

MRS

BULLETIN

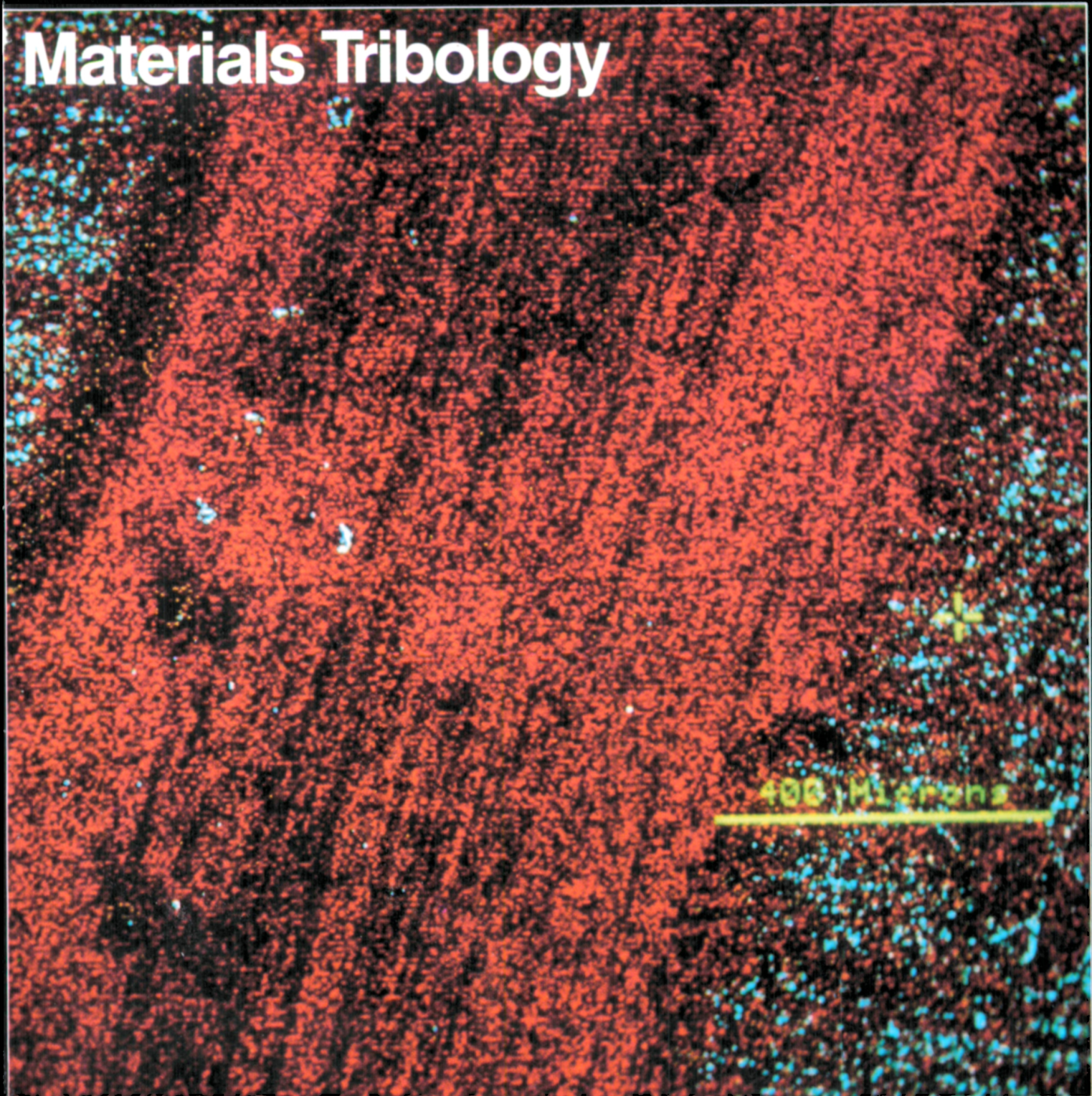
Serving the International
Materials Research Community

A Publication of the Materials Research Society

October 1991, Volume XVI, No. 10



Materials Tribology



400 microns

BEAMING IN ON THE USA



HIGH VOLTAGE ENGINEERING EUROPA B.V. OPENS ITS OWN SALES AND SERVICE OFFICE IN THE USA

On April 1, 1991 we opened our own Sales and Service Office in the United States in order to be able to serve you more effectively and efficiently.

