

REPORT

Materials Research in an Aberration-Free Environment

July 31-August 4, 2005
Hawaii Convention Center
Honolulu, Hawaii – USA



Microscopy and Art: Strontium by G. Richter, Fine Arts Museums of San Francisco

Organizers:

Christian Kiselowski
National Center for Electron Microscopy, Lawrence Berkeley National Laboratory

Bernd Kabius
Electron Microscopy Center, Argonne National Laboratory

Chris Kiely
Department of Materials Science and Engineering, Lehigh University

Ray Phaneuf
Maryland Center for Integrated Nano Science and Engineering, University of Maryland

Frances Ross
IBM TJ Watson Research Center

INTRODUCTION

Following the TEAM workshops in 2000, 2002, and 2003 a Focused Interest Group on **“Materials Research in an Aberration-Free Environment”** was founded within the Microscopy Society of America. In 2004 a Pre-meeting Congress was held in Savannah / Georgia that was attended by ~150 participants and documented the significant interest in this subject within the microscopy community. In 2005 the Focused Interest Group contributed to the regular M&M program. This report highlights contributions to the 2005 meeting.

SUMMARY

The symposium stimulated a comparison of STEM and TEM performance, gave application examples, and provided an update on progress that was made in terms of instrumentation by FEI, Jeol, Nion, and Zeiss.

Selected Highlights:

- The reciprocity of TEM and STEM was reviewed (Rose) and documented by recording Bright Field STEM images (Lupini) and Dark Field TEM images (Bals) with atomic resolution. BF - and DF STEM were utilized to image oxygen columns in strontium titanate and to clearly resolve dumbbells in Si [112] at 0.78Å spacing. DF-TEM was shown to be a new approach to electron tomography.
- In terms of instrumentation, Nion described the next generation probe corrector that allowed for imaging of oxygen columns in DF STEM and for resolution enhancement. FEI introduced their new line of instruments based on the Titan column. The basic instrument allowed for information transfer to 0.7Å on the exhibition floor, and atomically resolved diamond dumbbells (0.89Å) were recorded with an aberration corrected Titan STEM operated at 300 kV. Jeol announced the fabrication of a new double Wien Filter monochromator. Zeiss reported 0.7Å resolution obtained by recording Young fringes with the SATEM instrument.
- Discrete tomography (DT) is seen as a way to establish atomic resolution electron tomography. Batenburg and Chen demonstrated the applicability of the technique to include atom count errors and to distinguish chemically different atoms in images of electron exit waves. The Cornell group attempted a first reconstruction of a layered structure by STEM DT. Obstacles on the road towards Atomic Resolution Tomography were reviewed (Van Dyck).
- In terms of image formation theory, Lentzen et al. reconsidered TEM image formation using a Wien Filter monochromator and concluded that the present energy anisotropy (rainbow illumination) may cause an anisotropic information

limit. Spence compared resolution definitions between STEM and TEM that are by principle different. Novel approaches to reconstruct Electron Exit Waves were reported (Ishizuka, Kirkland).

- State-of-the-art materials research was addressed by Houben (TEM) and Bleloch (STEM). Mardinly considered future needs of the semiconductor industry.

WORKSHOP PUBLICITY AND ATTENDEE PROFILE

Outreach:

The 2005 meeting was publicized through advertisements in Microscopy and Microanalysis. The journal reaches out to the Microscopy Society of America, the Microbeam Analysis Society, The Microscopical Society of Canada, the Mexican Microscopy Society, the Brazilian Society for Microscopy and Microanalysis, the Venezuelan Society of Electron Microscopy, the European Microbeam Analysis Society, and the Australian Microscopy and Microanalysis Society. Further, existing e-mail contacts that were established during the TEAM workshops were used for solicitations.

Participation:

A total of 1618 scientists from 41 countries were registered at the meeting. Of the 73 topical sessions at the conference, this symposium was one the best-attended. Over its two-day period the audience at the symposium varied between 100 – 300 participants. 32 contributions were presented by scientists from 9 countries: USA (11), Germany (6), Japan (5), UK (2), Taiwan (2), Netherlands (2), Belgium (2), Canada (1), and Mexico (1).

