

**Scanning
Electron
Microscopy/1981**

Part 1

SCANNING ELECTRON MICROSCOPY/1981/I

An
INTERNATIONAL JOURNAL
of
SCANNING ELECTRON MICROSCOPY,
RELATED TECHNIQUES,
and
APPLICATIONS
PART I

Guest Editors

N.J. Zaluzec	Argonne National Lab., IL
M.H. Barrows	Illinois State Geol. Survey, Urbana
G.E. McGuire	Tektronix Inc., Beaverton, OR

Published by

SCANNING ELECTRON MICROSCOPY, Inc.
P.O. Box 66507
AMF O'Hare (Chicago), IL 60666, USA

Copyright C 1981, Scanning Electron Microscopy, Inc., except for contributions in the public domain.

All rights reserved.

Individual readers of these volumes and non-profit libraries acting for them, are freely permitted to make fair use of the material herein, such as to copy an article for use in teaching or research. Permission is granted to quote from these volumes in scientific works with the customary acknowledgement of the source. To print a table, figure, micrograph or other excerpt requires, in addition, the consent of one of the original authors and notification to SEM, Inc. Republication or systematic or multiple reproduction of any material in these volumes (including the abstracts) is permitted only after obtaining written approval from SEM, Inc., and in addition, SEM, Inc. requires that permission also be obtained from one of the original authors.

Every effort has been made to trace the ownership of all copyrighted material in these volumes and to obtain permission for its use.

For all additional information or inquiries contact:

Dr. Om Johari, SEM, Inc. (Phone: 312-529-6677)
P.O. Box 66507
AMF O'Hare, (Chicago), IL 60666, U.S.A.

LIBRARY OF CONGRESS CATALOGUE NO. 72-626068

ISBN: SEM/1978/Set	0-931288-00-2	SEM/1980/III	0-931288-13-4
SEM/1978/I	0-931288-01-0	SEM/1980/IV	0-931288-14-2
SEM/1978/II	0-931288-02-9	SEM/1980/Set	0-931288-15-0
SEM/1979/I	0-931288-04-5	SEM/1981/I	0-931288-17-7
SEM/1979/II	0-931288-05-3	SEM/1981/II	0-931288-18-5
SEM/1979/III	0-931288-06-1	SEM/1981/III	0-931288-19-3
SEM/1979/Set	0-931288-10-X	SEM/1981/IV	0-931288-20-7
SEM/1980/I	0-931288-11-8	SEM/1981/Set	0-931288-21-5
SEM/1980/II	0-931288-12-6		

LIBRARIANS AND OTHER USERS OF THIS PUBLICATION PLEASE NOTE:

For this publication the volume number and the year are the same. 1981 volume will have 4 parts, SEM/1980 had 4 parts, SEM/1979 had 3 parts and SEM/1978 had 2 parts.

The correct way to refer to papers in this journal is:

Scanning Electron Microsc. year; part: range of pages.

DIVISION OF PAPERS IN DIFFERENT PARTS:

Part I contains papers of general interest, techniques, and physical applications.

Part II contains general papers of biological interest, including cell biology, cell culture, biological microanalysis, and related topics.

Part III contains papers on biological applications, including cancer, clinical applications, biomedical applications, mineralized tissue, plants, and food microstructures.

Part IV will contain papers on all topics which were processed after above parts were prepared.

This division of papers is same as in 1980 volume

DATES OF FUTURE SEM MEETINGS:

Scanning Electron Microscopy/1983 - April 18-22, Dearborn (Detroit), MI.

PRINTED IN THE UNITED STATES OF AMERICA

GUEST EDITORS

See Title Page

EDITOR

Om Johari

ASSOCIATE EDITORS

Sudha A. Bhatt
Irene Corvin Pontarelli

EDITORIAL ADVISORY BOARD

B.E. Boardman
Deere & Co., Moline, IL

E. Kubalek
Gesam. Duisburg, W. Germany

E.K. Brandis
IBM, Hopewell Jct., NY

G.H. Ladle
Robertson Res. Inc., Houston, TX

R.W. Carpenter
Arizona State Univ., Tempe

G.B. Larrabee
Texas Instruments, Dallas

E.J. Chatfield
Ontario Research Fund., Canada

C. Le Gressus
CEN-Saclay, France

D.L. Crosthwait
Texas Instruments, Dallas

E. Lifshin
General Electric, Schenectady, NY

E.P. Dahlberg
Failure Analysis Assoc., TX

T.R. McKee
Southern Clay Products, Gonzales, TX

J.L. Daniel
Battelle-Northwest, Richland, WA

J.D. Meakin
University of Delaware, Newark

D.L. Davidson
Southwest Research Inst., San Antonio, TX

T.A. Peters
Peterson Museum, Paterson, NJ

J.R. Devaney
Hi-Rel Labs, Monrovia, CA

G.E. Pfeifferkorn
Univ. Münster, W. Germany

R.B. Finkelman
Exxon Prod. Res. Co., Houston, TX

J.A. Small
National Bureau of Standards, WDC

D.L. Gibbon
Calgon Corp., Pittsburgh, PA

S.W. Wise
Florida State Univ., Tallahassee

L.L. Kazmerski
Solar Energy Research Inst., Golden, CO

M.J. Yacamán
University of Mexico, Mexico City

EDITORIAL ASSISTANT

Joseph Staschke

SCANNING ELECTRON MICROSCOPY, INC. OFFICERS:

PRESIDENT

John D. Fairing

VICE PRESIDENT

Robert P. Becker

SECRETARY-TREASURER

Om Johari

ADVISORS

Takashi Makita, Yamaguchi, Japan
Gerhard E. Pfeifferkorn, Münster, W. Germany

REVIEWING PROCEDURE
AND
DISCUSSION WITH REVIEWERS

Each paper in this volume contains a Discussion with Reviewers. This discussion follows the text and should be read with the paper. Each paper submitted to SEM, Inc. for publication is reviewed by at least three, up to an average of five, reviewers. The reviewers are asked to separate their comments from their questions. The comments are useful in determining the acceptability of the papers as submitted. Although the comments require no written response, in several cases, the authors have included responses to comments, or to questions phrased from, or based on, comments (either as a result of editorial suggestions or on the author's own initiative). Based on these comments approximately 15% of the submitted papers were not accepted for publication; while almost all of the others were asked to make changes involving from minor to major revisions.