Our new office is located in the head offices of our parent company:

HIGH VOLTAGE ENGINEERING CORPORATION (HVEC)
The Schrafft Center, Suite 602
529 Main Street
Boston, MA 02129.
Phone: (617) 241 5000, Fax: (617) 241 5005.

In addition to the marketing of our wide range of equipment and replacement parts our new office will provide assistance in the installation and servicing of new and existing installations in the United States and Canada.

HIGH VOLTAGE ENGINEERING is the largest and most diverse manufacturer of particle accelerators for the scientific and industrial research communities.

Our product lines include:

– *Ion Accelerator Systems*

- Air insulated accelerators up to 500 kV
- Single ended Van de Graaff accelerators up to 4 MV
- Tandem Tandetron accelerators up to 3 MV/TV

– *Research ion implanters*

- Beam energies 10 keV-9 MeV and higher

– *Systems for ion beam analysis*

- Systems for RBS, PIXE, PIGE, NRA, ERD, AMS and MEIS

– *Components*

- HV power supplies, electron and ion accelerator tubes, ion sources, beamline components, beam monitoring equipment, UHV sample manipulators, etc.

To receive product literature, sales or service support just call or write the Sales and Service Office serving your area.

Please visit Booth No. 925 at the MRS Show in Boston, December 3-5, 1991.



More
Energy for Research

HIGH VOLTAGE ENGINEERING EUROPA B.V.

P.O. Box 99, 3800 AB Amersfoort, The Netherlands, Phone: (+31) 33 - 619741. Fax: (+31) 33 - 615291. Telex: 79100 HIVEC NL

For Japan: MARUBUN CORPORATION, 8-1 Nihombashi Odemmacho, Chuo-ku, Tokyo, 103 Japan, Phone 03-3639-9861, Fax 03-3661-7473

Published online by Cambridge University Press
https://doi.org/10.1017/S000497240005205 Published online by Cambridge University Press

Circle No. 1 on Reader Service Card.

SUPERIOR PRODUCTS THROUGH JOINT TECHNOLOGY

When High Voltage Engineering acquired General Ionex a "cluster" in ion beam technology was born.

Through integration and complementation of technologies an important step in the development of ion beam related equipment has been made.

This joint technology has resulted in new generation Tandetrans™: reliable, compact and versatile tandem accelerator systems able to produce MeV ion beams of virtually all periodic-system elements for material modification and analysis in a research environment.

Circle no. 4 reader service card for new product literature.

Please visit Booth No. 925 at the MRS Show in Boston, December 3-5, 1991.



DIVISIONS
GENERAL IONEX
DOWLISH DEVELOPMENTS



More
Energy for Research

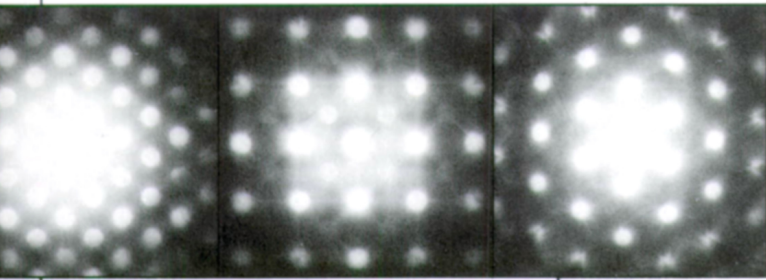
HIGH VOLTAGE ENGINEERING EUROPA B.V.

P.O. Box 99, 3800 AB Amersfoort, The Netherlands, Phone: (+31) 33 - 619741. Fax: (+31) 33 - 615291. Telex: 79100 HIVEC NL

For Japan: MARUBUN CORPORATION, 8-1 Nishibashi, Odemmacho, Chuo-ku, Tokyo, 103 Japan, Phone 03-3639-9861, Fax 03-3661-7473

For USA and Canada: HVEC, The Schrafft Center, Suite 602, 529 Main Street, Boston, MA 02129, Phone: (617) 241 5000, Fax: (617) 241 5005

THE BEST WAY TO GET AN ANGLE ON CRYSTALS.



