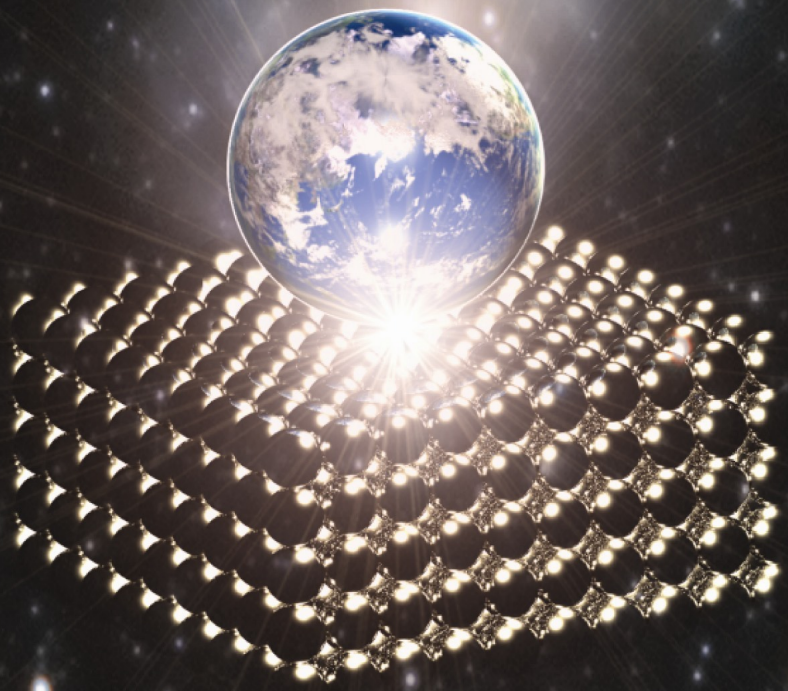
WPI-AIMR NEWS

Volume 1
December 24, 2007



Creative Development
Atomistic Characterization
Theoretical Understanding
Innovative Processing
New Device / System

World Premier International Research Center
Advanced Institute for Materials Research

Tohoku University

Volume 1

WPI-AIMR NEWS

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Produced by the WPI-AIMR Communication Office

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Contents

Preface

Inauguration of the WPI -Advanced Institute for Materials Research (WPI-AIMR)

Yoshinori YAMAMOTO

The WPI Advanced Institute for Materials Research, WPI-AIMR in short, has been launched on October 1, 2007. Today (November 15, 2007) we observe the successful inauguration of this new institute, as a fruit of the tremendous efforts, support, and leadership of Professor Akihisa Inoue, President of Tohoku University together with the President Office, as well as of the outstanding scientific achievements of all the WPI principal investigators and researchers. I thank all of those who have made their contributions to the establishment of WPI-AIMR for their great efforts and ceaseless support. The mission of WPI-AIMR is, through in-depth understanding and control at atomic and molecular level, to promote the development of new materials and substances, to invent innovative processes and devices, to construct new systems using those devices and materials, and ultimately, to benefit the society and mankind. It can be expected to organize a “dream team” for the materials research through the cooperation and unification of the existing institutes in a wide variety of disciplines including physics, chemistry, material science and engineering at Tohoku University, whose activities are already at world-top level, together with collaborations with world top-class researchers from other domestic and international institutes. I believe that, through this WPI-AIMR, we will be able to create entirely new materials and substances with innovative functions, contributing to welfare of mankind.

It is a great pleasure for me to publish the first volume of WPI-AIMR News before the end of year 2007. This volume contains a collection of the speeches by the President of Tohoku University and the distinguished guests at the WPI Inaugural Ceremony on November 15th, 2007, and the presentations of some of principal investigators in the technical sessions. We plan to publish this periodical quarterly.

In order to achieve the primal goal of WPI-AIMR, I would like once again to ask your continuous support, cooperation and advice for great success.

WPI-AIMR Launch

Overview

WPI-AIMR Launch - Overview

With President Akihisa Inoue's initiative, Tohoku University ran a comprehensive survey and review for the most exciting/innovative WPI research center. We decided to submit this university-wide "WPI (world-premier-international research center Initiative)" proposal and it was approved as one of the only five grants. We believe that this new program will succeed in this undertaking based on the past and current achievements made possible by the "Honda-Masumoto-Nishizawa-Inoue Initiatives."

It is named "WPI-Advanced Institute for Materials Research."
WPI-AIMR's objectives are threefold. Based on well-advanced university-wide materials science facilities and personal resources, we will try to further advance in the following three points

1) Advancements in methods based on atom, molecule level characterization and functional control,
2) Creative device development and
3) Eco-friendly material-system integration, all basically for better-future prosperity.

Tohoku University's solid foundation in theory/simulation, characterization/analysis and fabrication/process technology is very basic ingredients in achieving this endeavor.

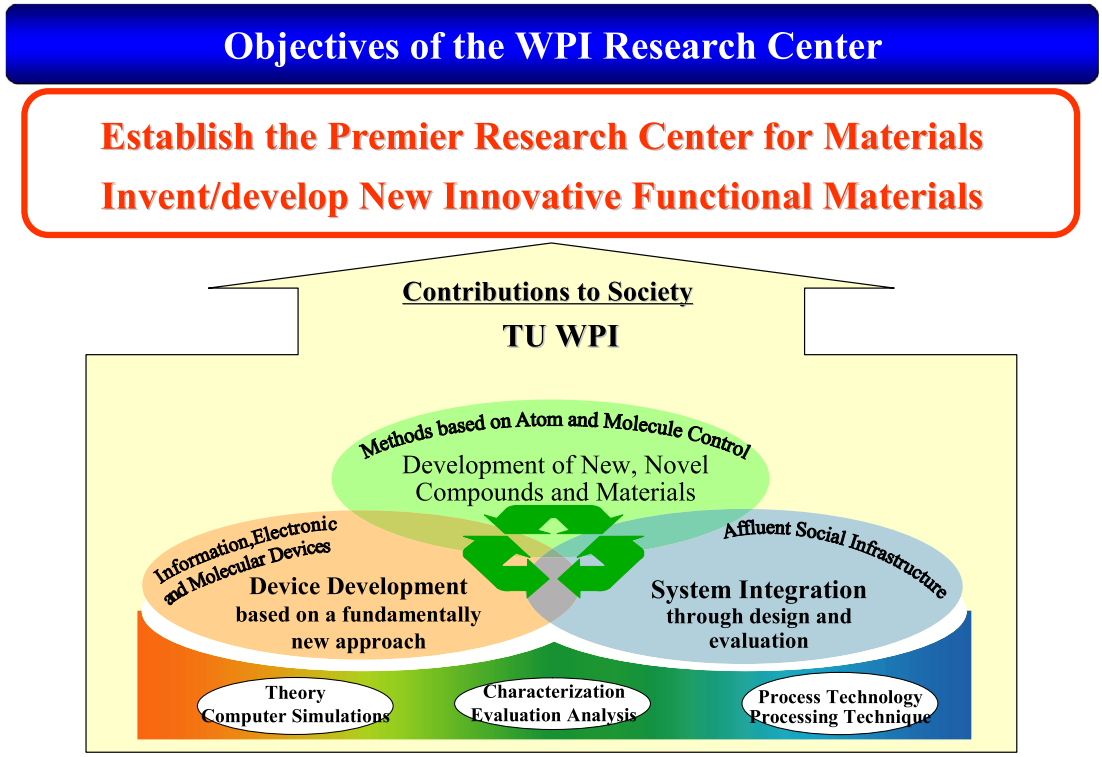


Fig. 1.

By working smart and wise under these principles, we believe that a truly world-premier Research Center for materials will be established upon the completion of the program.

Tohoku University is just celebrating the 100th anniversary this year, being founded in 1907. Our university is well-known for three major Innovative Concepts from its early days: While Tokyo and Kyoto Universities were initially formulated to produce elite bureaucrats to run the central government, Tohoku's aim was *research-first* from the beginning, and Professor Honda, founder of IMR, and the University President, introduced *basic-research for practical applications*, namely "Science for the benefit of mankind." Our *Open-door Policy* is well-known by accepting female students and technical high-school graduates.

These unique and innovative concepts are now the perfect base for WPI and our university stands well ahead among many national universities, as the Government is telling all academic institutions to do the same.

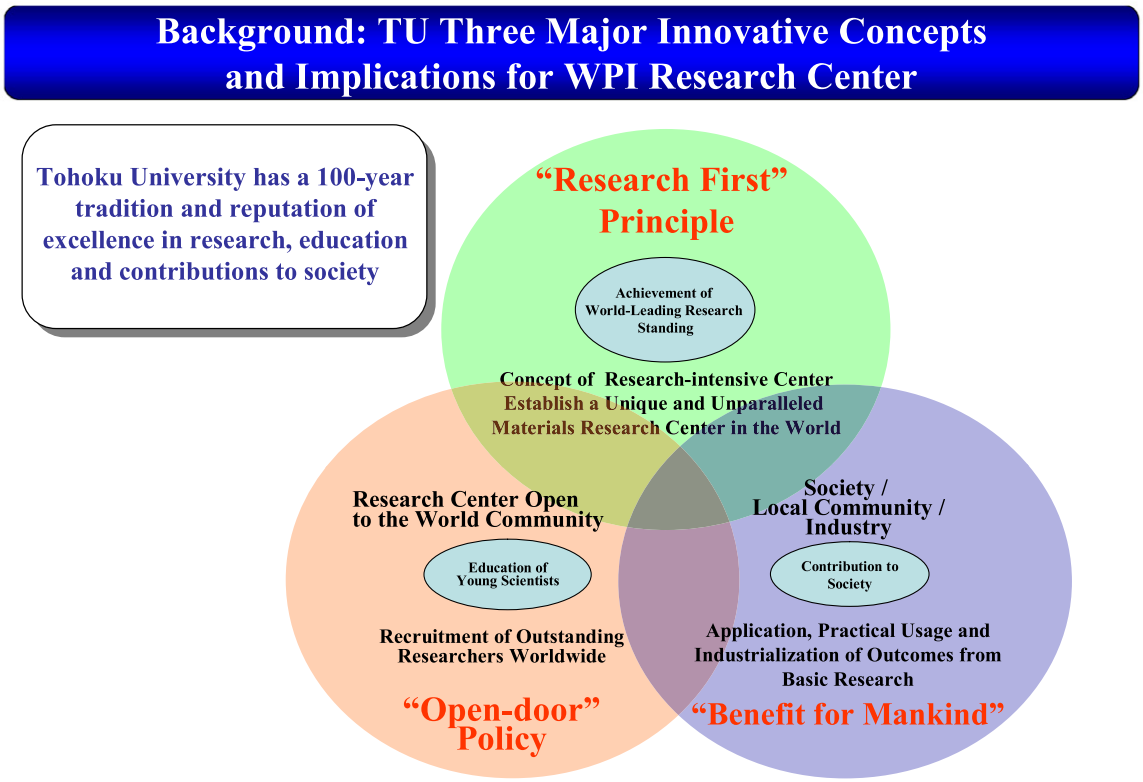


Fig. 2.