The questions, for the most part, originate as a result of statements included in our cover letter accompanying each paper sent to the reviewers. The reviewers are asked to suppose they are attendees at a conference where this paper, as written, is being presented, and then ask relevant questions which would occur to them resulting from the presentation. From the questions so asked, some are not included with the published paper because the authors attended to them by text revisions. In some cases, editorial and/or space considerations may exclude inclusion of all questions asked by reviewers. The authors are asked to prepare their Discussion with Reviewers section in a camera-ready format in accordance with detailed instructions which they are sent by SEM, Inc. In some instances the authors edit the questions and/or combine several similar questions from different reviewers to provide one answer. While all efforts are made to check that the questions in the printed version faithfully follow the views of the specific reviewer, the editors apologize, if in some instances, the actual meaning and/or emphasis may have been changed by the author.

The cover letter to the reviewers states:

- "1. Your name will be conveyed to the author with your review UNLESS YOU ASK US NOT TO.
2. The questions published in the Journal will be identified as originating from you UNLESS YOU ADVISE OTHERWISE..."

In all cases sincere efforts are made to respect the reviewer's wishes to remain anonymous; however, in nearly 95% of the cases, the reviewers have given permission to be identified; so their names are conveyed to the authors and are included with the questions printed with each paper. An overall list of reviewers is provided in the opening pages of each SEM part. We apologize for any error/omissions which may occur.

Finally, readers are urged to be cautious regarding the weight they attach to the authors' replies, since the answers to the questions represent the authors' unchallenged views--except for minor editorial changes--the authors generally have the last word. Also, please consider that the questions were, in most all cases, relevant to the originally submitted paper, and they may not have the same significance for the revised paper published in this volume.

If you disagree with the results, conclusions or approaches in a paper, please send your comments, as a Letter to Editor, typed in a column format (each column is 4-1/8 inches wide and 11-1/2 inches long; i.e., 10.5 by 29.3 cm.). Your comments along with author's response will be published in a subsequent issue.

The editor gratefully thanks the authors and reviewers (see p. ix-xiv) for their contributions, invites your comments on ways to improve this procedure and seeks qualified volunteers to assist with reviewing papers in the future. (see p. xiv)

ERRATA: Despite the best efforts of authors, reviewers and editors, errors may remain. Please help by pointing out errors that you notice. Please provide enough information to locate each error (volume, part, page, column, line, etc.) and indicate suitable correction.

REVIEWERS LIST

The editors gratefully acknowledge the help of the following reviewers for papers included in this part, and for other papers on similar topics which are either not being published or will be published in Scanning Electron Microscopy/1981/IV.

Arnott, H.J.	Univ Texas, Arlington, TX
Artz, B.E.	Ford Motor Co, Dearborn, MI
Ballard, D.B.	National Bureau of Standards, WDC
Barber, V.C.	Memorial Univ Newfoundland, St. John's, Canada
Barbi, N.C.	Princeton Gamma-Tech, Princeton, NJ
Barrows, M.H.	Ill State Geol Survey, Urbana, IL
Batson, P.E.	IBM Watson Res Ctr, Yorktown Heights, NY
Beall, J.R.	Martin Marietta Aerospace, Denver, CO
Bell, T.D., Jr.	Texas Instruments, Dallas, TX
Bence, A.E.	Exxon Prod Res Co, Houston, TX
Bennett, J.M.	US Dept Navy, China Lake, CA
Bennett, R.H.	Marine Geol & Geophysics Lab, US Dept Comm, Miami, FL
Bentley, J.	Oak Ridge National Lab, TN
Bhattacharyya, S.	IIT Res Inst, Chicago, IL
Bishop, H.E.	UKAEA/AERE, Harwell, U.K.
Black, K.M.	Cardiac Pacemakers Inc, St. Paul, MN
Boardman, B.E.	Deere & Co, Moline, IL
Bolon, R.B.	General Electric Co, Schenectady, NY
Bomback, J.L.	Ford Motor Co, Dearborn, MI
Boyde, A.	University College, London, U.K.
Brace, W.F.	Massachusetts Inst Tech, Cambridge, MA
Brewer, G.R.	Hughes Aircraft Co, Malibu, CA
Brillson, L.J.	Xerox Corp, Webster, NY
Brown, J.A.	Walter C. McCrone Assoc, Chicago, IL
Brown, R.E.	Geological Consultant, Pasco, WA
Brundle, C.R.	IBM Res Lab, San Jose, CA
Byers, C.W.	Univ Wisconsin, Madison, WI
Calvert, C.	Texas A & M Univ, College Station, TX
Campion, K.M.	Exxon Prod Res Co, Houston, TX
Carpenter, R.W.	Arizona State Univ, Tempe
Carter, R.F.	Atomic Weapons Res Est, Reading, U.K.
Cecil, C.B.	US Geological Survey, Reston, VA
Chamberlain, M.B.	Sandia National Labs, Albuquerque, NM
Chambers, W.F.	Sandia National Labs, Albuquerque, NM
Chang, C.C.	Bell Labs, Murray Hill, NJ
Chang, T.H.P.	IBM Watson Res Ctr, Yorktown Heights, NY
Chase, R.E.	Ford Motor Co, Dearborn, MI
Chatfield, E.J.	Ontario Research Found, Mississauga, Canada
Chodos, A.A.	California Inst Tech, Pasadena, CA
Christou, A.	Naval Res Lab, Washington, DC
Clarke, D.R.	Rockwell International, Thousand Oaks, CA
Cohen, P.	Consultant, Pittsburgh, PA
Coleman, J.R.	Univ Rochester Sch Med, NY
Colliex, C.	Univ Paris, France
Colter, V.S.	Floyd Oil Participations, London, U.K.
Comins, N.R.	National Res Physical Lab, Pretoria, S. Africa
Cosslett, V.E.	Cavendish Lab, Cambridge, U.K.
Cowley, J.M.	Arizona State Univ, Tempe
Crewe, A.V.	Univ Chicago, IL
Crosthwait, D.L.	Texas Instruments, Dallas, TX
Dahlberg, E.P.	Failure Analysis Assoc, Houston, TX
Daniel, J.L.	Battelle Northwest Labs, Richland, WA
Das, S.	Allied Corp, Morristown, NJ
Davidson, D.L.	Southwest Res Inst, San Antonio, TX
Davies, D.K.	Davies, Almon & Assoc, Houston, TX
Davis, W.L.	Baylor Coll Dent, Dallas, TX
De la Iglesia, F.A.	Parke Davis & Co, Ann Arbor, MI
DeNee, P.B.	Motorola Inc, Mesa, AZ
Devaney, J.R.	Hi-Rel Labs, Monrovia, CA
Diamond, S.	Purdue Univ, West Lafayette, IN