High resolution, electron microdiffraction analysis may require several tilt angles.

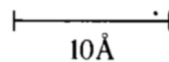
Please visit Booth No. 3 at the MRS Show in Boston, December 3-5, 1991.

If you need to determine elemental composition and molecular or atomic structure of crystals in minerals, metals, ceramics or polymers, our JEM-2010 is the best high resolution, analytical microscope for the job.

The JEM-2010 is a 200 kV TEM with superior optics and high probe current. It is optimized for analytical performance

not only in the analytical configuration, but also in the ultra-high resolution configuration as well.

With the EDS accessory, elemental analyses may be performed using probes as small as 10Å.



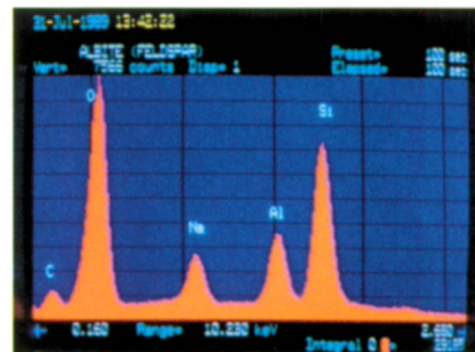
Equipped with the interchangeable, high resolution pole piece, the JEM-2010 is also an ultra-high resolution microscope with 1.9Å resolution over 10° of tilt and an x-ray collection angle of 0.07 steradians.

30°

Equipped with EDS, the JEM-2010 is capable of high sensitivity elemental analyses using probes as small as 10Å in diameter.

With its analytical pole piece, it offers 2.3Å resolution over 30° of tilt and an x-ray collection angle of 0.13 steradians. That is the best combination of analytical features of any instrument in the 200 kV class.

But the JEM-2010 is more than an analytical microscope.



High sensitivity elemental analysis is possible with the addition of an EDS system.

For purposes of analyzing obliquely oriented crystalline material in metal, mineral, ceramic or polymer matrices, the JEM-2010 offers 2.3Å resolution with a tilt angle of ± 30 degrees.



JEM-2010 Transmission Electron Microscope



Let us tell you more. Call (508) 535-5900. Or write JEOL USA, Inc., 11 Dearborn Road, Peabody, MA 01960.

Circle No. 5 on Reader Service Card.