There is no single measure to evaluate the research performance of various universities and many factors must be taken into account. However, global citation analysis by ISI over a 50 year-data base is one well-accepted measure. Using this ISI data, Tohoku University ranks

No. 3 in Materials Science, No. 9 in Physics and 18 in Chemistry. We used to be No. 1in Materials Science over ten years until 2 years ago when ISI began treating ENTIRE Max Planck Society and Entire Chinese Academy of Sciences as a single entity.

As for research achievements of the graduates of Tohoku University, Professor Nishizawa, Professor Masumoto, President Inoue, Dr. Iijima and Dr. Tanaka are very visible, together with Professor Yamamoto.

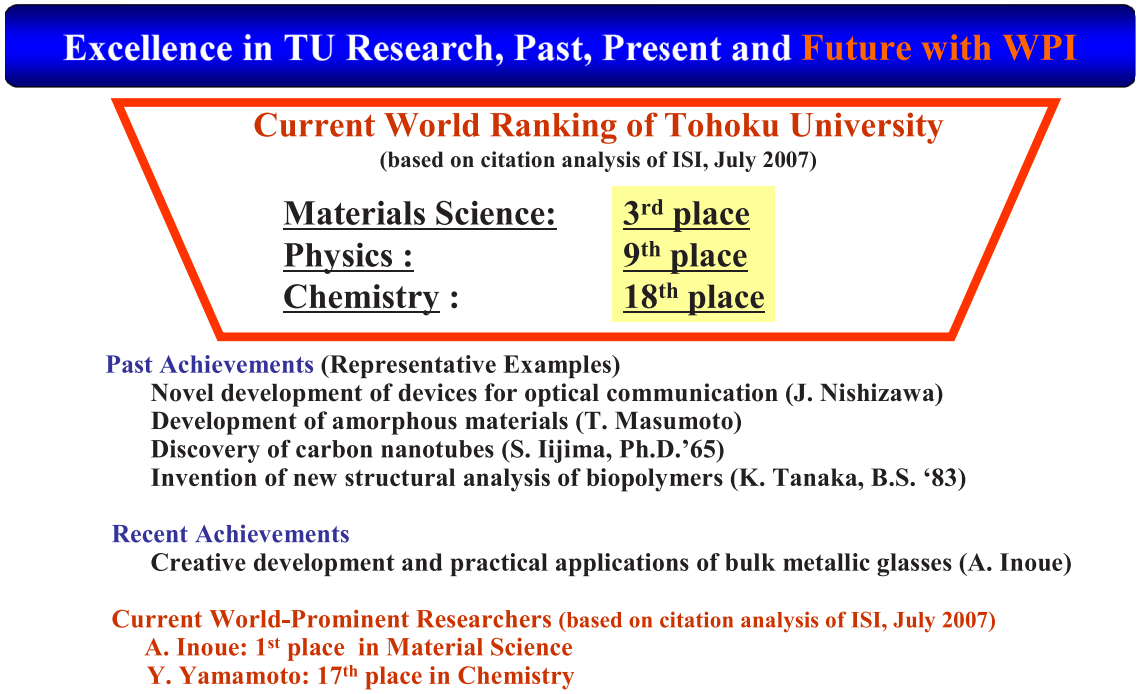


Fig. 3.

In WPI-AIMR, we try to enhance synergistic effects for highest research output by "fusion of each and every essential discipline. In the table below, invention of substances and materials, characterization, theory and simulation, device development, and system integration are shown vertically and horizontally, atom and molecule (that is to say, physics and chemistry), materials, and engineering are noted. All of the current 30 PIs are distributed coherently in this table based on their specialties and extended specialties. Through well-thought integration and fusion vertically and horizontally, we expect to excel in creating new materials and substances with innovative functions, developing new innovative device to system integration. "From atom and molecule to society through materials research" is a key in our WPI-AIMR.

How Can We Achieve the Objectives? Outline of Research Fields & Fusion

	Atom.Molecule (Phys, Chem)	Materials	Engineering
Invention of Substances & Materials	Inoue,Chen, Kawasaki,Tanigaki, Itaya,Nishi, Yamaguchi,Shimomura, Greer,Yavari	Inoue,Chen, Kawasaki,Tanigaki, Adschiri,Shimomura, Lagally,Hemker	Inoue, Kawasaki,Adschiri, Shimomura, Lagally,Hemker
Characterization	Takahashi,Yamada, Hashizume,Itaya,Nishi	Takahashi,Yamada, Hashizume,Ikuhara, Weiss,Xue	Itaya,Ikuhara, Weiss,Xue
Theory & Simulation	Tokuyama,Tsukada, Shluger	Tokuyama,Tsukada, Shluger,Wan	Shluger,Wan
Device Development	Xue,Tromp,Lagally, Hashizume	Miyazaki,Omi, Shimomura,Nakazawa, Tromp,Russell	Omi,Esashi, Nakazawa, Greer
System Integration	Tromp,Nishi, Esashi	Omi,Nakazawa, Gessner	Esashi,Omi, Gessner

Fig. 4.

Figure 5 illustrates what we expect as WPI-AIMR output through synergetic effects. We expect fused fundamental researches on physics, chemistry, materials, and engineering, and

A Synergetic Effect of the WPI, and Future Expected Outcomes

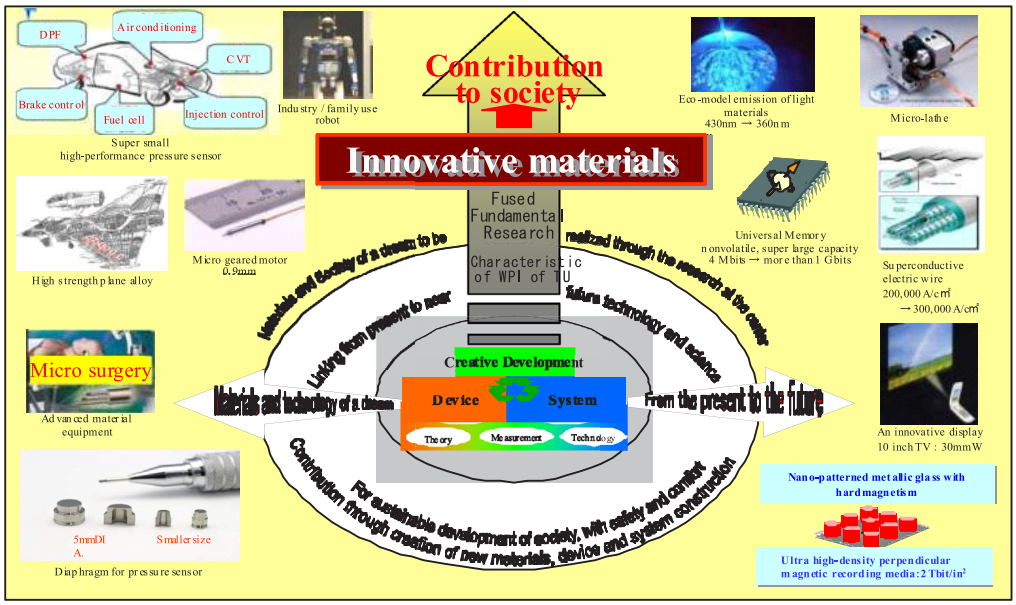


Fig. 5.

researches on material development, device, system, theory, characterization, and process technology should lead to creative development of innovative materials, which contribute very much to welfare of the mankind. For example, super small high-performance pressure sensor, micro geared motor, high strength plane alloy, advanced material equipment for micro surgery, diaphragm for pressure sensor, industry/family use robot, light materials for eco-model emission, micro-lathe, universal memory, superconductive electronic wire, an innovative display, nano-patterned metallic glass with hard magnetism, and ultra high-density perpendicular magnetic recording media are expected as outcomes from WPI-AIMR. This is just one example, and many important outcomes will evolve in the next 10 years under this program.

Successful implementation of "International Research Center" concept must be accompanied with well-coordinated overseas network. Tohoku University had a fortune to have had intensive global academic exchanges through its "research-first" policy. Figure 6 shows some of the Tohoku University's partners. The partners in North America are UC system, Harvard, MIT, Stanford, IBM, Penn State, University of Wisconsin. In addition, we have the US office of Tohoku University in California. In Europe, Cambridge, Oxford, Royal Institute of Technology in Stockholm, Lyon, ETH, are among our active partners. In Asia/Oceania, Seoul National, Tsinghua, KAIST, Sydney and others are our partners. We also have the China Office of Tohoku University in Beijing.
In the beginning of 2009, the total number of researchers and staff of WPI-AIMR will be approximately 200. Through the global networking and active cooperation the WPI-AIMR researcher groups encompass many regions of the world in the next 10 years.