Dingley, D.	Univ Bristol, U.K.
Doane, V.L.	Michigan Technological Univ, Houghton, MI
Donolato, C.	C.N.R., LAMEL, Bologna, Italy
Draftz, R.G.	IIT Res Inst, Chicago, IL
Drexhage, M.G.	US Air Force, Hanscom AFB, MA
Duraud, J.P.	CEN Saclay, France
Durham, W.B.	Lawrence Livermore Lab, Livermore, CA
Easterling, K.	Univ Lulea, Sweden
Egerton, R.F.	Univ Alberta, Edmonton, Canada
Elliott, J.C.	London Hospital Med College, London, U.K.
Everhart, T.E.	Cornell Univ, Ithaca, NY
Fairing, J.D.	Monsanto, St. Louis, MO
Falk, R.H.	Univ California, Davis
Feuerbaum, H.P.	Siemens, Munich, W. Germany
Finkelman, R.B.	Exxon Prod Res Co, Houston, TX
Fisher, G.L.	Battelle, Columbus, OH
Fisher, R.M.	US Steel Res Labs, Monroeville, PA
Fox, R.L.	Univ Hawaii, Honolulu
Fraser, H.L.	Univ Illinois, Urbana
Freiman, S.W.	National Bureau of Standards, WDC
Fujimoto, F.	Univ Tokyo, Japan
Geller, J.D.	JEOL USA, Peabody, MA
Gibbon, D.L.	Calgon Corp, Pittsburgh, PA
Goaz, P.W.	Baylor Coll Dent, Dallas, TX
Goldstein, J.I.	Leigh Univ, Bethlehem, PA
Gonzales, A.J.	Motorola SPD, Phoenix, AZ
Gooley, R.	Los Alamos Sci Lab, Los Alamos, NM
Gopinath, A.	MIT Lincoln Labs, Lexington, MA
Grant, P.	Imperial College, London, U.K.
Graustein, W.C.	Yale Univ, New Haven, CT
Greer, R.T.	Iowa State Univ, Ames, IA
Gude, A.J.	US Geological Survey, Denver, CO
Guyen, N.	Texas Tech Univ, Lubbock, TX
Habashi, F.	Laval Univ, Quebec, Canada
Hall, E.L.	General Electric Co, Schenectady, NY
Hall, M.G.	Univ Birmingham, U.K.
Hall, P.M.	Bell Labs, Allentown, PA
Harland, C.J.	Univ Sussex, Brighton, U.K.
Hart, R.K.	Pasat Res Assoc, Atlanta, GA
Hartley, A.	Leeds Polytech, U.K.
Harvey, R.D.	Ill Inst Natural Resources, Champaign, IL
Hastenrath, M.	Gesamthochschule Duisburg, W. Germany
Hauff, P.	US Geological Survey, Denver, CO
Hayes, T.L.	Univ California, Berkeley
Hearle, J.W.S.	Univ Manchester Inst Sci Tech, U.K.
Hearn, E.W.	IBM East Fishkill, Hopewell Junction, NY
Heinemann, K.	Stanford Univ, CA
Heinrich, K.F.J.	National Bureau of Standards, WDC
Herriott, D.R.	Bell Labs, Murray Hill, NJ
Heydenreich, J.	AdW-Inst Festkorperphys, Halle, DDR
Hiesinger, P.	Fraunhofer Inst, Freiburg, W. Germany
Hoenigman, J.R.	Univ Dayton, Dayton, OH
Holloway, P.H.	Univ Florida, Gainesville
Hörl, E.M.	Osterr Stud Atomenergie, Vienna, Austria
Horner, H.T.	Iowa State Univ, Ames, IA
Houston, J.E.	Sandia National Labs, Albuquerque, NM
Hren, J.J.	Univ Florida, Gainesville
Huggins, F.E.	US Steel Res Labs, Monroeville, PA
Hulbert, M.H.	NOAA-Environ Res Labs, Miami, FL
Hurd, D.A.	Technics, Springfield, VA
Ichinokawa, T.	Waseda Univ, Tokyo, Japan
Ingram, P.	Research Triangle Inst, RTP, NC
Jackson, M.L.	Univ Wisconsin, Madison, WI
Jakopic, E.	Zen. fur Elektronmikroskop, Graz, Austria
Jensen, S.W.	National Bureau of Standards, Boulder, CO
Johnson, D.	Exxon Prod Res Co, Houston, TX
Jones, K.A.	Colorado State Univ, Fort Collins, CO