MRS BULLETIN

October 1991

A Publication of the Materials Research Society

Volume XVI, Number 10 ISSN: 0883-7694 CODEN: MRSBEA

MATERIALS TRIBOLOGY

30 What is Tribology, Anyway?

F.A. Nichols, Guest Editor

33 Molecular Tribology

S. Granick

36 Adhesion, Friction, and Wear

D. Landheer and A.W.J. de Gee

41 Friction-Heating Maps and Their Applications

H.S. Kong and M.F. Ashby

49 Sliding Friction and Wear of Ceramics With and Without Soft Metallic Films

A. Erdemir, F.A. Nichols,
G.R. Fenske, and J-H. Hsieh

54 Boundary Lubrication of Materials

S.M. Hsu

INTERNATIONAL UNION OF MATERIALS RESEARCH SOCIETIES

59 Mexican MRS Holds First National Meeting

MRS NEWS

61 Preview: 1991 MRS Fall Meeting

70 Call for Papers: 1992 MRS Spring Meeting

DEPARTMENTS

6 Material Matters

8 Research/Researchers

20 From Washington

25 Resources

26 Book Reviews

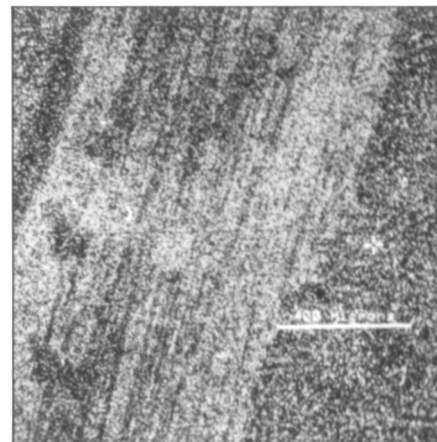
28 Editor's Choice

60 Advertisers in This Issue

68 Journal of Materials Research

69 Historical Note

72 Classified



ON THE COVER: Color-enhanced scanning electron microscopic view of a wear track on Ag-coated Si₃N₄ after testing in a pin-on-disk tribometer. Bright spots in the wear track indicate local asperities from which the Ag coating has been removed. For more about the realm of basic friction and wear mechanistic studies, see the article by A. Erdemir, F.A. Nichols, G.R. Fenske, and J-H. Hsieh on p. 49. Photo courtesy of A. Erdemir and R.H. Lee, Argonne National Laboratory.

MRS BULLETIN

Materials Research Society • 9800 McKnight Road • Pittsburgh, PA 15237

About the Materials Research Society

The Materials Research Society (MRS), a nonprofit scientific association founded in 1973, promotes interdisciplinary goal-oriented basic research on materials of technological importance. Membership in the Society includes more than 10,000 scientists, engineers, and research managers from industrial, government, and university research laboratories in the United States and more than 40 countries.

The Society's interdisciplinary approach differs from that of single-discipline professional societies because it promotes information exchange across the many technical fields touching materials development. MRS sponsors two major international annual meetings encompassing approximately 50 topical symposia, and also sponsors numerous single-topic scientific meetings. The Society recognizes professional and technical excellence, conducts short courses, and fosters technical interaction in local geographic regions through Sections and University Chapters.

MRS participates in the international arena of materials research through the International Union of Materials Research Societies (IUMRS). MRS is an affiliate of the American Institute of Physics.

MRS publishes symposium proceedings, *MRS Bulletin*, *Journal of Materials Research*, and other publications related to current research activities.

MRS Bulletin (ISSN: 0883-7694) is published 12 times a year by the Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237. Application to mail at second class rates is pending at Pittsburgh, PA and at additional mailing offices. POSTMASTER: Send address changes to *MRS Bulletin* in care of the Materials Research Society, at the address listed; phone (412) 367-3003; Fax (412) 367-4373

Membership in MRS is \$65 annually for regular members, \$20 for students and retired members. Dues include an allocation of \$25 (\$15 for students and retirees) to a subscription to *MRS Bulletin*. Individual member subscriptions are for personal use only. Non-member subscription rates are \$88 for one calendar year (12 issues) within the U.S.A. and \$128 elsewhere. Single copies may be purchased for \$15 each. Send subscription orders to Subscription Department, Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237.

MRS Bulletin is included in *Current Contents/Physical, Chemical & Earth Sciences™* and *Research Alert*. Back volumes of *MRS Bulletin* are available in 16mm microfilm, 35mm microfilm, or 105mm microfiche through University Microfilms Inc., 300 North Zeeb Road, Ann Arbor, Michigan 48106.