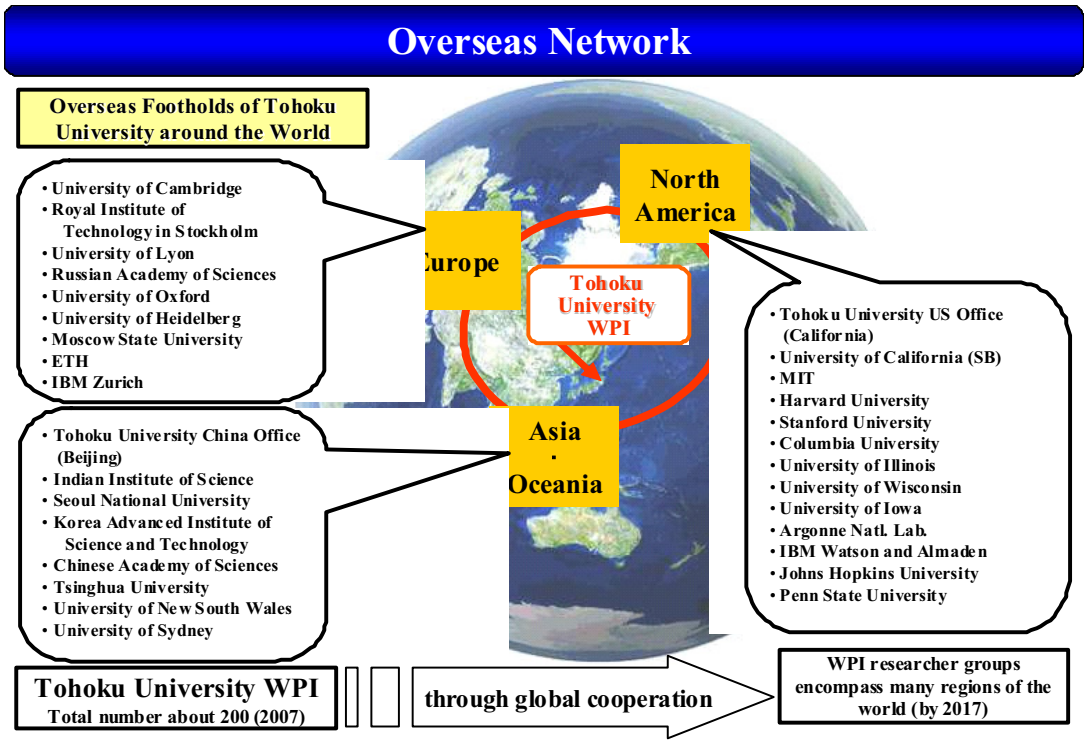
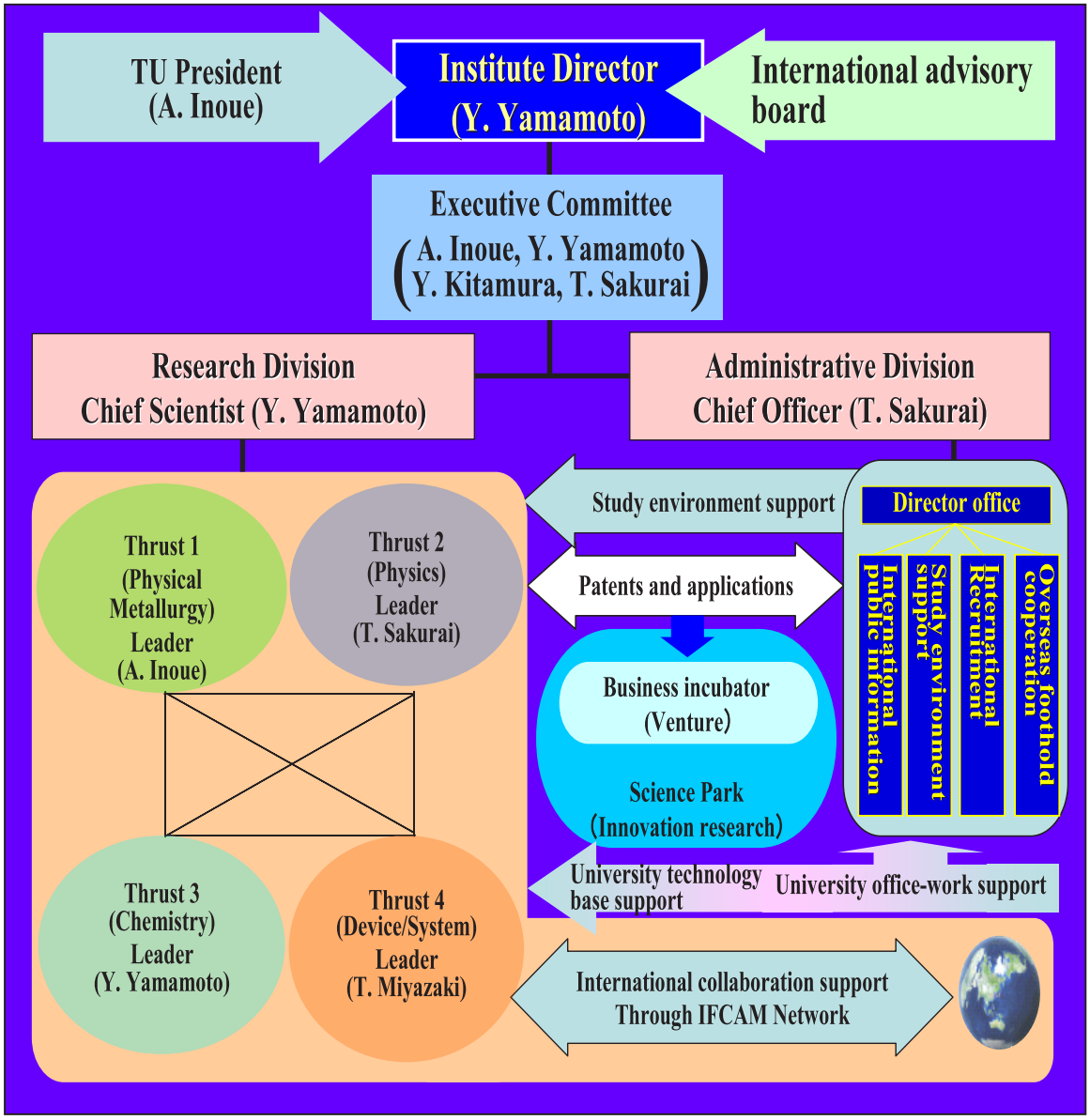


Fig. 6.

Organization

WPI-AIMR Organization Chart as of October 1, 2007



International advisory board members

Dr. Heinrich H. Rohrer, Chair (Tohoku University Honorary Doctor, 1986 Physics Nobel Laureate)

Professor Robert J. Birgeneau (Chancellor, University of California, Berkeley)

Professor Herbert Gleiter (Director, Institut für Nanotechnologie Forschungszentrum Karlsruhe)

Professor Bing-Lin Gu (President, Tsinghua University, Beijing)

Mr. Tadashi Onodera (President and Chairman, KDDI Corp.)

Professor Konrad Osterwalder (President, The UN University, Japan, and President, ETH Zurich)

Professor Robert J. Silbey (Dean, College of Science, MIT)

Personnel
Administration profile

Curriculum Vitae of University President

Akihisa INOUE

PRIMARY AFFILIATION:
President and University-Professor
Principal Investigator
Tohoku University
2-1-1, Katahira, Aoba-ku
Sendai, 980-8577 Japan
E-mail：akihisa@president.tohoku.ac.jp
URL：http://www.inoue.imr.tohoku.ac.jp/

ACADEMIC:

1970 B.S. Materials Science and Engineering, Himeji Institute of Technology, Himeji, Japan
1972 M.S. Materials Science and Engineering, Tohoku University, Sendai, Japan
1975 Dr. Materials Science and Engineering, Tohoku University, Sendai, Japan

ACADEMIC DEGREE: Doctor of Materials Science and Engineering, 1975

PROFESSIONAL EXPERIENCE:

1976-1985	Research Associate, Institute for Materials Research, Tohoku University
1985-1990	Associate Professor, Institute for Materials Research, Tohoku University
1990-2006	Professor, Institute for Materials Research, Tohoku University
2000-2006	Director, Institute for Materials Research, Tohoku University
2002-2006	Deputy President, Tohoku University
2006-present	President, Tohoku University

CURRENT RESEARCH:

The study of advanced nonequilibrium metallic materials with amorphous/glassy, quasicrystalline or nanocrystalline phase etc. exhibiting useful physical and chemical properties

RECOGNITION:

- ✦The Acta Metallurgica et Materialia Best Paper Award for 1992 (1994)
- ✦Citation Laureate Award (2000)
- ✦Japan Academy Prize (2002)
- ✦The Kelly Lecture - Cambridge University (2003)
- ✦The Swedish royal college of engineering honorary doctorate degree award (2005)
- ✦Membership of the Japan Academy (2006)
- ✦The Prime Minister Prize (2006)

Curriculum Vitae of Institute Director

Yoshinori YAMAMOTO

PRIMARY AFFILIATION:
Institute Director
WPI-AIMR
Tohoku University
2-1-1, Katahira, Aoba-ku
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E-mail：yoshi@mail.tains.tohoku.ac.jp
URL：http://hanyu.chem.tohoku.ac.jp/~web/lab/index.shtml

ACADEMIC:

1965 B.S. Faculty of Engineering Science, Osaka University
1967 M.S. Faculty of Engineering Science, Osaka University
1970 Ph. D Faculty of Engineering Science, Osaka University

ACADEMIC DEGREE: Ph. D. in Chemistry, 1970

PROFESSIONAL EXPERIENCE:

1970-1977	Assistant, Department of Chemistry, Faculty of Engineering Science, Osaka University
1970-1972	Postdoctoral Fellow, Department of Chemistry, Purdue University
1977-1985	Associate Professor, Department of Chemistry, Faculty of Science, Kyoto University
1986-2007	Professor, Department of Chemistry, Graduate School of Science, Tohoku University
2006-2007	Deputy President, Tohoku University
2007-present	Institute Director, WPI-AIMR

CURRENT RESEARCH:

The study of new synthetic methods with catalysts, and their application to the synthesis of biologically active compounds and of organo-materials

RECOGNITION:

✦The award of the Chemical Society of Japan (1996)
✦Alexander von Humboldt Research Award (2002)
✦Purple Ribbon Medal from the Cabinet, Japan Government (2006)
✦A. C. Cope Scholar Award, American Chemical Society (2007)

Curriculum Vitae of Administrative Director

Toshio SAKURAI

PRIMARY AFFILIATION:
Professor
Kotaro Honda Professor
Institute for Materials Research (IMR)
Advisor to the President
Tohoku University
2-1-1, Katahira, Aoba-ku
Sendai, 980-8577 Japan
E-mail：sakurai@imr.tohoku.ac.jp
URL：http://apfim.imr.tohoku.ac.jp/

ACADEMIC:

1967 B. S. Department of Applied Physics, The University of Tokyo
1979 M. S. Department of Applied Physics, The University of Tokyo
1974 Ph. D. in Physics, The Pennsylvania State University, PA, USA

ACADEMIC DEGREE: Ph. D. in Physics, 1974

PROFESSIONAL EXPERIENCE:

1974-1977	Limited-Term MTS (Member of Technical Staff) AT&T Bell Telephone Laboratories, Murray Hill, N. J. USA
1977-1981	Assistant Professor/Associate Professor, Department of Physics, The Pennsylvania State University, PA, USA
1981-1989	Associate Professor, Institute of Solid State Physics (ISSP), The University of Tokyo
1989-present	Professor, Institute for Materials Research (IMR), Tohoku University
2006-present	Advisor to the President, Tohoku University
2007-present	Head of International Frontier Center for Advanced Materials (IFCAM)

CURRENT RESEARCH:
Atomistic investigation of surfaces and interfaces of novel functional materials using scanning tunneling microscopy, atom-probe filed ion microscopy and low energy electron microscopy.