Jones, R.G.	Baylor Coll Dent, Dallas, TX
Joshi, A.	Perkin Elmer, Mt. View, CA
Joy, D.C.	Bell Labs, Murray Hill, NJ
Kazmerski, L.L.	Solar Energy Research Inst, Golden, CO
Keller, W.D.	Univ Missouri, Columbia
Kelly, J.F.	US Steel Research Labs, Monroeville, PA
Kirkpatrick, C.G.	Rockwell International, Thousand Oaks, CA
Kirschner, J.	KFA Julich, W. Germany
Krakow, W.	IBM, Yorktown Heights, NY
Kranz, R.L.	Lemont-Doherty Geol Observatory, Palisades, NY
Krinsley, D.H.	Arizona State Univ, Tempe, AZ
Kubalek, E.	Gesamth-Elektrotechnik, Duisburg, W. Germany
Kyser, D.F.	Philips Res Lab, Santa Clara, CA
Laabs, F.C.	Iowa State Univ, Ames, IA
Ladle, G.H.	Sohio Petroleum Co, San Francisco, CA
Lafon, G.M.	Exxon Prod R&D Ctr, Houston, TX
Landis, W.J.	Childrens Hospital, Boston, MA
Lane, W.C.	Consultant, Fremont, CA
Larese, R.E.	Amoco Research Ctr, Tulsa, OK
Larrabee, G.B.	Texas Instruments, Dallas, TX
Larson, L.A.	NASA/Ames Res Ctr, Moffett Field, CA
Lawless, K.R.	Univ Virginia, Charlottesville
Le Bihan, R.	Univ Nantes, France
Le Gressus, C.	CEN Saclay, France
LeFurgey, A.	Duke Univ Medical Ctr, Durham, NC
Leamy, H.J.	Bell Labs, Murray Hill, NJ
Leapman, R.D.	NIH, Bethesda, MD
Lee, D.A.	Honeywell Inc, Plymouth, MN
Lee, R.J.	US Steel Research Labs, Monroeville, PA
Levenson, L.L.	Univ Colorado, Colorado Springs
Lewin, S.Z.	New York Univ, NY
Lewis, D.	Naval Res Lab, Washington, D.C.
Lewis, N.	General Electric Co, Schenectady, NY
Lewis, R.K.	IBM, Hopewell Junction, NY
Lifshin, E.	General Electric Co, Schenectady, NY
Linton, R.W.	Univ North Carolina, Chapel Hill, NC
Lippold, J.C.	Sandia National Labs, Livermore, CA
Little, J.	Cambridge Univ, U.K.
Loper, C.R.	Univ Wisconsin, Madison, WI
Lorimer, G.W.	Univ Manchester, U.K.
Lyman, C.E.	E.I. Dupont Co, Wilmington, DE
Macmillan, N.H.	Pennsylvania State Univ, University Park
Madden, H.H.	Sandia National Labs, Albuquerque, NM
Mann, G.M.W.	Central Electricity Res Labs, Leatherhead, U.K.
Margolis, S.V.	Univ Hawaii at Manoa, Honolulu, HI
Marks, L.D.	Cambridge Univ, U.K.
Markuszewski, R.	Iowa State Univ, Ames, IA
Marrian, C.R.K.	Cambridge Univ, U.K.
Martin, G.B.	ARCO Oil & Gas Co, Houston, TX
Martin, J.H.	Baylor Coll Dent, Dallas, TX
Martin, L.	British Museum Natural History, London, U.K.
Maruse, S.	Nagoya Univ, Japan
Matthews, J.L.	Baylor Coll Dent, Dallas, TX
Maussion, M.	Univ Nantes, France
Maynard, B.	Univ Cincinnati, OH
McAfee, W.S.	US Army, Fort Monmouth, NJ
McCall, J.L.	Battelle, Columbus, OH
McClellan, G.H.	International Fertilizer Dev Ctr, Muscle Shoals, AL
McConnell, M.D.	General Electric Co, Schenectady, NY
McCool, J.I.	SKF Technology Services, King of Prussia, PA
McGuire, G.E.	Tektronix Inc, Beaverton, OR
McKee, T.R.	Southern Clay Products, Gonzales, TX
Meakin, J.D.	Univ Delaware, Newark, DE
Meier, G.H.	Univ Pittsburgh, PA
Melton, C.W.	Battelle, Columbus, OH
Menzel, E.	Univ Duisburg, W. Germany
Miller, D.E.	Lawrence Livermore Lab, Livermore, CA

Moddeman, W.E.	Monsanto Res Corp, Miamisburg, OH
Moll, S.H.	AMRAY Inc, Bedford, MA
Montoto, M.	Univ Oviedo, Spain
Moor, H.	Inst Zellbiologie/ETH, Zurich, Switzerland
Morabito, J.M.	Bell Labs, Allentown, PA
Moza, A.K.	Calgon Corp, Pittsburgh, PA
Mulvey, T.	Aston Univ, Birmingham, U.K.
Mumpton, F.A.	State Univ New York, Brockport, NY
Munro, E.	Imperial Coll Sci Tech, London, U.K.
Murata, K.	Univ Osaka Prefecture, Japan
Murday, J.S.	Naval Res Lab, Washington, D.C.
Murphy, J.A.	Southern Illinois Univ, Carbondale, IL
Murr, L.E.	Oregon Graduate Ctr, Beaverton, OR
Myklebust, R.L.	National Bureau of Standards, WDC
Nancollas, G.H.	State Univ New York, Buffalo, NY
Neidrig, H.	Tech Univ, Berlin, W. Germany
Newbury, D.E.	National Bureau of Standards, WDC
Nickel, E.	Rijksuniv Utrecht, Netherlands
Nicolas, D.P.	NASA, Marshall Space Flight Ctr, AL
Nixon, W.	Cambridge Univ, U.K.
Norton, J.F.	General Electric Co, Schenectady, NY
O'Brien, N.R.	State Univ New York, Potsdam, NY
Odom, I.E.	Northern Illinois Univ, DeKalb, IL
Organ, R.	The Smithsonian Inst, Washington, D.C.
Padden, T.R.	Westinghouse Electric Corp, Madison, PA
Pameijer, C.H.	Boston Univ Sch Dent, Boston, MA
Pantano, C.G.	Pennsylvania State Univ, University Park
Parsons, D.F.	New York State Dept Health, Albany, NY
Partain, L.D.	Chevron Res Co, Richmond, CA
Pawley, J.B.	Univ Wisconsin, Madison, WI
Pearman, G.T.	Bell Labs, Allentown, PA
Peters, K.-R.	Yale Univ Sch Med, New Haven, CT
Peters, T.A.	Paterson Museum, Paterson, N.J.
Petit, H.	Baylor Coll Dent, Dallas, TX
Petroff, P.M.	Bell Labs, Murray Hill, NJ
Pfeiffer, H.C.	IBM, Hopewell Junction, NY
Pickering, N.E.	US Air Force, Hanscom AFB, MA
Pittman, E.D.	Amoco Prod Co, Tulsa, OK
Plomp, F.H.	NV Philips, Eindhoven, Netherlands
Pooley, A.S.	Yale Univ Peabody Museum, New Haven, CT
Possin, G.E.	General Electric Co, Schenectady, NY
Powell, C.J.	National Bureau of Standards, WDC
Randich, E.	Sandia National Labs, Albuquerque, NM
Rau, E.I.	Moscow State Univ, USSR
Raymond, R.	Los Alamos Sci Lab, Los Alamos, NM
Reimer, L.	Univ Muenster, W. Germany
Reuter, W.	IBM Watson Res Ctr, Yorktown Heights, NY
Richardson, J.H.	The Aerospace Corp, Los Angeles, CA
Ridley, I.	Exxon Prod Res Co, Houston, TX
Robards, A.W.	Univ York, Heslington, U.K.
Romig, A.D., Jr.	Sandia National Labs, Albuquerque, NM
Rose, J.C.	Univ Arkansas, Fayetteville
Ruff, G.F.	General Motors Corp, Warren, MI
Ruscica, R.	International Scientific Instru, Santa Clara, CA
Russ, J.C.	North Carolina State Univ, Raleigh, NC
Ryder, P.L.	Univ Bremen, W. Germany
Sanger, G.M.	Lawrence Livermore Lab, Livermore, CA
Sanner, W.S., Jr.	US Dept Energy, Pittsburgh, PA
Saparin, G.V.	Moscow State Univ, USSR
Saubermann, A.J.	Univ Texas Health Sci Ctr, Houston
Schamber, F.H.	Tracor Northern Inc, Middleton, WI
Scheib, R.M.	Tennessee Valley Authority, Muscle Shoals, AL
Schidlovsky, G.	Brookhaven Natl Lab, Upton, NY
Schneider, E.J.	Consultant, Scottsdale, AZ
Seliger, R.L.	Hughes Res Lab, Malibu, CA
Seltow, L.W.	US Geological Survey, Reston, VA
Sewell, P.B.	National Res Council, Ottawa, Canada

