a Photoacoustic Technique, G. Louis, P. Peretti, J. Billard* and B. Mangeot**, Département de Recherches Physiques, (Laboratoire associé au CNRS n° 71), Université Pierre et Marie Curie, 4 Place Jussieu 75230 Paris Cedex 05, France. *Laboratoire de Physique de la Matière Condensée du Collège de France (Laboratoire associé au CNRS n° 241), Place M. Berthelot 75231 Paris Cedex 05, France. **Laboratoire de Spectroscopie Biomédicale, 45 rue des Saints Pères, 75006 Paris, France.

First and second order phase transitions in a thermotropic liquid crystal are investigated by means of a photoacoustic technique by using a rear-surface excitation. The thickness dependence study of the phase signal by a scanning method allows the determination of thin samples thermal diffusivities.


A simple method is demonstrated for determining the thermal diffusivity of opaque solids, by measuring the phase-lag between a front and rear illumination, at a single chopping frequency. The method is tested using semiconductors samples.

WA10 Photoacoustic Calorimetry at First Order Phase Transitions The Melting of Thin In Films, P. Korpiun, A. Faber and J. Weiser, Physik-Department E13, Technische Universität München, D-8046 Garching, FRG.

The PAE is measured on 20 to 100 nm In films at the melting point. The latent heat can be obtained using a model for thermally extremely thin samples.
WA11 Some Applications of Photoacoustic Technique to Inorganic Materials and Device, Q.-R. Yin, G. Li and T. Wang, 865 Chang-ning Road, Shanghai Institute of Ceramics, Academia Sinica, Shanghai, China.

Study of phase transition on ferroelectric ceramics, quantitative analysis of Cr$_2$O$_3$ content, determination of sensitivity of low frequency piezoelectric sensor, were demonstrated.

10:15 AM QUESTION AND COMMENT PERIOD

THERMAL INSPECTION

J.C. Murphy, Presider

10:35 AM INVITED PAPER


11:10 AM SELECTED ORAL PRESENTATIONS

11:35 AM POSTER VIEWING

WB2 Theory of Mirage Effect Measurement of Thermal Diffusivity, P.K. Kuo, E.D. Sendler, L.D. Favro and R.L. Thomas, Dept. of Physics, Wayne State University, Detroit, MI 48202, U.S.A.

A three dimensional theory of a mirage effect technique for measuring thermal diffusivity of solids is presented.


A mirage effect thermal wave method for the measurement of thermal diffusivities of solids is described.


A converging-thermal-wave technique is described for the measurement of thermal diffusivity by annular surface heating and temperature monitoring with a focused infrared detector.

WB5 Determination of Thermal Parameter Profiles from Surface Data, H.J. Vidberg, J. Jaarinen, M. Luukkala and D.O. Riska, Departement of Physics, University of Helsinki, Siltavuorenpenkeri 20 M, SF-00170 Helsinki, Finland.
The inverse problem of constructing the thermal parameter profiles from the thermal wave surface data due to a local harmonic heat source is solved.

**WB6 Time-Resolved "Stimulated" I-R Thermography Applied to the subsurface Control of Materials, J.L. Beaudoin, R. Danjoux, E. Merienne and M. Egée, Service Universitaire d’Energétique and Laboratoire de Recherches Optiques, Faculté des Sciences de REIMS; BP 347, 51062 REIMS CEDEX, France.**

A new infrared thermography numerical system, allowing time-resolved imaging, is used for the photothermal analysis of subsurface defects in composite materials.


The piezoelectric photoacoustic signal measured on coals of different carbon content were proportional to a thermal-elastic parameter of the coal. Experimental results are in agreement with theory.

**WB8 Quantitative IR Thermography in Nuclear Fusion Research and its Relationship to Photoacoustics, B.K. Bein and E.R. Mueller*, Institut für Experimentalphysik VI, Ruhr-Universität Bochum, D-4630 Bochum 1, FRG. *Max-Planck-Institut für Plasmaphysik, EURATOM-Association, D-8046 Garching (bei München), FRG.**

Part of the plasma power losses in magnetic confinement based nuclear fusion devices is deposited on limiter or divertor plates. This part can be deduced quantitatively from time-dependent IR surface temperature measurements at the limiter or divertor plates.

**WB9 Problems Encountered in Using Thermal Wave Interferometry for the Testing of Plasma Sprayed Coatings, P.M. Patel, D.P. Almond and H. Reiter, School of Materials Science, University of Bath, Bath BA2 7AY, UK.**

The influence of variations in roughness and reflectivity on the photothermal response of plasma sprayed coatings. Distinguishing between defect and coating thickness change response.