RECOGNITION:

- ✦Kumagaya Prize of Japan Vacuum Society (1987)
- ✦Materials Science Foundation Award (1991)
- ✦The Acta Metallurgica et Materialia Best Paper Award for 1992 (1994)
- ✦Best Paper Award of Japanese Institute of Metals (JIM), 1996, 2000

Principal Investigators profile

Curriculum Vitae

Tadafumi ADSCHIRI

PRIMARY AFFILIATION:
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Division of Advanced System
Institute of Multidisciplinary Research for Advanced Materials
Tohoku University
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Sendai, 980-8577, Japan
E-mail：ajiri@tagen.tohoku.ac.jp
URL：http://www.tagen.tohoku.ac.jp/labo/ajiri/index-e.html

ACADEMIC:

1981 B.S. in Chemical, The University of Tokyo, Tokyo, Japan
1983 M.S. in Chemical Engineering, The University of Tokyo, Tokyo, Japan
1986 Dr. Eng. in Chemical Engineering, The University of Tokyo, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1986

PROFESSIONAL EXPERIENCE:

1985-1987	JSPS Fellow, Department of Chemical Engineering, The University of Tokyo
1987-1989	Assistant professor, Department of Chemical Engineering, The University of Tokyo
1989-1991	Assistant professor, Department of Bio and Chemical Engineering, Tohoku University
1991-2001	Associate Professor, Department of Bio and Chemical Engineering, Tohoku University
2001-present	Professor, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University

CURRENT RESEARCH:

Adschiri lab has beginning-research programs spanning broad research areas from computer simulations to nanostuctured materials, magnetism, bioimaging, polymer and nanoparticle synthesis. Since its establishment in 2002, Adschiri lab is growing and focuses their research efforts on synthesis, characterization and studies of surface-modified inorganic nanoparticles, which are soluble into water and/or organic solvents, and peptide/polymer engineering for nanostructured hybrid materials by using the hybrid nanoparticles.

RECOGNITION:

- ✦The JIE Award for Distinguished Paper (1999)
- ✦ The CSJ Award for Creative Work (2002)
- ✦The SCEJ Award for Distinguished Research (2007)

Curriculum Vitae

Mingwei CHEN

PRIMARY AFFILIATION:
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International Frontier Center for Advanced Materials
Institute for Materials Research
Tohoku University
2-1-1, Katahira, Aoba-ku
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E-mail：mwchen@imr.tohoku.ac.jp
URL：http://www.chen.imr.tohoku.ac.jp/

ACADEMIC:

1988 B.S. in Engineering, China University of Mining and Technology, P. R. China
1991 M.S. in Engineering, Taiyuan University of Technology, P. R. China
1995 Dr. Eng. in Engineering, Shanghai Jiao Tong University, P. R. China

ACADEMIC DEGREE: Doctor of Engineering, 1995

PROFESSIONAL EXPERIENCE:

1995-1997	Associate Professor, Shanghai Jiao Tong University, China
1997-1999	Guest Research, Institute for Material Research, Tohoku University
1999-2000	NRC Fellow, Naval postgraduate School, California, USA
2000-2003	Research Associate / Associate Research Professor, Johns Hopkins University, USA
2003-present	Professor, IFCAM, Institute of Material Research, Tohoku University

CURRENT RESEARCH

1) Atomic-scale mechanisms of bulk metallic glass formation and mechanical behavior
2) Deformation and failure of nanostructured materials under extreme loading conditions
3) 3D nanoporous metals for functional applications

RECOGNITION:

- ✦Best Paper Award of Chinese Metal Heat Treatment Society (1994)
- ✦Best Paper Award of Chinese Mechanical Engineering Society (CMES) (1996)
- ✦National Research Council Associateship Award from the National Academy of Sciences(1999)
- ✦Best Paper Award of Japanese Institute of Metals (JIM) (2000)
- ✦Award of 25th U.S. Army Science Conference (2006)
- ✦Paul A. Siple Memorial Award for Army Research Achievements, U. S. Army (2006)
- ✦Best Reviewer Award of Scripta Materialia and Acta Materialia (2006)

Curriculum Vitae

Masayoshi ESASHI

PRIMARY AFFILIATION:
Professor
Micro/Nanomachining Research and Education Center
Graduate School of Engineering
Tohoku University
6-6-1, Aoba, Aramaki, Aoba-ku
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URL：http://www.mems.mech.tohoku.ac.jp/index_e.html

ACADEMIC:

1971 B.S. in Electronic Engineering, Tohoku University, Sendai, Japan
1973 M.S. in Electronic Engineering, Tohoku University, Sendai, Japan
1976 Dr. Eng. in Electronic Engineering, Tohoku University, Sendai, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1976

PROFESSIONAL EXPERIENCE:

1976-1981	Research Associate, Department of Electronic Engineering, Faculty of Engineering, Tohoku University
1981-1984	Associate Professor, Department of Electrical Communication, Faculty of Engineering, Tohoku University
1984-1990	Associate Professor, Department of Electronic Engineering, Faculty of Engineering, Tohoku University
1990-1997	Professor, Department of Mechatronics and Precision Engineering, Faculty of Engineering, Tohoku University
1997-1998	Professor, Department of Nanomechanics, Graduate School of Engineering, Tohoku University
1998-2004	Professor, New Industry Creation Hatchery Center (NICHe), Tohoku University
2004-2005	Professor, Department of Nanomechanics, Graduate School of Engineering, Tohoku University
2005-present	Professor, Micro/Nanomachining Research and Education Center, Graduate School of Engineering, Tohoku University

CURRENT RESEARCH:
Study of advanced materials for MEMS (Micro Electro Mechanical Systems)

RECOGNITION:

✦Japan IBM Science Award (1993)
✦SSDM Award (2001)
✦Best of Small Tech Awards (Small Times Magazine) (2003)
✦Purple Ribbon Award (2006)

Curriculum Vitae

Thomas GESSNER

PRIMARY AFFILIATION:
Professor
Director of Chemnitz Branch of
Fraunhofer Institute for Reliability and Microintegration (FhG-IZM)
Director of Center for Microtechnologies of
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ACADEMIC:

1979 M.S. in physics, University of Technology Dresden, Germany
1983 Ph. D in Physics, University of Technology Dresden, Germany
1989 Dr.-Ing.habil. in Microelectronics Technologies, University of Technology Karl-Marx-Stadt, Salicide technology for ULSI under special consideration of MoSix

ACADEMIC DEGREE: Ph.D (Device Science/Technology), 1983

PROFESSIONAL EXPERIENCE:

1979–1983	PhD/Scientific Co-worker, Central Institute of Nuclear Science at the Academy of Science, Rossendorf/Saxony, Germany
1983–1990	Leader, Center of Microelectronics Dresden ZMD
1991–present	Director and Founder, Center for Microtechnologies (ZfM) Dept. of Electrical Engineering and Information Technology, Chemnitz University of Technology,
1993–present	Professor, Dept. of Electrical Engineering and Information Technology, Chemnitz University of Technology,
1994–1997	Vice-chancellor, Chemnitz University of Technology
1995–2006	Head of the Collaborative Research Center 379
1998–2007	Head of the department "Multi Device Integration" Chemnitz at Fraunhofer Institute for Reliability and Microintegration (FhG-IZM)
2006–present	Deputy Director of the FhG-IZM and Director of Branch Chemnitz of FhG-IZM
2006–present	Dean of the Faculty, Electrical Engineering and Information Technology, Chemnitz University of Technology
2006–present	Head of the International Research Training Group 1215

RECOGNITION:

✦Winner of the Excellent Student Award (PhD) of the TU Dresden (1982)
✦Award for the application of new materials for micromechanical kinetic sensors, VDI Germany (1995)
✦Member of the Academy of Science in Saxony, Germany (1996-)
✦Member of the Scientific Advisory Board of the Federal Republic of Germany (1998-2004)
✦Award for the establishment of an interfaculty course in Microtechnology and Mechatronics from the VDI/VDE Germany (2000)
✦ Member of the "Senatsausschuss Evaluierung der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz"(2001-)
✦Member of acatech (Council of Technical Sciences of the Union of German Academies of Sciences and Humanities) (2003-)

Curriculum Vitae

Alan Lindsay GREER

PRIMARY AFFILIATION:
Professor
Department of Materials Science & Metallurgy
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CB2 3QZ, UK
E-mail: alg13@hermes.cam.ac.uk
URL: http://www.msm.cam.ac.uk/Department/DeptInfo/StaffProfiles/Greer.html

ACADEMIC DEGREE: Ph.D. (Metallurgy & Materials Science), 1979

PROFESSIONAL EXPERIENCE:

1980-1981	NATO Research Fellow in the Division of Applied Sciences, Harvard University, Cambridge, USA
1981-1984	Assistant Professor, Applied Physics, Division of Applied Sciences, Harvard University, Cambridge, USA
1984-1988	Senior Assistant Researcher, Department of Materials Science and Metallurgy, University of Cambridge, UK
1988-1996	University Lecturer, Department of Materials Science & Metallurgy, University of Cambridge, UK
1994-1994	Invited Professor at the Institut National Polytechnique de Grenoble, and Visiting Scientist at the Centre d'Études Nucléaires de Grenoble.
1996-2001	Reader in Microstructural Kinetics, University of Cambridge
2001-2005	Deputy Head of Dept. of Materials Sci. & Metallurgy, Univ. of Cambridge
2005-2005	Clark Harrison Distinguished Visiting Professor of Physics, Center for Materials Innovation, Washington University, USA
2001-present	Professor, Materials Science, University of Cambridge
2006-present	Head of Department of Materials Science & Metallurgy, University of Cambridge

CURRENT RESEARCH:
General interests are in microstructural kinetics and the glassy state. Current research projects are on: nucleation in condensed systems, modeling of grain refinement in aluminum alloys, electromigration effects on metallic interdiffusion, chalcogenide phase-change materials for computer memory, production and mechanical properties of bulk metallic glasses. This last topic relates directly to the WPI, and has included work on the mechanisms of plastic deformation and on strategies for improving the plasticity of metallic glasses.

RECOGNITION:
- ✦IBM Faculty Development Award (1983)
- ✦W. H. Zachariasen Award of the Journal of Non-Crystalline Solids (1989)
- ✦Light Metals Award of TMS (USA) (1998)
- ✦Cast Shop Technology Award of TMS (USA) (1999)
- ✦Cook-Ablett Award of the Institute of Materials (UK) (2000)
- ✦Pilkington Teaching Prize of the University of Cambridge (2000)
- ✦Senior Scientist Medal of the International Symposium on Metastable, Mechanically Alloyed and Nanocrystalline Materials (2000)
- ✦Honda Kotaro Medal of Tohoku University, Sendai, Japan (2004)
- ✦Hume Rothery Prize of the Institute of Materials, Minerals and Mining (UK) (2006)

Curriculum Vitae

Tomihiro HASHIZUME

PRIMARY AFFILIATION:
Senior Research Scientist &
Deputy Laboratory Manager,
Bio and Measurement Systems Laboratory,
Advanced Research Laboratory, Hitachi,
Ltd. Hatoyama, Saitama 350-0395, Japan
E-mail：tomihiro.hashizume.qb@hitachi.com
URL：http://www.wpi-aimr.tohoku.ac.jp/en/jobopp02.html

ACADEMIC:

1981 B. S. in Applied Physics, The University of Tokyo, Japan
1983 M. S. in Applied Physics, The University of Tokyo, Japan
1986 Ph. D. in Applied Physics, The University of Tokyo, Japan

ACADEMIC DEGREE: Ph. D. in Applied Physics, 1986

PROFESSIONAL EXPERIENCE:

1986-1987	Postdoctoral Member of Technical Staff AT&T Bell Laboratories.
1987-1989	Research Associate, The Institute for Solid State Physics, The University of Tokyo.
1989-1994	Associate Professor, Institute for Materials Research, Tohoku University.
1994-1996	Senior Contract Research Scientist, Advanced Research Laboratory, Hitachi, Ltd.
1996-present	Senior Research Scientist, Advanced Research Laboratory, Hitachi, Ltd.
2005-present	Liaison Professor, Department of Physics, Tokyo Institute of Technology.