Shaffner, T.J.	Texas Instruments, Dallas, TX
Shellis, R.P.	Medical Research Council, Bristol, U.K
Shimizu, R.	Osaka Univ, Japan
Sikorski, J.	Univ Leeds, U.K.
Simmons, G.	Massachusetts Inst Tech, Cambridge, MA
Slater, C.S.	Charles Evans & Assoc, San Mateo, CA
Slater, L.E.	Vought Corp, Dallas, TX
Slayter, H.S.	Sidney Farber Cancer Inst, Boston, MA
Small, J.A.	National Bureau of Standards, WDC
Smart, P.	Univ Glasgow, U.K.
Smith, K.C.A.	Cambridge Univ, U.K.
Smith, M.A.	Univ Missouri, Rolla
Smith, M.M.	St. George Hosp Med School, London, U.K.
Somerscales, E.F.C.	Rensselaer Polytech Inst, Troy, NY
Spackman, W.	Pennsylvania State Univ, University Park
Spalaris, C.N.	General Electric Co, San Jose, CA
Sparrow, G.R.	Advanced R&D Inc, St. Paul, MN
Spence, J.C.H.	Arizona State Univ, Tempe
Spurr, A.R.	Univ California, Davis
Staib, P.	Max Planck Inst, Garching, W. Germany
Stanton, R.	US Geological Survey, Reston, VA
Stasny, J.T.	Structure Probe, West Chester, PA
Statham, P.	Link Systems Ltd, High Wycombe, U.K.
Steere, R.L.	USDA Agri Res Ctr, Beltsville, MD
Stewart, I.M.	Walter C. McCrone Assoc, Chicago, IL
Stock, L.G.	Shell Development Co, Houston, TX
Strausser, Y.E.	Hewlett Packard, Palo Alto, CA
Strickler, D.W.	Pennsylvania State Univ, University Park
Strojniak, A.	Arizona State Univ, Tempe
Surdam, R.C.	Univ Wyoming, Laramie
Swindells, N.	Univ Liverpool, U.K.
Taylor, M.E.	M.E. Taylor Engineering, Wheaton, MD
Teague, C.E.	National Bureau of Standards, WDC
Thirlwall, J.T.	National Res Physical Lab, Pretoria, S. Africa
Thomas, G.	Univ California, Berkeley
Thomas, T.	Battelle Northwest, Richland, WA
Todd, G.	INTERSIL, Cupertino, CA
Tovey, N.K.	Univ East Anglia, Norwich, U.K.
Tregilgas, J.	Texas Instruments, Dallas, TX
Tschernich, R.W.	Zeolite Res & Exploration, Everett, WA
Tullis, J.	Brown Univ, Providence, RI
Uchikawa, Y.	Nagoya Univ, Japan
Ura, K.	Osaka Univ, Japan
Valdre, U.	Univ Bologna, Italy
Van Essen, C.	Patscentre International, Melbourn, U.K.
Van Veld, R.D.	Du Pont de Nemours Co, Kinston, NC
Venables, J.A.	Univ Sussex, Brighton, U.K.
Vook, R.W.	Syracuse Univ, NY
Wagner, S.	Princeton University, NJ
Walker, D.A.	Geological Survey Canada, Ottawa
Walker, J.S.	US Steel Research Labs, Monroeville, PA
Wallace, J.F.	Case Western Reserve Univ, Cleveland, OH
Warke, W.P.	Standard Oil Co, Naperville, IL
Wells, O.C.	IBM Watson Res Ctr, Yorktown Heights, NY
Wergin, W.P.	USDA Agri Res Ctr, Beltsville, MD
Wert, C.A.	Univ Illinois, Urbana, IL
Whalley, W. B.	Queens Univ, Belfast, U.K.
Wiggins, W.	Johns Hopkins Univ, Baltimore, MD
Wildman, H.S.	IBM, Hopewell Junction, NY
Williams, D.B.	Lehigh Univ, Bethlehem, PA
Wilson, M.D.	AGAT Consultants, Denver, CO

Wise, S.W.	Florida State Univ, Tallahassee
Wise, W.S.	Univ California, Santa Barbara
Wolf, E.D.	Cornell Univ, Ithaca, NY
Wu, P.C.S.	US Nuclear Regulatory Commission, Washington, D.C.
Yacamán, M.J.	UNAM, Inst Física, Mexico
Zehner, D.M.	Oak Ridge National Lab, TN
Zinkernagel, U.	Bochum, W. Germany
Zipp, R.D.	International Harvester, Hinsdale, IL

CALL FOR REVIEWERS

The contribution of reviewers to the quality of this publication and our meetings is tremendous. We find suitable reviewers from the suggestions we receive from the authors, our advisors, and from our past contacts. We will welcome your suggesting your own name or others' names (along with full mailing address) as reviewers.

Important Note: The time restrictions we work under require that each reviewer returns his review (along with the manuscript sent) within a set time from its receipt. Please do not commit yourself if you feel that you cannot respond within this time frame; while we are grateful for your desire and efforts to help us, the reviewers who do not respond in time, in fact, seriously hamper our efforts.

CONTACT: Om Johari, SEM Inc., P.O. Box 66507, AMF O'Hare, IL 60666, USA
Phone: 312-529-6677.