PROGRAM

Materials Research in an Aberration-Free Environment

Monday

Potential, Practicalities and Problems of Aberration Minimized FESEM

E D Boyes; DuPont

Platform Invited

Day 1-Monday, 323C, 08:00

Resolution and Image Fidelity in STEM and TEM (HREM)

J C H Spence; Cambridge University

Platform Invited

Day 1-Monday, 323C, 08:30

On the Reciprocity of TEM and STEM

H Rose, C F Kisielowski; Lawrence Berkeley National Laboratory

Platform Invited

Day 1-Monday, 323C, 09:00

Imaging of Materials through Aberration Corrected STEM

A R Lupini, G M Veith, N J Dudney, M F Chisholm, K van Benthem, M Varela, A Y Borisevich, Y Peng, S N Rashkeev, S J Pennycook; Oak Ridge National Laboratory

Platform Invited

Day 1-Monday, 323C, 09:30

10:00 - 10:30 Break

Obstacles on the Road Towards Atomic Resolution Tomography

D Van Dyck, S Van Aert, M D Croitoru; University of Antwerp

Platform Invited

Day 1-Monday, 323C, 10:30

Annular Dark Field Tomography in TEM

S Bals; University of Antwerp; C F Kisielowski; Lawrence Berkeley National Laboratory; M Croitoru, G Van Tendeloo; University of Antwerp

Platform Invited

Day 1-Monday, 323C, 11:00

Atomic Resolution Electron Tomography on a Discrete Grid: Atom Count Errors

K J Batenburg; Leiden University; J R Jinschek, C F Kisielowski; Lawrence Berkeley National Laboratory

Platform Student

Day 1-Monday, 323C, 11:30

Atomic Precision Measurement of Individual Atom Positions in Defects by Aberration Corrected HRTEM

L Houben, A Thust, K Urban; Research Centre Juelich, Germany

Platform Invited

Day 1-Monday, 323C, 11:45

12:15 – 13:30 Break

Atomic Motion Observed with the IBM Sub-Angstrom STEM

P E Batson; IBM Thomas J. Watson Research Center

Platform, Invited

Day 1-Monday, 323C, 13:30

Resolution Limit Measured by Fourier Transform: 0.61 Angstrom Information Transfer through HAADF-STEM

Y Peng, A Y Borisevich, A R Lupini, S J Pennycook; Oak Ridge National Laboratory

Platform

Day 1-Monday, 323C, 14:00

High Angle Annular Dark Field Imaging On and Away from the Pole

A Bleloch; SuperSTEM Laboratory, UK; P Wang; Liverpool University, UK; U Falke; SuperSTEM

Laboratory, UK; P Goodhew; Liverpool University, UK

Platform

Day 1-Monday, 323C, 14:15

Advantages of Cs-correctors for Spectrometry in STEM

M Watanabe, D W Ackland, A Burrows, C J Kiely, D B Williams; Lehigh University; M Kanno, R Hynes;

JEOL USA

Platform

Day 1-Monday, 323C, 14:30

Performance of a new Monochromator for a 200 kV Analytical Electron Microscope

M Mukai, T Kaneyama, T Tomita, K Tsuno; JEOL; M Terauchi, K Tsuda; Tohoku University, Japan; M

Naruse, T Honda; JEOL; M Tanaka; Tohoku University, Japan

Platform

Day 1-Monday, 323C, 14:45

Design and Performance Characteristics of the ORNL Advanced Microscopy Laboratory and JEOL 2200FS-AC Aberration-Corrected STEM/TEM

L F Allard, D A Blom; Oak Ridge National Laboratory; M A O'Keefe; Lawrence Berkeley National

Laboratory; S Mishina; JEOL USA

Platform

Day 1-Monday, 323C, 15:00

Aberration Corrected Microscopy and Moore's Law: Capabilities Aiding Progress for the Next Decade

J Mardinly; Intel

Platform

Day 1-Monday, 323C, 15:15

Monday Posters

Cross-sectional Observations of Surface Structures on MgO{100} by Cs-corrected TEM

J Yamasaki, N Tanaka, Y Nakagaki, S Fukami; Nagoya University; H Sawada; JEOL, Japan

Poster

Day 1-Monday, Exhibit Hall, 15:30

Transport of Intensity Equation Applied to Study Quasi-Dynamic Surface and Boundary Reconstruction

K Ishizuka; HREM Research, Japan
Poster
Day 1-Monday, Exhibit Hall, 15:30

Three-Dimensional Aberration-Free Imaging Recovery by the Oversampling Method and Tomography

W-Y Yen, F-R Chen, J-J Kai; National Tsing-Hua University, Taiwan
Poster Student
Day 1-Monday, Exhibit Hall, 15:30

Measurement of 3rd Order Spherical Aberration Coefficient for Scanning Transmission Electron Microscopy