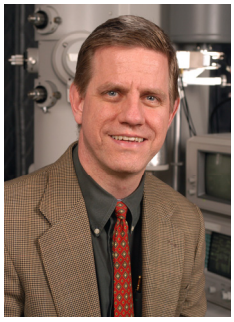
CURRENT RESEARCH: Interfaces of materials have been attracting great attention due to their appealing physical and industrial properties. In order to understand these fascinating interfaces in an atomic scale, we explore new interface physics at the organic/inorganic interfaces and oxide heterostructures, such as ferromagnetism, superconductivity, and charge transfer, by utilizing scanning probe microscopy (SPM), atom probe, and other advanced nanomeasurement techniques.

RECOGNITION:

✦Kumagaya Award for the Best Annual Vacuum Science Paper(1987)
✦Inoue Award for Young Scientists(1988)
✦Scientific Measurement Award(1992)
✦Metallic Materials Science Award(1992)
✦Harada Award for Young Scientists(1992)

Curriculum Vitae

Kevin J. HEMKER



PRIMARY AFFILIATION:
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Mechanical Engineering
Materials Science and Engineering
Johns Hopkins University
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ACADEMIC:

1985 B.S. in Metallurgical Engineering, University of Cincinnati, USA
1987 M.S. in Materials Science and Engineering, Stanford University, USA
1990 Ph. D. in Materials Science and Engineering, Stanford University, USA

ACADEMIC DEGREE: Ph. D. Materials Science and Engineering, 1990

PROFESSIONAL EXPERIENCE:

1985-1990	Research Assistant, Materials Science and Engineering, Stanford University, USA
1990-1993	Postdoctoral Fellow, Ecole Polytechnique Fédérale Lausanne, Switzerland
1990-2007	Assistant Professor of Mechanical Engineering, Whiting School of Engineering, Johns Hopkins University (JHU), USA
1993-present	Secondary Appointment, Department of Materials Science and Engineering, Whiting School of Engineering, JHU
1995	Invited Professor, Ecole Polytechnique Fédérale Lausanne, Switzerland
1997-2001	Associate Professor of Mechanical Engineering, Whiting School of Engineering, JHU, USA
1993-present	Co-director, Johns Hopkins University Electron Microscopy Facility, USA
1998-present	Joint Appointment, Department of Earth and Planetary Sciences, Krieger School of Arts and Sciences, JHU, USA
2000	Invited Professor, Université Paris Nord, Institut Galilée, Paris, France
2001-present	Professor of Mechanical Engineering, Whiting School of Engineering, JHU, USA
2001-present	Chair, Mechanical Engineering Program, Part-time Engineering, JHU, USA

RECOGNITION:

- ✦National Young Investigator, National Science Foundation, Division of Materials Research, Metals Research Program (1994).
- ✦Research Initiation Award, National Science Foundation, Directorate for Engineering, Mechanics and Materials Program (1994).
- ✦Materials Science Research Silver Medal, American Society of Materials (ASM) (2001).

Curriculum Vitae

Yuichi IKUHARA

PRIMARY AFFILIATION:
Professor
Institute of Engineering Innovation
School of Engineering
The University of Tokyo
2-11-16 Yayoi, Bunkyo-ku,
Tokyo 113-8656, Japan
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ACADEMIC:

1983 B. S. in Metallurgy, Kyushu University, Fukuoka, Japan
1985 M. S. in Materials Science, Kyushu University, Fukuoka, Japan
1988 Dr. Eng. in Materials Science, Kyushu University, Fukuoka, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1988

PROFESSIONAL EXPERIENCE:

1988-1993	Japan Fine Ceramics Center (JFCC)
1993-1996	Division Manager, Microstructure Characterization Division, JFCC
1996-2003	Associate Professor, Materials Sciences, The University of Tokyo
2003-present	Director and Professor, Institute of Engineering Innovation, The University of Tokyo

CURRENT RESEARCH:

(1)Atomic structure characterizations by advanced STEM and HREM
(2)Interface structures and properties for ceramics, semiconductor and metal.
(3)Design of interface controlled device

RECOGNITION:

✦Honda Silver Award, Honda Memorial Foundation (1990)
✦Murakami Promotion Award, Murakami Memorial Foundation (1998)
✦Society promotion award, Japanese Society of Materials (1998)
✦The Academic Prize, Ceramics Society of Japan (2001)
✦The Exploits Award, Japan Institute of Metals (2001)
✦Fulrath Award, American Ceramics Society (2002)
✦The Testimonial Prize, Japan Institute of Metals (2006)
✦The Academic Prize (Seto Award), Japanese Microscopy Society (2007)

Curriculum Vitae

Kingo ITAYA

PRIMARY AFFILIATION:
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Department of Applied Chemistry
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6-6-04 Aoba, Aramaki, Aoba-ku
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ACADEMIC:

1972 B. S. in Engineering, Tohoku University, Sendai, Japan
1974 M. S. in Engineering, Tohoku University, Sendai, Japan
1977 Dr.Eng. in Engineering, Tohoku University, Sendai, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1977

PROFESSIONAL EXPERIENCE:

1977-1979	Post-doctorial researcher at University of Texas at Austin
1979-1982	Research Assistant at Institute of Electric Communication in Tohoku University
1982-1984	Research Assistant at Faculty of Engineering, Tohoku University
1984-1991	Associate Professor at Faculty of Engineering, Tohoku University
1991-present	Professor at Faculty of Engineering, Tohoku University
1992-1997	Research Director of “Itaya-Solid/Liquid Interface” of ERATO Project/JST
2002-2008	Research Director of CREST/JST

RECOGNITION:

✦Honorary Professor of Chinese Academy of Science (Chemical Institute)
✦The CSJ Award for Young Chemists (1983)
✦The CSJ Award for Creative Work (1993)
✦Nishina Memorial Prize (1996)
✦Medal with Purple Ribbon (2003)
✦The Chemical Society of Japan (CSJ) Award (2004)

Curriculum Vitae

Masashi KAWASAKI

PRIMARY AFFILIATION:
Professor
Superstructured Thin Film Chemistry
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URL：http://www.kawasaki.imr.tohoku.ac.jp/English/top.html

ACADEMIC:

1984 B. S. University of Tokyo, Tokyo, Japan
1986 M. S. University of Tokyo, Tokyo, Japan
1989 Dr. Eng. University of Tokyo, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1989

PROFESSIONAL EXPERIENCE:

1989-1989 JSPS Post Doc Fellow at Hitachi Central Research Center (Tokyo)
1989-1991 Post Doc Fellow, IBM Thomas J. Watson Research Center (New York, USA)
1991-1997 Research Associate, Tokyo Institute of Technology
1997-2001 Associate Professor, Tokyo Institute of Technology
2001-present Professor, Tohoku University

CURRENT RESEARCH: Exploration of novel physical properties and their functionalization as prototype devices in heterostructured oxide materials.

RECOGNITION:

- ✦The Best Paper Award, MRS-Japan (1989)
- ✦The JSPS Committee Award, JSPS 146 Committee (1996)
- ✦The Symposium Highlight Award, MRS (1997)
- ✦Science and Technology of Superconductivity Award (1997)
- ✦Marubun Young Investigator Award (2001)
- ✦The IBM Japan Science Prize (2005)
- ✦Marubun Prize (2006)
- ✦JSPS Prize (2007)
- ✦Yamazaki-Teiichi Prize (2007)

Curriculum Vitae

Max G. LAGALLY

PRIMARY AFFILIATION:
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Erwin W. Mueller Professor
Department of Materials Science and Engineering and Department of Physics
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URL : http://www.engr.wisc.edu/mse/faculty/lagally_max.html

ACADEMIC:

1963 B.S. in Physics, Pennsylvania State University, USA
1965 M.S. in Physics, University of Wisconsin-Madison, USA
1968 Ph.D. in Physics, University of Wisconsin-Madison, USA

ACADEMIC DEGREE: Ph.D. (Surface Science & Technology), 1968

PROFESSIONAL EXPERIENCE:

1982-1993 Director, Thin-Film Deposition and Applications Center, University of Wisconsin
1994-present Director, Interdisciplinary Research Group 1 (IRG1) of the NSF-sponsored Materials Research Science and Engineering Center (MRSEC)

RECOGNITION:

- ✦Fellow, American Physical Society (1980)
- ✦Gordon Godfrey Visiting Professor of Physics, University of New South Wales, Sydney, Australia
- ✦Medard W. Welch Award, American Vacuum Society (1991)
- ✦Humboldt Senior Research Fellowship, Forschungszentrum Jurich, Germany (summers 1992 and 1993)
- ✦David Adler Lectureship Award, American Physical Society (1994)
- ✦Fellow, American Vacuum Society (1994)
- ✦MRS Medal, Materials Research SocietySociety (1994)
- ✦Davisson-Germer Prize, American Physical Society (1995)
- ✦Named a Rohm & Haas Lecturer, University of North Carolina (1995)
- ✦Outstanding Science Alumnus Award, Pennsylvania State University (1996)
- ✦Fellowship in the American Association for the Advancement of Science (AAAS) (1999)
- ✦Member of the Deutsche Akademie der Naturforscher - Leopoldina (the German National Academy of Science) (1999)
- ✦Member of the National Academy of Engineering (2000)
- ✦Fellow, American Association for the Advancement of Science (AAAS) (2000)
- ✦Tibbetts Award, U.S. Small Business Association (2000)
- ✦Fellow, Institute of Physics, UK (2004)

Curriculum Vitae

Terunobu MIYAZAKI

PRIMARY AFFILIATION:
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WPI Advanced Institute for Materials Research
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ACADEMIC:

1967 B.S in Applied Physics, Graduate School of Engineering, Tohoku University, Sendai, Japan
1969 M.S. in Applied Physics, Graduate School of Engineering, Tohoku University, Sendai, Japan
1972 Dr. Eng. in Applied Physics, Graduate School of Engineering, Tohoku University, Sendai, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1972

PROFESSIONAL EXPERIENCE:

1972-1973	Research associate, Department of Applied Physics, Faculty of Engineering Tohoku University
1973-1975	Research associate, University of Regensburg
1975-1985	Research associate, Tohoku University
1985-1991	Associate Professor, Tohoku University
1991-2007	Professor, Tohoku University
2007-2007	Guest Professor, Tohoku University
2007-present	Professor, WPI-AIMR

CURRENT RESEARCH:

We are making various kinds of investigations in search of new and highly functionalized magnetic materials. Our mottos are "inorganic to organic", "macroscopic to microscopic", and "single function to multi-function". Followings are examples of specific themes. (1)Spin and transport in nanoscale magnetic materials. (2) Microfabrication process in hybrid magnetic materials and development of magnetic random access memory (MRAM). (3) The search for new and highly functionalized magnetic materials.