TABLE OF CONTENTS

Editorial Board; SEM Inc.	iii
Discussion with Reviewers, Errata	iv
Reviewers List, Call for Reviewers	ix
THE ANALYSIS OF ORGANIC SURFACES (Keynote Paper) P. Echlin	1
PROPOSAL FOR A NEW LOW ABERRATION PROBE FORMING LENS L. Y. Huang and H. N. Lei	21
SIMPLE THEORETICAL MODELS FOR ELECTRON BACKSCATTERING FROM SOLID FILMS (Review Paper)* H. Niedrig	29
MONTE CARLO CALCULATIONS FOR ELECTRON MICROSCOPY, MICROANALYSIS, AND MICROLITHOGRAPHY D. F. Kyser (Tutorial Paper)*	47
QUANTITATIVE ANALYSIS WITH A WINDOWLESS ENERGY DISPERSIVE X-RAY DETECTOR A. O. Sandborg and A. B. Merkle	63
IMAGING STRATEGY IN THE SCANNING ELECTRON MICROSCOPE (Tutorial Paper) D. E. Newbury	71
RECENT ADVANCES IN SPECIMEN COATING TECHNIQUES (Tutorial Paper) P. Echlin	79
RECENT DEVELOPMENTS IN STEREO SEM (1981 - UPDATE) (Tutorial Paper) A. Boyde	91
A MINI SCANNING ELECTRON MICROSCOPE AND PARTICLE ANALYZER FOR SPACE APPLICATIONS R. K. Hart, A. L. Albee, A. A. Finnerty and R. Frazer	97
ANALYTICAL ELECTRON MICROSCOPY USING EXTENDED ENERGY LOSS FINE STRUCTURE (EXELFS) D. E. Johnson, S. Csilag and E. A. Stern (Review Paper)	105
CURRENT STATUS OF HIGH VOLTAGE TRANSMISSION SCANNING ELECTRON MICROSCOPY (Review Paper) A. Strojnik	117
THE ARIZONA HV STEM - AN IMPROVED SYSTEM A. Strojnik	123
ELECTRIC EFFECTS IN CONTAMINATION AND ELECTRON BEAM ETCHING J. T. Fourie	127
THE ASSESSMENT OF ANALYTICAL TRANSMISSION ELECTRON MICROSCOPY IN THE DETERMINATION OF MINERALOGICAL CONTENTS OF COAL MEASURE ROCKS N. Rowlands and B. D. G. Smart	135
MICRODIFFRACTION FROM GOLD MICROCRYSTALS J. M. Cowley and R. A. Roy	143
THICKNESS FRINGE CONTRAST AT GRAIN BOUNDARIES IN TEM AND STEM: COMPARISON WITH TOP- BOTTOM EFFECT J. Bentley, M. J. Goringe and R. W. Carpenter	153
ANALYTICAL ELECTRON MICROSCOPY OF PRESSURE VESSEL STEEL WELDMENTS J. Sankar and D. B. Williams	159

*See page viii

ANALYTICAL ELECTRON MICROSCOPY EVALUATION OF LASER WELDED 308 STAINLESS STEEL J. M. Vitek and S. A. David	169
ANALYTICAL ELECTRON MICROSCOPY OF TiB ₂ -Ni CERAMICS P. S. Sklad and J. Bentley	177
IMAGING WITH RUTHERFORD SCATTERED ELECTRONS IN THE SCANNING TRANSMISSION ELECTRON MICROSCOPE M. M. J. Treacy (Review Paper)	185
MIRROR ELECTRON MICROSCOPY IN SURFACE RESEARCH C. Guittard, M. Babout, S. Guittard and M. Bujor (Review Paper)	199
APPLICATION OF SCANNING ELECTRON MICROSCOPY (SEM) TO ANALYSIS OF SURFACE DOMAIN STRUCTURE OF FERROELECTRICS Y. Uchikawa and S. Ikeda (Review Paper)	209
APPLICATION OF MONTE CARLO TECHNIQUE TO QUANTITATIVE AUGER ANALYSIS - AN APPROACH FOR QUANTITATIVE CORRECTION OF ELECTRON BACKSCATTERING EFFECT R. Shimizu and S. Ichimura (Review Paper)	221
BACKSCATTERING FACTOR IN Au-Cu ALLOYS FOR QUANTITATIVE ANALYSIS BY SCANNING AUGER ELECTRON MICROSCOPY S. Ichimura, R. Shimizu and T. Ikuta	231
AUGER ELECTRON SPECTROSCOPY ON FRACTURED GLASS SURFACE J. P. Lacharme, P. Champion and D. Léger	237
MATRIX EFFECTS CORRECTION IN QUANTITATIVE AUGER ANALYSIS - APPLICATION TO Ni-Pt ALLOYS T. Sekine, A. Mogami and J. D. Geller	245
CHANGES OF SECONDARY ELECTRON IMAGE BRIGHTNESS UNDER ELECTRON IRRADIATION AS STUDIED BY ELECTRON SPECTROSCOPY C. Le Gressus, H. Okuzumi and D. Massignon (Review Paper)	251
HYDROGEN DETECTION BY REFLEXION ELECTRON ENERGY LOSS SPECTROSCOPY F. Pellerin	263
ANALYTICAL SCANNING ELECTRON MICROSCOPY IN UHV FOR SOLID SURFACE (Review Paper) T. Ichinokawa, Y. Ishikawa, N. Awaya and A. Onoguchi	271
MICROANALYSIS OF OXIDE/CuInSe ₂ INTERFACES L. L. Kazmerski, P. J. Ireland, O. Jamjoum and A. H. Clark	285
COMPOSITION OF LOW-STRENGTH SOLDER JOINTS IN SOLAR CONCENTRATOR CELL ARRAYS M. B. Chamberlain and T. V. Nordstrom	291
ELECTRON BEAM INDUCED CURRENT ANALYSIS OF INTEGRATED CIRCUITS (Tutorial Paper) J. D. Schick	295
ELECTRON BEAM TEST TECHNIQUES FOR INTEGRATED CIRCUITS (Tutorial Paper) E. Menzel and E. Kubalek	305
LOCAL FIELD EFFECTS ON VOLTAGE MEASUREMENT USING A RETARDING FIELD ANALYSER IN THE SCANNING ELECTRON MICROSCOPY H. Fujioka, K. Nakamae and K. Ura	323
FURTHER RESULTS ON SCANNING ELECTRON MICROSCOPY OF VIBRATING QUARTZ CRYSTALS H. Bahadur, V. K. Lall and R. Parshad	333
MICRON AND SUBMICRON LITHOGRAPHY FOR VLSI DEVICE FABRICATION (Tutorial Paper) G. L. Varnell	343
COMBINED APPLICATION OF SEM (EBIC) AND TEM FOR THE INVESTIGATION OF THE ELECTRICAL ACTIVITY OF CRYSTAL DEFECTS IN SILICON J. Heydenreich, H. Blumtritt, R. Gleichmann and H. Johansen (Review Paper)	351
SEM IN SITU OBSERVATION OF GRAIN BOUNDARY MIGRATION DURING RECRYSTALLIZATION OF COLD WORKED COPPER SINGLE CRYSTALS P. F. Schmidt and H. G. Grewe	367