Thermal wave anisotropy has been investigated on carbon fibre reinforced plastics (CFRP). The relevance for applications in nondestructive evaluation of composite materials is discussed.
Scanned photothermal radiometry is used for remote scanned seam inspection. From the signal we determined seam profiles and distinguished good quality seams from faulty seams.

12:15 PM QUESTION AND COMMENT PERIOD

NDE 3: ULTRASONICS

G.S. Kino, Presider

3:30 PM INVITED PAPER

WC1 Photoacoustic Ultrasonic Generation, D.A. Hutchins, Department of Physics, Queen’s University, Kingston, Ontario, Canada, K7L 3N6.

4:05 PM SELECTED ORAL PRESENTATIONS

4:30 PM POSTER VIEWING

WC2 The Application of High-Frequency Transducers in Air as Photoacoustic Sensors, R.G. Stearns and G.S. Kino, Edward L. Ginzton Laboratory, W.W. Hansen Laboratories of Physics, Stanford University, Stanford, CA 94305, U.S.A.

A photoacoustic measurement in air is described at 2 MHz. Experiments measuring oxide film thickness, surface topography, and surface recombination in silicon will be discussed.


A confocal Fabry-Perot interferometer receiving laser light scattered by a sample is used to detect ultrasound generated by a second laser.


Converging surface-acoustic-waves may be generated by surface irradiation with a pulsed annular laser beam. The amplified wave is detected interferometrically at the convergence point.
The possible contribution of nonthermal effects to the laser-generated sound in liquids is discussed on the basis of temperature-dependance measurements in $H_2O$, $D_2O$ and aqueous solutions.

Optical Detection of Photo-Acoustic Pulses in Thin Silicon Wafers. H. Sontag and A.C. Tam, IBM Research Laboratories K06-282, 5600 Cottle Road, San Jose, CA 95193, U.S.A.

A probe beam deflection method is used to study the propagation of photoacoustic longitudinal waves and plate modes in silicon wafers.

Efficient Surface-Acoustic Wave Generation by Thermoelasticity, W. Arnold, B. Betz and B. Hoffmann, Fraunhofer-Institute for Non-Destructive Testing, Bldg. 37, University, D6600, Saarbrücken, FRG.

We have experimentally verified the conditions for maximal generation of SAW using a pulsed laser. A theoretical analysis of our results is also presented.

A Photoacoustic Investigation of Shear Wave to Rayleigh Wave Mode Conversion at Slots, D.A. Hutchins, F. Nadeau* and P. Cielo*, Department of Physics, Queen’s University, Kingston, Ontario, Canada, K7L 3N6. *Industrial Materials Research Institute, 75, de Mortagne Blvd., Boucherville, Québec, Canada, J4B 6Y4.

The interaction of bulk waves with rectangular slots in aluminum plates has been studied using photoacoustic generation by a Q-switched Nd:YAG laser and detection by Michelson interferometer. Analysis of received waveforms has indicated that the dominant effect is mode conversion from the shear mode to a Rayleigh wave, over the range of geometries investigated.

5:10 PM QUESTION AND COMMENT PERIOD

5:30 PM INVITED PAPER

Thermal and Acoustic Wave Techniques in Scanning Electron Microscopy, L.J. Balk, Universität Duisburg, Fachgebiet Werkstoffe der Elektrotechnik, Kommandenstrasse 60, D-4100 Duisburg 1, FRG.

6:05 PM SELECTED ORAL PRESENTATIONS

6:30 PM POSTER VIEWING
We present a spatially-resolved contactless method for the study of thermal and electronic transport in semiconductors. The technique employs the deflection of a probe beam to measure transport parameters via their contributions to the refractive index of the semiconductor.

The dynamics of nonradiative recombination processes are investigated by measuring the thermal expansion and subsequent displacement of a sample surface caused by the absorption of a modulated laser beam.

We describe the free-carrier plasma density generated in a semiconductor by a modulated laser as a critically damped propagating wave analogous to the thermal wave.

We present a noncontact method for detecting thermal waves through the dependence of optical reflectance on temperature. The technique is highly sensitive and nondestructive.

We report a new noncontact, nondestructive method for measuring ion-implanted dose and uniformity of dopants in Si and GaAs that is applicable prior to annealing.

The photoacoustic response of a working photovoltaic cell has been successfully simulated, thus improving the possibility of photoacoustically elucidating energy loss mechanisms in semiconductor devices.
Detection of thermal radiation, at the non-illuminated surface of a Si solar cell, in response to either intensity or load-resistance modulation, allows partial electrical characterization of such a cell.