RECOGNITION:

- ✦MSJ Distinguished Paper Award. (1997)
- ✦MSJ Society Award (2003)
- ✦Yamazaki Prize.(2005)
- ✦Prizes for Science and Technology by Minister of Education, Culture, Sports, Science and Technology (2006)

Curriculum Vitae

Masataka NAKAZAWA

PRIMARY AFFILIATION:
Professor
Broadband Engineering Division
Research Institute of Electrical Communication
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ACADEMIC:

1975 B.S. in Electronics, Kanazawa University, Kanazawa, Japan
1977 M.S. in Physical Electronics, Tokyo Institute of Technology, Tokyo, Japan
1980 Dr. Eng. in Applied Electronics, Tokyo Institute of Technology, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1980

PROFESSIONAL EXPERIENCE:

1980-1984	Scientist, Ibaraki Electrical Communication Laboratory of Nippon Telephone and Telegraph (NTT)
1984-1985	Visiting Scientist, Optics and Quantum Electronics Group, Massachusetts Institute of Technology
1985-1989	Group Leader, Nonlinear Optical Transmission Group, NTT
1989-1999	NTT Fellow engaged in research on optical soliton and high-speed transmission, femtosecond pulse generation, and rare-earth doped optical fiber amplifiers and their applications
2001-present	Professor, Research Institute of Electrical Communication, Tohoku University Engaged in research on ultrahigh-speed and coherent optical transmission and lectures on electromagnetism (undergraduate course) and optical communications (graduate course)

RECOGNITION:

✦IEE Electronics Letters Premium Award, U.K. (1990)
✦IEEE Daniel E. Noble Award, U.S.A. (2002)
✦OSA R. W. Wood Prize, U.S.A. (2005)
✦Thomson Scientific Laureate (2006)
✦Member of Japan Society of Applied Physics
✦Member of Laser Society of Japan

Curriculum Vitae

Toshio NISHI

PRIMARY AFFILIATION:
Professor
Department of Organic and Polymeric Materials
Graduate School of Science and engineering
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URL：http://west.polymer.titech.ac.jp/

ACADEMIC:

1965 B.S. in Applied Physics, The University of Tokyo, Tokyo, Japan
1967 M.S. in Applied Physics, The University of Tokyo, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1972

PROFESSIONAL EXPERIENCE:

1967-1980	Member of Research Staff, Bridgestone Tire Corporation
1972-1975	Visiting Scientist, Bell Laboratories, N. J. USA
1980-2003	Lecturer, Associate Professor, Professor of The Department of Applied Physics, The University of Tokyo
1985	IBM Summer Faculty Fellow, USA
1986-1987	Bell Laboratories Consultant, USA
1993	Harold A. Morton Distinguished Visiting Professor of The University of Akron, Ohio, USA
2001-2006	Guest Professor of The University in the Air
2003-present	Emeritus Professor of The University of Tokyo
2003-present	Professor of The Department of Organic and Polymeric Materials, Tokyo Institute of Technology

CURRENT RESEARCH:

1) Nano-mechanical properties mapping of polymeric nano-materials by atomic force microscopy and related techniques. 2) Nanofishing of single polymer chains by atomic force microscopy. 3) 3D-visularization of polymer processing by 3D transmission electron microscopy

RECOGNITION:

✦The Award of the Society of Polymer Science, Japan (1991)
✦SPSJ Award for Outstanding Achievement in Polymer Science and Technology (2005)

Curriculum Vitae

Tadahiro OHMI

PRIMARY AFFILIATION:
Professor
Industry Creation Section
New Industry Creation Hatchery Center
Tohoku University
6-6-10 Aoba, Aramaki, Aoba-ku
Sendai 980-8579, Japan

ACADEMIC:

1961 B. S. in Electrical Engineering, Tokyo Institute of Technology, Tokyo, Japan
1963 M. S. in Electrical Engineering, Tokyo Institute of Technology, Tokyo, Japan
1966 Dr. Eng. in Electrical Engineering, Tokyo Institute of Technology, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1966

PROFESSIONAL EXPERIENCE:

1966-1972	Research Associate, Department of Electronics of Tokyo Institute of Technology
1972-1976	Research Associate, Research Institute of Electrical Communication, Tohoku University
1976-1984	Associate Professor, Research Institute of Electrical Communication, Tohoku University
1985-1998	Professor, Department of Electronics, Faculty of Engineering, Tohoku University
1998-2002	Professor, New Industry Creation Hatchery Center, Tohoku University
2002-present	Emeritus and guest Professor, New Industry Creation Hatchery Center, Tohoku University

CURRENT RESEARCH:

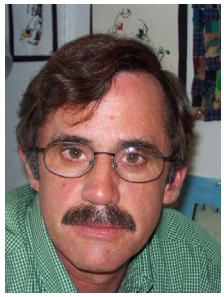
Contents of research are (1) Radical reaction gate insulator film formation, (2) Atomic order flat interface between the gate insulator film and silicon, (3) Formation of very low workfunction difference at the metal-silicide/silicon interfcace, (4) Balanced CMOS ultrahigh performance LSI on (551) SOI wafer, and (5) Circuit design using new MOS transistors on (551) SOI wafer.

RECOGNITION:

✦The Werner Kern Award (2001)
✦The ECS Electronics Division Award (2003)
✦Member of the Institute of Electrical and Electronics Engineers (2003)

Curriculum Vitae

Thomas P. RUSSELL



PRIMARY AFFILIATION:
Silvio O. Conte Distinguished Professor
Department of Polymer Science and Engineering
University of Masachusetts Amherst
Room A516, Conte Research Center
120 Governors Drive
Amherst, MA 01003, USA
E-mail：russell@mail.pse.umass.edu
URL：http://www.pse.umass.edu/~trussell/russellgroup.html

ACADEMIC:

1976 B. S. in Chemistry, Boston State College, USA
1976 M. S. in Polymer Science and Engineering, University of Massachusetts at Amherst
1979 Ph. D. in Polymer Science and Engineering, 1979, University of Massachusetts at Amherst, USA

ACADEMIC DEGREE: Ph.D. Polymer Science and Engineering, 1979

PROFESSIONAL EXPERIENCE:

1974-1979	Research Assistant, University of Massachusetts at Amherst
1979-1981	Research Fellow, Institut fuer Physikalische Chemie, Universitaet Mainz
1981-1996	Research Staff Member, IBM Almaden Research Center
1996-present	Professor, Polymer Science and Engineering, University of Massachusetts at Amherst
2004-present	Silvio O. Conte Distinguished Professor, Polymer Science and Engineering

CURRENT RESEARCH:

Research interests include the surface and interfacial properties of polymers, phase transitions in polymers, directed self-assembly processes, the use of polymers as scaffolds and templates for the generation of nanoscopic structures, the interfacial assembly of nanoparticles, hierarchical ordering of synthetic and biologically-based systems, wrinkling and crumpling of thin polymer films, and the influence of supercritical fluids on phase transitions and dynamics in polymer thin films.

RECOGNITION:

- ✦American Chemical Society, PMSE Division: Arthur K. Doolittle Award (1984 with J. T. Koberstein); Cooperative Research Award (2003, with C.J. Hawker)
- ✦Dutch Polymer Award (2004)
- ✦Polymer Physics Prize, Division of Polymer Physics, American Physical Society (2004)
- ✦Fellow: American Physical Society, American Association for the Advancement of Science, Neutron Scattering Society of America

Curriculum Vitae

Masatsugu SHIMOMURA

PRIMARY AFFILIATION:
Professor
Division of Materials Design
Institute of Multidisciplinary Research for Advanced Materials
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ACADEMIC:

1978 B. S. in Engineering, Kyushu University, Fukuoka, Japan
1980 M. S. in Engineering, Kyushu University, Fukuoka, Japan
1985 Dr. Eng. in Engineering, Kyushu University, Fukuoka, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1985

PROFESSIONAL EXPERIENCE:

1980-1985	Assistant Professor, Department of Organic Synthesis, Kyushu University
1985-1993	Associate Professor, Department of Industrial Chemistry, Tokyo University of Agriculture and Technology
1993-2001	Professor, Research Institute for Electronic Science, Hokkaido University
1999-present	Team Leader of Dissipative Hierarchic Structure Research Lab. of Frontier Research System of RIKEN Institute
2001-2007	Professor, Nanotechnology Research Center, Hokkaido University
2007-present	Professor emeritus of Hokkaido University
2007-present	Professor, Research Institute of Multidisciplinary Research for Advanced Materials, Tohoku University

CURRENT RESEARCH:

(a)Preparation and application of metallized honeycomb and pincushion polymer films prepared by self-organization.(b) Simple preparation of new polymer assemblies from nano-particles having hierarchical micro-phase separation structures.(c) Novel tissue culture devices for the regeneration medicine based on Honeycomb-patterned polymer films

RECOGNITION:

✦ The Chemical Society of Japan (CSJ) Award for Creative Work (2000)
✦Nano Tech International Nanotechnology Exhibition & Conference Award (2007)

Curriculum Vitae

Alexander SHLUGER

PRIMARY AFFILIATION:
Professor
Department of Physics and Astronomy and London Centre for Nanotechnology
University College London
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URL：http://www.cmmp.ucl.ac.uk/~ayg/group

ACADEMIC:

1976 B.S. Latvia State University, Riga, Latvia
1981 Ph.D. in Chemical Physics, L. Karpov Physics and Chemistry Research Institute, Moscow, USSR
1988 Dr. Sci. in Chemical Physics, L. Karpov Physics and Chemistry Research Institute, Moscow, USSR
1992 Dr. Habil, Latvia University, Riga, Latvia

ACADEMIC DEGREE: Ph.D. (Chemical Physics), 1981/Dr. Sci.(Chemical Physics), 1988/Dr. Habil., 1992

PROFESSIONAL EXPERIENCE:

1976-1988	Junior Research Associate, Senior Research Associate, Leading Research Associate, Chemical Faculty, Latvia State University, Riga
1988-1994	Head of the Department of Chemical Physics of Condensed Matter, Latvia State University, Riga
1994-1997	Professor, Director Institute of Chemical Physics, University of Latvia, Riga
1995-2002	Senior Research Fellow, Principal Research Fellow, Department of Physics and Astronomy, University College London, UK
2002-2004	Reader, Department of Physics and Astronomy University College London, UK
2004-present	Professor, Department of Physics and Astronomy, University College London, UK
2006-present	Head of Condensed Matter and Materials Physics, Department of Physics and Astronomy and London Centre for Nanotechnology, University College London, UK

CURRENT RESEARCH:

My main research interests broadly concern the mechanisms of defect processes in the bulk and at surfaces of **insulators**. I develop theoretical methods for predictive modeling of point defects, self-trapped **excitons** and **polarons** in insulating materials; created new models of self-trapped excitons and **point defects** and predicted their properties in a broad range of insulators; pioneered theoretical modeling of **Scanning Force Microscopy** imaging of insulating surfaces and developed the mechanisms of chemical resolution in Scanning Force Microscopy; developed the mechanisms of **photo-induced desorption** of insulating surfaces and selective photo-induced modification of insulating surfaces; developed new theoretical models of defects in **amorphous silica** and in **new high-k gate oxides** for micro-electronics applications. My current research is focused on predicting properties of defects and mechanisms of defect processes at semiconductor/oxide and metal/SAM **interfaces**, developing mechanisms of **manipulation** of atoms and molecules at insulating surfaces and thin films using Atomic Force Microscope tips and predicting **diffusion** and chemical properties of molecules and nanoclusters at surfaces.