Y Kotaka; Fujitsu; T Yamazaki; Tokyo University of Science; K Watanabe; Tokyo Metropolitan College of Technology; Y Kikuchi; MIRAI Project; N Nakanishi, I Hashimoto; Tokyo University of Science
Poster
Day 1-Monday, Exhibit Hall, 15:30

Tuesday

Aberration Free Microscopy for Life Science Applications

J M Plitzko; Max-Planck-Institute of Biochemistry; B Freitag; FEI; R Hegerl; Max-Planck-Institute of Biochemistry; U Luecken; FEI
Platform
Day 2-Tuesday, 323C, 08:00

The TEAM Project - An Update

U Dahmen; Lawrence Berkeley National Laboratory
Platform Invited
Day 2-Tuesday, 323C, 08:15

Design Features and Ultimate Performance of an Ultra-High Resolution Aberration-Corrected, Monochromatized 200 keV FEG-TEM

A E Thesen, M Matijevic, G Benner; Carl Zeiss
Platform
Day 2-Tuesday, 323C, 08:30

First Experiences using Electron Holography with a Cs-Corrected TEM

M Lehmann, D Geiger, H Lichte; Dresden University
Platform
Day 2-Tuesday, 323C, 08:45

The Design and First Results of a Dedicated Corrector (S)TEM.

M A van der Stam, P Tiemeijer, B Freitag, M Stekelenburg, J Ringnalda; FEI, The Netherlands
Platform
Day 2-Tuesday, 323C, 09:00

Cs Corrected Bright Field Imaging of Radiation Sensitive Materials

M Malac; National Institute for Nanotechnology, Canada; M Beleggia; Brookhaven National Laboratory; R F Egerton; University of Alberta; Y Zhu; Brookhaven National Laboratory
Platform

Day 2-Tuesday, 323C, 09:15

An Assessment of Imaging Models for Exit Wave Restoration

A I Kirkland, L-Y Chang; Oxford University

Platform

Day 2-Tuesday, 323C, 09:30

Contrast Transfer Theory for Transmission Electron Microscopes Equipped with a Wien-Filter Monochromator

M Lentzen, A Thust; Research Centre Juelich, Germany

Platform

Day 2-Tuesday, 323C, 09:45

10:00 - 10:30 Break

Toward Z-Contrast HRTEM by Reversed Multislice Process

F-R Chen; National Tsing-Hua University, Taiwan; C Kisielowski, J Jinshek; Lawrence Berkeley National Laboratory; J M Plitzko; Max-Planck-Institut fuer Biochemie; J-J Kai; National Tsing-Hua University, Taiwan

Platform Invited

Day 2-Tuesday, 323C, 10:30

Design and Testing of a Quadrupole/Octopole C3/C5 Aberration Corrector

N Dellby, O L Krivanek, M F Murfitt; Nion; P D Nellist; Trinity College, Ireland

Platform Invited

Day 2-Tuesday, 323C, 11:00

12:00 – 13:30 Break

Roundtable Discussion, K. Urban (chair)

Platform

Day 2-Tuesday, 323C, 13:30 –15:30pm

13:30 – 13:45 pm

Design and impact of a Cc-corrector

B. Kabius, Argonne National Laboratory, USA

13:45 – 14:00 pm

Image Contrast in Sub-Angstrom Annular Dark Field STEM

D. A. Muller, Z. Yu, K. A. Mkhoyan, L. Fitting, M. Weyland, E.J. Kirkland and J. Silcox, Cornell University

Through a combination of quantitative experiments and multislice simulations we examine the effects of sample tilt and thickness on ADF images and identify areas in which instrumentation can be improved to fully exploit the new generation of corrected optics.

14:00 – 14:15 pm

Evaluation of results from a Titan Cs Corrected Microscope

M. Lozada-Cassou*, V. Garibay*, B. Freitag**, H.A. Calderon***, C. Kisielowski****

* Instituto Mexicano del Petroleo, Ingeneiria Molecular., **FEI, *** Instituto Politecnico Nacional, ESFM.
**** NCEM-LBNL

Evaluation of the performance of the first Cs corrected microscope operating a 300 KeV is done with a variety of samples including Au, Ag, InN, Diamond and a Co-Ni catalyst.

14:15 – 14:30 pm

CBED measurements of strain with a monochromated and energy filtered LIBRA

P. Zhang, University of California Berkeley and LBNL

First results of strain distribution measurements by Convergent Beam Electron Diffraction in strained Si/SiGe thin films are presented and discussed.

14:30 – 15:30

Focused Interest Group Business Meeting