Thermal conductivity and optical absorption are measured on a GaAlAs layer epitaxied on GaAs. Optical photothermal data are in good agreement with spectroscopic ellipsometry data.

Non-destructive inspections of some GaAs semiconductor devices were carried out by means of a home-made photoacoustic microscope (PAM) and photothermal beam deflection microscope (PBDM). Particularly PAM and PBD images of a Zn-doped region and dislocations of GaAs wafers have been discussed in the paper.

Photoacoustic spectroscopy is shown to provide additional information to photocurrent spectra in studying electron and hole transport phenomena in (0001) CdS. Experimental results leading to the measurement of photoexcited semiconductor carrier parameters will be discussed.

Photoacoustic microscopy has been carried out on PMOS integrated circuits, using laser excitation and piezoelectric detection (25 Hz 300 kHz). Subsurface features have been seen.
THURSDAY, AUGUST 8th, 1985
APPLICATIONS TO BIOLOGY
D. Cahen, Presider

8:30 AM INVITED PAPER
ThA1 Application of Photoacoustics to Biology, D. Balasubramanian and Ch. M. Rao, Centre for Cellular and Molecular Biology, R.R.L. Campus, Hyderabad 500 007, India.

9:05 AM SELECTED ORAL PRESENTATIONS

9:30 AM POSTER VIEWING
The induction kinetics presented allow to study the first steps of light-induced chlorophyll biosynthesis and the development of photosynthetic activity during greening in the light.

Photoacoustics was employed to monitor oxygen evolution and energy storage of photosynthesis. In this study, electron transfer reactions resulting in oxygen uptake were demonstrated.

ThA4 Fast Transients of Photosynthetic Oxygen Evolution and Uptake in Intact Leaves Expressed by Photoacoustic Signals, S. Malkin Biochemistry Department, Weizmann Institute of Science, Rehovot, Israel.
A dark adapted leaf gives a photoacoustic pulse upon low-frequency modulated illumination expressing limited capacity for O₂-evolution. Subsequently slower transients indicate O₂-uptake and restoration of normal photosynthesis.

ThA5 Phase-Resolved Photoacoustic Microscopy: Application to Biological Layered Samples, O. Pessoa Jr., C.L. César, C.A.S. Lima, H. Vargas and L.C.M. Miranda*, Instituto de Física, Universidade Estadual de Campinas, 13100 Campinas, SP, Brazil. *Instituto de Estudos Avançados, Centro Técnico Aeroespacial, 12200 S.J. Campos, SP, Brazil.
The method for spectra phase separation (MSφ) is applied to layered biological samples. A distinction is
made between a simple case and a general one, to which corrections have to be introduced.

**ThA6 Photoacoustic In-Vivo Study of the Penetration of Sunscreen into Human Skin, A. Nicolaus, K. Giese and K. Kolmel*. Institut für Medizinische Physik und Biophysik der Universität, Goßlerstraße 10 f, D-3400 Gottingen, FRG. *Universitäts-Hautklinik, von-Siebold-Straße 3, D-3400 Gottingen, FRG.**

We report on the diffusion behavior of sunscreen, as studied by in-vivo measurements. The transfer function of open-ended detectors is discussed in detail.

**ThA7 Monitoring Energy Conversion in Photosystem I of Cyanobacterial Heterocysts by Photoacoustic Spectroscopy, R. Carpentier, H.C.P. Matthijs, R.M. Leblanc* and G. Hind, Biology Department, Brookhaven National Laboratory, Upton, NY 11973, U.S.A. *Centre de recherche en photobiophysique, Université du Québec à Trois-Rivières, Trois-Rivières, Québec, Canada, G9A 5H7.**

Photoacoustic spectroscopy was used to monitor photosynthetic energy conversion in isolated heterocysts. Addition of electron donors and removal of oxygen provided maximum energy storage yields.

**ThA8 The Origin of the Photoacoustic Effect in Leaves from Impatiens Petersiana, B. Larue, R.M. Leblanc and A. Desormeaux, Centre de recherche en photobiophysique, Université du Québec à Trois-Rivières, Trois-Rivières, Québec, Canada, G9A 5H7.**

In intact leaves from *Impatiens petersiana*, 1° light scattering effects contribute heavily to the photoacoustic spectrum and 2° the photothermal component of the signal consists of two distinct acoustic waves, originating respectively from the internal air space and from the surface of the leaf.