RECOGNITION:

✦Member of the Steering Committee of NATRIBO European Science Foundation Scientific Programme

Curriculum Vitae

Takashi TAKAHASHI

PRIMARY AFFILIATION:
Professor
Department of Physics
Graduate School of Science
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ACADEMIC:

1974 B.S. in Physics, University of Tokyo, Tokyo, Japan
1979 M.S. in Chemical Physics, University of Tokyo, Tokyo, Japan
1982 Dr. Sci. in Solid-State Physics, University of Tokyo, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Science (Solid-State Physics) 1982

PROFESSIONAL EXPERIENCE:

1974-1977	Researcher, Hitachi Electric Co. Ltd.
1981-1994	Assistant Professor, Department of Physics, Tohoku University
1994-2001	Associate Professor, Department of Physics, Tohoku University
2001-present	Professor, Department of Physics, Graduate School of Science, Tohoku University

CURRENT RESEARCH:

High-resolution angle-resolved photoemission spectroscopy (ARPES) study of the electronic structure and mechanism of properties in novel functional materials

1. High-temperature superconductors and related materials
2. Graphite and related materials (graphene, carbon nanotubes, graphite intercalation compounds)
3. One-dimensional quantum metal wires and super thin metal films
4. Surface magnetism
5. Development of ultrahigh-resolution spin-resolved photoemission spectrometer

RECOGNITION:

✦ MEXT Science and Technology Award by Ministry of Education, Culture, Sports, Science and Technology of Japan (2005)

Curriculum Vitae

Katsumi TANIGAKI

PRIMARY AFFILIATION:
Professor
Department of Physics
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ACADEMIC:

1978 B.S. in Applied Chemistry, Yokohama National University, Japan
1980 M.S. in Applied Chemistry, Yokohama National University, Japan
1989 Dr. Eng. in Materials Engineering, Yokohama National University, Japan

ACADEMIC DEGREE: Doctor of Engineering, 1989

PROFESSIONAL EXPERIENCE:

1980-1989	Principal Researcher, Central Research Laboratories, NEC Corporation.
1989-1998	Research Leader of Molecular Electronics, Fundamental Research Laboratories, NEC Corporation
1998-2004	Professor, Department of Materials Science, Graduate of Science, Osaka-City University
2004-present	Professor, Department of Physics, Graduate of Science, Tohoku University

CURRENT RESEARCH:

Our research focuses on fabrication of novel materials that cannot be produced by the conventional nano fabrication technology, from which we can expect very intriguing physical properties and apply them to observe new scientific phenomena as well as to pursue the advanced electronic devices. We are currently developing exotic materials together with their single crystal and thin film fabrication techniques to explore an important research area to be spreading as the world-wide research in the future.

RECOGNITION:

✦The Osaka Prize (2000)

Curriculum Vitae

Michio TOKUYAMA

PRIMARY AFFILIATION:
Professor
Complex Flow Division
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Tohoku University
2-1-1, Katahira, Aoba-ku
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E-mail：tokuyama@fmail.ifs.tohoku.ac.jp
URL：http://www.ifs.tohoku.ac.jp/tokuyama-lab/

ACADEMIC:

1972 B.S. in Physics, Kyushu University, Fukuoka, Japan
1974 M.S. in Physics, Kyushu University, Fukuoka, Japan
1977 Dr. Sci. in Physics, Kyushu University, Fukuoka, Japan

ACADEMIC DEGREE: Doctor of Science, 1977

PROFESSIONAL EXPERIENCE:

1977-1980	Research Associate, M.I.T., Cambridge, USA
1980-1981	Research Associate, University Stuttgart, Germany, Stuttgart, Germany
1981-1982	Research Associate, Michigan State University, East Lansing, USA
1984-1990	Associate Professor, Department of Engineering, Tohwa University
1987-1988	Visiting Scholar, Stanford University, Palo Alto, USA
1990-2001	Professor, Department of Engineering, Tohwa University
1993-1994	Visiting Scientist, M.I.T., Cambridge, USA
2001-present	Professor, Institute of Fluid Science, Tohoku University

CURRENT RESEARCH:

In our Laboratory, the theoretical and simulation study of structure and dynamics in glass-forming liquids are made from a unified point of view recently obtained. The research covers a wide area of different fields from fragile glass-forming systems, including colloidal glasses and proteins, and metallic glasses to strong glass-forming systems.

Curriculum Vitae

Rudolf M. TROMP

PRIMARY AFFILIATION:
Senior Researcher
IBM Thomas J. Watson Research Center
1101 Kitchawan Road, Route 134,
Yorktown Heights, N.Y. 10598, USA
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URL：http://domino.research.ibm.com/comm/pr.nsf/pages/bio.rudolf_tromp.html

ACADEMIC:

1972 B. S. Gymnasium, Alkmaar, Netherlands
1976 M.S. in Physics Engineering, Twente University of Technology, Netherlands
Physics Engineer,
1982 Ph. D in Physics and Mathematics, FOM Institute for Atomic and Molecular Physics, Amsterdam Cum Laude, Utrecht, Netherlands

ACADEMIC DEGREE: Ph.D. (Surface Science & Technology), 1982

PROFESSIONAL EXPERIENCE:

1983-1987	Research Staff Member, IBM T.J. Watson Research Center
1987-1993	Manager Interface Science, IBM Watson Research Center
1996-2000	Manager Analytical Science, IBM Watson Research Center
2000-2001	Consultant, IBM Corporate Technical Strategy Development
2001-2002	Research Staff Member, IBM Watson Research Center
2002	IFCAM Professor Tohoku University, Sendai, Japan
2002-2004	Manager of Molecular Assemblies and Devices, IBM Watson Research Center
2004-present	Senior Manager of Nanoscale Materials and Devices, IBM Watson Research Center
2006-present	Professor of Physics, University of Leiden, Netherlands

RECOGNITION:

- ✦Wayne B. Nottingham Prize at P. E. C. (1981)
- ✦IBM Outstanding Innovation Award (1987)
- ✦IBM Outstanding Innovation Award (1991)
- ✦ IBM Outstanding Technical Achievement Award (1992)
- ✦Materials Research Society Medal (1995)
- ✦Davisson-Germer Prize of the American Physical Society (2003)
- ✦IBM Outstanding Technical Achievement Award (2003)
- ✦Medard W. Welch Award of the American Vacuum Society (2004)

Curriculum Vitae

Masaru TSUKADA

PRIMARY AFFILIATION:
Professor
Graduate School of Advanced Science and Engineering
Waseda University
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Tokyo 169-8555, JAPAN
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ACADEMIC:
1965 B.S. in Physics, University of Tokyo, Tokyo, Japan
1967 M.S. in Physics, University of Tokyo, Tokyo, Japan
1970 Dr. Sci. in Physics, University of Tokyo, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Science, 1970

PROFESSIONAL EXPERIENCE:

1970-1976	Research Associate at the Department of Physics, University of Tokyo
1976-1982	Associate Professor at Institute for Molecular Science
1982-1991	Associate Professor at the Department of Physics, University of Tokyo
1991-2004	Professor at the Department of Physics, University of Tokyo
2004-present	Visiting Professor at Waseda University, Graduate School of Science and Engineering

CURRENT RESEARCH:
Theoretical studies are pursued mainly with computational approaches on properties of nano-scale materials and their bridge structures with electrodes, such as atomic and electronic structures, formation processes, transport properties, combined photonic and electronic processes, and their nano-mechanical control. Novel theoretical or computational methods for the above are developed; appropriate computational methods or analytical methods for the nano-scale systems as non-equilibrium nonlinear open system over different scales are developed, and with use of such methods, novel nano-materials with useful functions are explored. Novel useful composite materials systems of organic molecules, including polymers and bio-molecules, and inorganic materials are explored and designed. Development of the methods of theoretical analyses for scanning probe microscopy (SPM), in particular the simulation methods for SPM are studied and applied for the proposals of innovating artificial nano-materials and their functionalization.