MRS BULLETIN

Publisher

G. A. Oare

Technical Editor

E. L. Fleischer

Assistant Editor

F. M. Wieloch

Copy Editor

D. M. Varner

Art Director

C. Love

Design/Production

W. A. McCalip, J. Probert

Editorial Assistants

J. Dininny, M. M. Costello

Advertising and Circulation

M. E. Kaufold

Associate Editor—Europe

I. W. Boyd

University College London

Dept. of Electronic and

Electrical Engineering

Torrington Place

London WC1 E7 JE

United Kingdom

71-387-7050 ext. 3956 or 7304

Editorial and Advertising Offices

9800 McKnight Road
Pittsburgh, PA 15237
Telephone (412)-367-3036
Fax (412) 367-4373

MRS Office of Public Affairs

2000 Florida Ave. NW, Third Floor
Washington, DC 20009
Telephone (202) 483-6771

Guest Editors

F. A. Nichols

Special Contributors

K. J. Anderson, M.L. Good

CHAIRMAN—EDITORIAL BOARDS

E. N. Kaufmann • Argonne National Laboratory • Argonne, Illinois, USA

INTERNATIONAL ADVISORY BOARD

M. Balkanski
University of Pierre and Marie Curie
Paris, France

R. G. Elliman
Australian National University
Canberra, Australia

S. Hsu
Chung Shan Institute of Science
and Technology
Taiwan, China

L. C. Ianniello
U. S. Department of Energy
Washington, DC, USA

H-D. Li
Tsinghua University
Beijing, China

P. R. Rao
Defence Metallurgical Research
Laboratory
Hyderabad, India

R. Roy
Pennsylvania State University
University Park, Pennsylvania, USA

T. Sugano
University of Tokyo
Tokyo, Japan

TECHNICAL EDITORIAL BOARD

J. C. Bravman
Stanford University
Stanford, California, USA

C. W. Draper
AT&T Engineering Research Center
Princeton, New Jersey, USA

F. Y. Fradin
Argonne National Laboratory
Argonne, Illinois, USA

G. L. Liedl
Purdue University
West Lafayette, Indiana, USA

S. Namba
Osaka University
Osaka, Japan

A. D. Romig Jr.
Sandia National Laboratories
Albuquerque, New Mexico, USA

K. C. Taylor
General Motors Research
Laboratories
Warren, Michigan, USA

MRS BULLETIN PUBLICATIONS SUBCOMMITTEE

A. Barkatt
Catholic University of America
Washington, DC

A. J. Hurd
Sandia National Laboratories
Albuquerque, New Mexico

M. R. Libera
Stevens Institute of Technology
Hoboken, New Jersey

G. J. McCarthy
North Dakota State University
Fargo, North Dakota

J. M. Phillips
AT&T Bell Laboratories
Murray Hill, New Jersey

S. M. Prokes
Naval Research Laboratory
Washington, DC

W. H. Sutton
United Technologies
Research Center
East Hartford, Connecticut

C. W. White
Oak Ridge National Laboratory
Oak Ridge, Tennessee

1991 MRS EXECUTIVE COMMITTEE

President

J. B. Roberto
Oak Ridge National Laboratory

First Vice President and President-Elect

G. S. Cargill III
IBM T. J. Watson Research Center

Second Vice President

S. T. Picraux
Sandia National Laboratories

Secretary

C. M. Jantzen
Westinghouse Savannah River Co.

Treasurer

C. B. Duke
Xerox Research Laboratories

Immediate Past President

R. R. Chianelli
Exxon Research and Engineering

Executive Director
Materials Research Society
John B. Ballance

INTERNATIONAL UNION OF MATERIALS RESEARCH SOCIETIES

President

R. P. H. Chang
Northwestern University, USA
Tel. (708) 491-3598; Fax (708) 491-4181

Vice President

Paul Siffert
Centre de Recherches Nucléaires, France
Tel. (88) 28 65 43; Fax (88) 28 09 90

Secretary

Rodney C. Ewing
University of New Mexico, USA
Tel. (505) 277-4163; Fax (505) 277-0090

Treasurer

Shigeyuki Sōmiya
Nishi Tokyo University, Japan
Tel. (81) 3 417 2866; Fax (81) 3 415 6619

IUMRS ADHERING BODIES

Australian Materials Research Committee (AMRC)
J. S. Williams

Chinese Materials Research Society (C-MRS)
Hengde Li

European Materials Research Society (E-MRS)
B. Stritzker

Materials Research Society (MRS)
James B. Roberto

Materials Research Society of India (MRS-I)
C. N. R. Rao

Materials Research Society of Japan (MRS-J)
Shigeyuki Sōmiya

Materials Research Society of Korea (MRS-Korea)
Min Che Chon

Materials Research Society of Taiwan (MRS-T)
Ping-Tien Wu

Mexican Materials Research Society (Mexican MRS)
M. J. Yacaman

STEP UP TO BERTAN HIGH VOLTAGE SOLUTIONS.

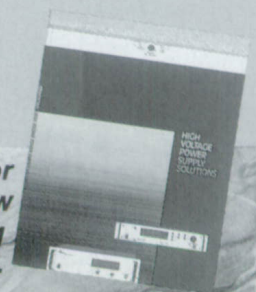


For grounded and isolated
target X-Ray sources

BA BERTAN High Voltage

121 New South Road • Hicksville, NY 11801
516-433-3110 • Fax: 516-935-1766

Send for
our new
catalog
today.



Circle No. 6 on Reader Service Card.