**ThA9 Photoacoustic Spectroscopy of Bovine Retina and Retinal Pigment Epithelium, F. Boucher and R.M. Leblanc, Centre de recherche en photobiophysique, Université du Québec à Trois-Rivières, Trois-Rivières, Québec, Canada, G9A 5H7.**

The delicate posterior ocular tissues of cattle eyes are probed by PAS. The frequency dependence of the spectra is used to obtain the chromophore distribution within the retina and the retinal pigment epithelium.

**ThA10 Photoacoustic Study of Photosynthesis of Lichens, O. Canaani, R. Ronen*, J. Garty*, D. Cahen, S. Malkin and M. Galun*, Weizmann Institute of Science, Rehovot and *Tel-Aviv University, Tel-Aviv, Israel.**

Photoacoustic signals from the lichen *R. Duriae* result from both (modulated) oxygen evolution and heat emission, as in intact leaves. Photosynthetic parameters were obtained, which were also used to monitor air pollution.
The photoacoustic technique was used as a tool for diagnosis of development of stress conditions, specifically chilling and water deficiency, in various plants.

10:15 AM QUESTION AND COMMENT PERIOD

BIO-CHEMISTRY AND RELAXATION PROCESSES

D. Cahen, Presider

10:35 AM SELECTED ORAL PRESENTATIONS

11:00 AM POSTER VIEWING


ThB2 Photoacoustic and Photothermal Spectroscopy in Chromatography, V.P. Zharov, Department of Biomedical Instruments, Moscow High Technical School, 107005, Moscow, USSR.

ThB3 Photoacoustic Study of Charge-Transfer Interactions, V. Upadhyaya, Department of Chemistry, S.C. College, Ballia 277001, India.

ThB4 Ruby Quantum Efficiency by Photoacoustic Technique Revisited, J. Fernandez*, J. Etxebarria, J. Zubillaga and M.J. Tello, Departamento de Fisica, Facultad de Cien-
The absolute luminiscence quantum efficiency of ruby crystals with various dopant concentrations has been obtained. The energy transfer rate is fitted to a law depending on the square of the dopant concentration.


A study of the deexcitation mechanisms of NaCl:Eu^{2+} has been performed using photoacoustic, absorption, and excitation spectroscopies. Absolute luminescence quantum efficiencies were determined at the ultraviolet region.

**ThB6 Unusual Solvent Dependence of Quantum Yield of Triplet State Formation in 1-Azacarbazole and Indoloquinoxaline Determined by Pulsed Photoacoustic Calorimetry (PAC), S.J. Komorowski and J. Waluk, Institute of Physical Chemistry of the Polish Academy of Sciences, Kasprzaka 44/52, 01-224 Warsaw, Poland.**

A large decrease of quantum yield of triplet formation in ethanol in comparison with n-heptane is due to the excited state double proton transfer in 1-azacarbazole complex with alcohol and to the reordering of excited states upon changing the polarity and protic strength of the solvent in indoloquinoxaline.

**ThB7 The Study of Time-Dependent Phenomena in Materials by Impulse Response Photoacoustic Spectroscopy, R.M. Miller, C.T. Tye and I.P. Vickery, Department of Instrumentation and Analytical Science, University of Manchester Institute of Science and Technology, P.O. Box 88, Manchester M60 1QD, UK.**

Examination of dye diffusion in solids and herbicide attack on plant material using impulse response photoacoustic spectroscopy to study the time-varying distribution of chromophores.

**ThB8 Phase Shift of Photoacoustic Signals and its Applications to Study of Energy Migration in Liquids T. Kitamotri, M. Sakagami, T. Sawada* and Y. Gohshi* Energy Research Laboratory, Hitachi, Ltd., 1168 Moriyama, Hitachi, Ibaraki 316, Japan. 8*Department of Industrial Chemistry, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113, Japan.**

Photoacoustic signal phase shifts were analyzed using linear response theory. Novel methods for characterization of turbid particles and measurement of non radiative relaxation time were proposed.

As a model for the photo-active centers in photochromic glasses small aggregates of silver are investigated by thermal deflection spectroscopy. The results are compared to those obtained with commercial photochromic glasses.


The photoacoustic spectra of chlorophyll a in various model systems are compared with each other and are discussed in terms of aggregation of chlorophyll a.

11:40 AM QUESTION AND COMMENT PERIOD

12:00 PM INVITED PAPER

ThC1 Thermal Wave Physics Comes of Age, A. Rosencwaig, Therma-Wave, Inc., Fremont, CA 94539, U.S.A.