ASSESSMENT OF DEFECT DENSITY MAGNITUDE BY CHANGES IN SELECTED AREA ELECTRON CHANNELING PATTERNS	(Review Paper)	373
D. L. Davidson		
ROCKING CRYSTAL ELECTRON CHANNELING PATTERNS, BACKSCATTERING AND TRANSMISSION	(Review Paper)	385
M. Brunner		
A NEW TECHNIQUE FOR ELECTRON CHANNELING PATTERN MEASUREMENTS		397
R. C. Farrow and D. C. Joy		
HOW TO USE THE SCANNING ELECTRON MICROSCOPE FOR FAILURE ANALYSIS AND METALLOGRAPHY	(Tutorial Paper)	403
D. L. Davidson		
METALLOGRAPHY IN THE SEM	(Tutorial Paper)	409
M. G. Hall		
PRESERVATION AND CLEANING OF FRACTURES FOR FRACTOGRAPHY - UPDATE	(Tutorial Paper)	423
E. P. Dahlberg and R. D. Zipp		
AUGER ELECTRON SPECTROSCOPY AS APPLIED TO THE STUDY OF THE FRACTURE BEHAVIOR OF MATERIALS	(Tutorial Paper)	431
M. Schmerling, D. Finello and H. L. Marcus		
COMPOSITIONAL CHANGES IN TRIPLE SUPERPHOSPHATE FERTILIZER GRANULES		439
S. Henstra, D. van der Eijk, A. Boekestein, F. Thiel and L. van der Plas		
QUANTITATIVE PARTICLE ANALYSIS IN ELECTRON BEAM INSTRUMENTS	(Tutorial Paper)	447
J. A. Small		
UTILIZATION OF ALTERNATIVE CHEMISTRY FILE STRUCTURES FOR MATERIALS CHARACTERIZATION		463
K. J. Karcich, M. P. Moore, R. Klein, R. A. Morton and J. C. Russ		
A CHEMICAL ELEMENT COMPARISON OF INDIVIDUAL PARTICLE ANALYSIS AND BULK ANALYSIS METHODS		469
D. L. Johnson, B. McIntyre, R. Fortmann, R. K. Stevens and R. B. Hanna		
ERRORS OBSERVED IN THE ANALYSIS OF PARTICLE MIXTURES BY OVERSCANNING		477
R. L. Myklebust, J. A. Small and D. E. Newbury		
ELECTRON SPECTROSCOPY AND MICROSCOPY FOR STUDYING SURFACE CHANGES OF MECHANICALLY PREPARED PYRITE AND QUARTZ	(Review Paper)	483
G. Remond, P. H. Holloway and C. Le Gressus		
ELECTRON PROBE MICROANALYSIS IN GEOSCIENCES	(Tutorial Paper)	493
R. Gooley		
SOME APPLICATIONS OF ION MICROSCOPY TO BIOMINERALIZATION INVOLVED INTO SEDIMENTARY ROCKS	(Review Paper)	503
J. Archambault-Guezou and R. Lefèvre		
COLD STAGE SCANNING ELECTRON MICROSCOPY OF CRUDE OIL AND BRINE IN ROCK		515
P. S. Pesheck, L. E. Scriven and H. T. Davis		
CAUSES OF QUARTZ CATHODOLUMINESCENCE COLORS		525
E. S. Sprunt		
QUANTITATIVE SEM METHODS FOR SOIL FABRIC ANALYSIS	(Review Paper)	537
N. K. Tovey and V. N. Sokolov		
AN HF-SEM TECHNIQUE FOR CHARACTERIZATION OF THE WEATHERING PROPERTIES OF BUILDING STONES. I. GRANITE		555
S. Z. Lewin and A. E. Charola		
PLANT LIFE ON STONE SURFACES AND ITS RELATION TO STONE CONSERVATION		563
S. Z. Lewin and A. E. Charola		
SEM STUDY OF SHALE FABRIC - A REVIEW	(Review Paper)	569
N. R. O'Brien		
LITHOLOGIC CHARACTERISTICS AND DIAGENESIS OF SOME SILICEOUS COASTAL PLAIN ROCKS		577
S. W. Wise, Jr., M. P. Ausburn, D. A. Textoris, W. H. Wheeler, R. B. Daniels and E. E. Gamble		

DIRECT OBSERVATION OF EXPLOSIVELY INDUCED DAMAGE IN SANDSTONE WITH APPLICATION TO RESERVOIR STIMULATION W. B. Durham	585
ENAMEL ULTRASTRUCTURE AND ITS IMPLICATION TO PALEONTOLOGY D. G. Gantt and F. D. Cring	595
THE SCANNING ELECTRON MICROSCOPE -- A POWERFUL TOOL OF THE MINERALOGIST: AN OVERVIEW T. A. Peters (Tutorial Paper)	603
APPLICATIONS OF SEM IN PETROLOGY OF MUDROCKS (RESULTS OF STUDIES OF DEVONIAN MUDROCKS FROM WEST VIRGINIA AND VIRGINIA) E. B. Nuhfer, R.J. Vinopal, M. E. Hohn and D. S. Klanderman (Review Paper)	625
CHARACTERIZATION OF ZEOLITE FORMS, INTERGROWTHS, AND SEQUENCES WITH SEM W. S. Wise and D. Pierce	633
MAGNETITE AND WATER-FORMED DEPOSITS IN STEAM BOILERS: SEM AND EDX OBSERVATIONS D. L. Gibbon, F. H. Seels and G. C. Simon	641
MANGROVE ROOT INTRUSION: A MEANS FOR ENRICHING SULFUR IN UNDERLYING PEATS R. Raymond, Jr. and T. D. Davies	651
REACTIONS IN PYRITE FRAMBOIDS INDUCED BY ELECTRON BEAM HEATING IN A HVEM L. A. Harris, E. A. Kenik and C. S. Yust	657
SUBJECT INDEX	663
AUTHOR INDEX	666

*EXPLANATION OF THE TYPES OF PAPERS IN THIS VOLUME:

TUTORIAL: Presentation of established material in teaching format emphasizing techniques.

REVIEW: A review of the chosen subject with emphasis on author's own work, placing it in context with relevant literature and putting the topic in perspective.

Volunteers to prepare tutorial, review papers or bibliographies should contact Om Johari (see page ii).

THE ANALYSIS OF ORGANIC SURFACES

Patrick Echlin

The Botany School, University of Cambridge,
Cambridge CB2 3EA, United Kingdom

Abstract

The characterization of a surface involves more than just obtaining high resolution topographic images along the X and Y axes and the chemical identity of the surface layer of atoms. It should also include a co-ordinated in-depth analysis along the Z axis at as high a resolution as may be obtained with a particular form of instrumentation. Surface characterization techniques may be divided into those methods covering microtopography and those involved in chemical analysis. The former category is served by optical microscopy and scanning and transmission electron microscopy while the latter techniques are based on excitation of atoms and molecules at the surface by photons, electrons and ions. A surprisingly large number of techniques are available for surface analysis, although the properties of most organic samples prevents all these techniques being used. Optimal specimen preparation is critical in order that these surface characteristics give adequate information, and cryotechnology plays a central role in specimen preparation, examination and analysis.

Introduction

"We live in an age of surfaces" (Oscar Wilde).

Although we live in a complex, three dimensional world lit from above, our cognition of this environment takes place by a process of visual perception of interlocking two dimensional surfaces. Through experience, we can recognize patterns and shapes, and because we possess the remarkable facility of binocular vision, we are able to synthesize a series of planar surfaces into familiar three dimensional shapes. In many instances, and in particular in microscopy, we are able to codify and recognize new images which we have never seen before. No object is mysterious, the mystery is in our eyes. With a few exceptions, we are unable to see below the surface of natural objects, yet our experience tells us that many of the sub-surface features of an object are important in determining the surface characteristics which are presented to us. Organic surfaces, and in particular biological surfaces, are heterogeneous and generally more complex than inorganic surfaces. The surface of a block of metal, a crystal of an inorganic salt or a piece of concrete appear the same from whichever direction they are viewed, although important sub-microscopic and crystallographic differences do exist. If we were to section or fracture these homogeneous materials the internal surfaces we reveal are, at a macroscopic level, identical to the external surface. This is not true with many organic materials and much of their functional significance can be related to the internal surfaces which are normally hidden from our view.

An analysis of organic surfaces must necessarily look below the surface and it is important to consider some of the ways we can expose internal surfaces without introducing artefacts during the preparative procedures. These manipulations are particularly important in the examination of biological surfaces, and great care must be taken in converting or replicating the specimens into a form which is conducive to the alien environment of the systems used to image and abstract the information.

It is convenient to consider the properties of surfaces from the point of view of their morphology and their composition. The

KEY WORDS: Morphology, analysis, low temperatures, electrons, photons, ions, lasers, organic biological

morphological features of a surface may be divided into an examination and measurement of the micro-structural features (topography) and a quantitation of their inter-relationships (topology). This morphological information is essentially two dimensional and is frequently represented as a series of picture points along the X and Y coordinates. The real surface, as seen by our eyes, and images of the surface (photographs, drawings, maps etc) only becomes three dimensional because our previous experience in pattern recognition tells us that the various surface features are separated along an axis normal to the mean depth of the surface. This recognition is usually quite easy in the real world but may become problematic when we examine images of unfamiliar objects, for here the third dimension may not be directly observed but only perceived. In these circumstances it is essential to subject the planar surface projections to stereo-pair analysis, whereby it is possible to more easily perceive the distances between points on a non-planar surface. Stereogrammetric techniques are the only way in which accurate measurements may be made on non-planar surfaces.

The compositional analysis of a surface must necessarily delve below the surface although it could well be argued that the wavelength contrast (colour), albedo (solar reflectivity) and specular features (shininess) can give us compositional information about an object (the shiny yellow colour of gold is a good example). The depth analysis may be confined to the first few atomic layers of the surface, or penetrate several micrometres below the surface. The information which may be gained can be related to the elemental, molecular and even macromolecular composition of the surface.

Although it is convenient to consider morphology and composition separately, they are in reality very closely linked. This link sometimes puts very severe restraints on the effectiveness of the imaging systems for while one particular technique may give accurate compositional information the very act of quantitation may destroy the specimen. The obverse is also true, and in most instances the process of preserving and subsequently observing may only be achieved at the expense of the natural composition of the object. This paradox, "the very act of observing introduces artefacts", is alas one of the problems we have to accept in the microscopy and analysis of organic materials.

The discussion in this paper is limited to a consideration of the in situ analysis of organic samples, as they usually present greater problems in preparation, examination and analysis than do their inorganic counterparts. Biological specimens present the most severe challenge to the microscopist and analyst, because they are nearly always highly hydrated. The presence of water is less of a problem in the other types of organic samples, such as natural and artificial polymers, and elastomers, and the low water content and structural characteristics of some of the more robust plant and animal products (chitin, wood, bone, teeth etc) is such that they require little preparation prior to examination in

the microscope.

Analysis of surface morphology

The structural features of the specimen surface may be readily localized using a beam of photons or electrons. Although other imaging systems exist, for example those based on sound waves, X-rays and ions, they do not at present give any more information than can be achieved using photons and electrons. An interesting exception to this may be found in ultra-soft X-ray microscopy, which although not a new technique, has recently become a subject of renewed interest (Parsons, 1980). The X-ray imaging depends on the differential absorption of X-rays in the wavelength range 1-10nm, by the various components in the specimen. Recent work by Rudolph et al (1980) has shown that it is possible to obtain high resolution (70nm) images of organic material using zone plate optics in conjunction with a high X-ray flux. Alternatively the image need not be viewed directly but a replica is formed on a photo-resist by the X-rays which pass through the specimen. In areas of high mass density the X-rays are absorbed and these regions appear in high relief after the photoresist is chemically developed and examined in an SEM. The spatial resolution varies but can be as good as 5nm. The advantages of the system are the reduced specimen damage and the ability to examine hydrated samples.

This procedure is quite distinct from direct X-ray microscopy which although giving information from wet specimens up to 5µm thick can only produce images up to a magnification of x200. The only advantage of acoustic microscopy, in which acoustic waves are reflected or deflected by variations in specimen density, is that it can only be carried out on unstained specimens immersed in water. The resolution is consequently no better than 2.0µm. By using cryogenic liquids (Rugar et al, 1980) instead of water it has been possible to obtain a spatial resolution of about 100nm.

The limited resolution of light microscopes is the only restraint which can be put on this form of imaging system. If we use light in the visible range we are able to obtain information about the surfaces of living, physiologically intact specimens. The information is presented to the observer in both wavelength and amplitude contrast, albeit at somewhat limited spatial resolution (c. 100-200nm). The process of information transfer does not appear to damage or unduly perturbate the organic specimen and we assume we are observing the specimen close to its natural state.

In order to increase the spatial resolution of the imaging system, we must use an illuminating system of much reduced wavelength. High energy electrons are a convenient imaging system and although the spatial resolution is increased to a few tens of nanometres, the use of electron beams creates serious problems for many organic specimens. The short mean free