RECOGNITION:
✦Surface Science Society Award (1999)
✦Nanoprobe Technology Award (2000)
✦The Chair of the Surface Science Society of Japan (2002)

Curriculum Vitae

Li-Jun WAN

PRIMARY AFFILIATION:
Professor, Director
Institute of Chemistry
Chinese Academy of Science (CAS)
Beijing 100080, P.R. China
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ACADEMIC:

1982 B.E. in Materials Science, Dept. of Materials Science and Engineering, Dalian University of Technology, P. R. China
1987 M.S. in Materials Science, Dept. of Materials Science and Engineering, Dalian University of Technology, P. R. China
1996 Dr. Eng. in Materials Chemistry, Dept. of Applied Chemistry, Faculty Engineering, Tohoku University, Japan

ACADEMIC DEGREE: Ph. D. (Materials Chemistry), 1996

PROFESSIONAL EXPERIENCE:

1987-1992	Lecturer in Institute of Materials and Technology, Dalian Maritime University, Dalian, P.R. China
1996-1997	Researcher in Itaya Electromicroscopy Project, ERATO/JST, Japan
1997-1998	Visiting Professor in Catalysis Research Center, Hokkaido University, Sapporo, Japan
1998-2000	Assistant Professor, Tohoku University, Sendai, Japan
1999-present	Professor, Institute of Chemistry, Chinese Academy of Sciences, Beijing, China
2004-present	Director Institute of Chemistry, CAS, Beijing, China
2005-present	Director, Beijing National Laboratory for Molecular Sciences, Beijing, China

CURRENT RESEARCH:
Molecular Self-Assembly and Devices, Scanning Probe Microscopy, Materials Chemistry, Electrochemistry

RECOGNITION:

✦Fellow of the Royal Society of Chemistry (2007)
✦2nd –class Award of National Natural Science of China (2007)
✦1st –class Award of Natural Science of Beijing (2005)
✦1st –class Award of China Association of Instrumentation and Analysis (2003)
✦Young Knowledge Innovation Prize of Chinese Chemical Society-BASF (2001-2002)

Curriculum Vitae

Paul S. WEISS

PRIMARY AFFILIATION:
Distinguished Professor
Departments of Chemistry and Physics
The Pennsylvania State University
University Park, PA 16802-6300, USA
E-mail：stm@psu.edu
URL：http://www.nano.psu.edu/

ACADEMIC:

1980 S.B. and S.M. in Chemistry, Massachusetts Institute of Technology, USA
1986 Ph.D. in Chemistry, University of California, Berkeley, USA

ACADEMIC DEGREE: Ph.D. (Chemistry), 1986

PROFESSIONAL EXPERIENCE:

1986-1988	Post-Doctoral Member of Technical Staff, AT&T Bell Laboratories, USA
1988-1989	Visiting Scientist, IBM Almaden Research Center, USA
1989-present	Assistant through Distinguished Professor, Pennsylvania State University, USA
2005-present	Distinguished Professor of Chemistry and Physics, and Nanofabrication Fellow, Pennsylvania State University, USA
1996-1997	Visiting Professor of Molecular Biotechnology, University of Washington, USA
1998	Visiting Professor, Venture Business Laboratory, Kyoto University

CURRENT RESEARCH:

Atomic-scale chemical, physical, optical, mechanical and electronic properties of molecules, materials and supramolecular assemblies
Develop and apply new techniques to expand the functionality, applicability and chemical specificity of scanning probe microscopies
Molecular and nano-scale devices
Advance nanofabrication down to ever smaller scales and greater chemical specificity.

RECOGNITION:

- ✦National Science Foundation Presidential Young Investigator (1991-1996)
- ✦B. F. Goodrich Collegiate Inventors Award (1994)
- ✦Alfred P. Sloan Foundation Fellowship (1995-1997)
- ✦American Chemical Society Nobel Laureate Signature Award for Graduate Education in Chemistry (1996)
- ✦John Simon Guggenheim Memorial Foundation Fellowship (1997-1998)
- ✦American Association for the Advancement of Science, Elected Fellow (2000)
- ✦American Physical Society, Elected Fellow (2002)
- ✦Pennsylvania State University, Named Nanofabrication Fellow (2005)
- ✦Pennsylvania State University, Named Distinguished Professor of Chemistry and Physics (2005)
- ✦University of Pittsburgh, Levine Lecturer (2007)
- ✦American Vacuum Society, Elected Fellow (2007)

Curriculum Vitae

Qi-Kun XUE

PRIMARY AFFILIATION:
Member of The Chinese Academy of Sciences
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URL：http://surface.iphy.ac.cn/english/sf4E/introduction.htm

ACADEMIC:

1984 B.S. in Science, Optics Department, Shandong University, P. R. China
1990 M.S. in Physics, Institute of Physics, Chinese Academy of Sciences (CAS), P. R. China
1994 Ph. D. in Physics, Institute of Physics, Chinese Academy of Sciences (CAS), P. R. China

ACADEMIC DEGREE: Ph. D. in Physics, 1994

PROFESSIONAL EXPERIENCE:

1992-1994	Visiting Scientist, Institute for Materials Research (IMR), Tohoku University, Japan
1994-1999	Assistant Professor, Institute for Materials Research (IMR), Tohoku University, Japan
1996-1997	Visiting Assistant Professor, Physics Department, North Carolina State University, USA
1999-2005	Director of State Key Laboratory for Surface Physics, CAS, P. R. China
1999-2007	Professor, State Key Laboratory for Surface Physics, Institute of Physics, CAS, P. R. China
2005-present	Distinguished Professor, Department of Physics, Tsinghua University, P. R. China

CURRENT RESEARCH:

(1) Low temperature scanning tunneling microcopy and spin-polarized scanning tunneling microcopy
(2) Atomic-scale study of growth/fabrication and quantum effects of low-dimensional nano-structures (metal nano-dots/clusters, nanowires and ultra thin films)
(3) Spin-polarized electron transport for quantum computation/information and spintronics

RECOGNITION:

✦President Prize for Excellent PhD Students, Chinese Academy of Sciences (1994)
✦Member of The Chinese Academy of Sciences (2005-present)
✦ The 2nd-Class Award for Advancements in Science and Technology of China (2004)

Curriculum Vitae

Kazuyoshi YAMADA

PRIMARY AFFILIATION:
Professor
Neutron and γ-Ray Spectroscopy on Condensed Matters
Institute for Materials Research
Tohoku University
2-1-1, Katahira, Aoba-ku
Sendai, 980-8577 Japan
E-mail：kyamada@imr.tohoku.ac.jp
URL：http://www.yamada-lab.imr.tohoku.ac.jp/

ACADEMIC:

1972 B.S. Graduate School of Science, Tohoku University, Sendai, Japan
1974 M.S. in Faculty of Science, Tohoku University, Sendai, Japan
1978 Dr. Sci. in Faculty of Science, Tohoku University, Sendai, Japan

ACADEMIC DEGREE: Doctor of Science, 1978

PROFESSIONAL EXPERIENCE:

1979–1980	Post Doctoral, Japan Society for the Promotion of Science
1980–1994	Research Associate, Graduate School of Science and Faculty of Science, Tohoku University
1994–1998	Assistant Professor, Graduate School of Science and Faculty of Science, Tohoku University
1998–2003	Professor, Institute for Chemical Research, Kyoto University
2003-present	Professor, Institute for Materials Research, Tohoku University

CURRENT RESEARCH:

The microscopically study exotic physical phenomena such as superconductivity in strongly correlated electron systems by using neutron-scattering and other related techniques, and development neutron scattering techniques by using spectrometers installed in the research reactor JRR-3 in Tokai.

Curriculum Vitae

Masahiko YAMAGUCHI

PRIMARY AFFILIATION:
Professor
Department of Organic Chemistry
Graduate School of Pharmaceutical Sciences
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URL：http://www.pharm.tohoku.ac.jp/~sekkei/yakan-ehome.html

ACADEMIC:

1977 B. S. Department of Chemistry, University of Tokyo, Tokyo, Japan
1979 M. S. Department of Chemistry, University of Tokyo, Tokyo, Japan
1982 Dr. Sci. Department of Chemistry, University of Tokyo, Tokyo, Japan

ACADEMIC DEGREE: Doctor of Science, 1982

PROFESSIONAL EXPERIENCE:

1982-1991	Assistant & Associate Professor, Kyushu Institute of Technology
1987-1988	Fellow of Ministry of Education, Culture, Sports, Science, and Technology, Yale University, USA
1991-1997	Associate Professor, Department of Chemistry, Tohoku University
1997-present	Professor, Graduate School of Pharmaceutical Sciences, Tohoku University

CURRENT RESEARCH:

The research of this group is directed to the development of materials containing organic and biological nanomolecules, which respond to the external stimuli such as temperature, light, electric field, magnetic field, ions, oxidation/reduction, catalyst, and others. This research will be conducted based on high potential of organic synthesis including multistep synthesis, synthetic methodology, catalysis, chemical reaction process, and chemical modification of biological polymers.

RECOGNITION:

✦ Chemical Society of Japan Award for Young Chemists (1987)

Curriculum Vitae

Alain Reza YAVARI

PRIMARY AFFILIATION:
Professor
Grenoble Institute of Technology
1130 rue de la Piscine,
BP 75, Domaine Universitaire, 38402
Saint-Martin-d'Hères, France
E-mail：yavari@ltpcm.inpg.fr
URL：http://bmg-rtn.inpg.fr/participants/grenoble.html

ACADEMIC:

1967 American College, Paris, France
1970 B. S. in Chemical Engineering, Massachusetts Institute of Technology (MIT), USA
1980 Ph.D. in Applied Physics, Harvard University, USA
1987 Habilitation Diploma, INP de Grenoble, France

ACADEMIC DEGREE: Ph.D. (Physical Metallurgy), 1980

PROFESSIONAL EXPERIENCE:

1980	Research Associate, Harvard University (with Pr David Turnbull)
1980-1981	Assistant Professor, Institut National Polytech Grenoble (INPG)
1982-89	Chargé de Recherche CNRS (Assistant Research Professor)
1986	Visiting Professor, Kyoto University
1990-	Directeur de Recherche CNRS (Research Professor)
1993	Senior Scientist, AlliedSignal, Corporate Headquarters, N.J., USA
1995-1996	Honorary Professor, University of Complutense, Madrid, Spain
2000	Invited Professor, Tohoku University, Sendai Japan
1990-2001	Director of Research, CNRS

・Head of Euronano:"Matériaux Nanocristallins et Métastables"
・Coordinator of the EU Research Network «H-Sorption in Nano-Mg Composites»
・Coordinator of the EU Research Network «Ductile BMG Composites»
・Senior Guest Scientist, European Synchrotron Radiation Facilities (ESRF)

RECOGNITION:

✦ISMANAM Gold Medal (1996)
✦NEDO international grant (1997)
✦1st Betancourt-Perronet Prize of the French and Spanish Academies of Sciences (1997)
✦International Copper Association ICA 2006 Award (2006)

Inauguration Ceremony

(Nov. 15 & 16, 2007)

Inauguration Ceremony

(November 15 and 16, 2007)

Program

----------[November 15, 2007]----------

I. Inauguration Ceremony (Katahira Sakura Hall 1F) 12:00 noon~

Opening Remarks:	**Yoshinori YAMAMOTO** (Director of WPI-AIMR)
Presidential Remarks:	**Akihisa INOUE** (President of Tohoku University)
Congratulatory Remarks:	**Yasutaka MORIGUCHI** (Director of Science and Technology, MEXT)
	Hiroyuki YOSHIKAWA (President of Advanced Industrial Science and Technology)
	Hiroyuki ABE (Former President of Tohoku University, Advisor of Japan Science and Technology Agency)
Luncheon/Mixer	

II. Technical Sessions (Katahira Sakura Hall 2F) 14:00~

2:00 pm ~ 2:30 pm	**Yoshinori YAMAMOTO**: Overview of the WPI-AIMR
2:30 pm ~ 3:00 pm	**Minwei CHEN**: Bulk metallic glasses
3:00 pm ~ 3:30 pm	**Paul S. WEISS**: Chemistry of surface science
3:30 pm ~ 4:00 pm	**Rudolf M. TROMP**: Physics of nano-science/technology
4:00 pm ~ 4:30 pm	**Toshio NISHI**: Polymer science

III. Reception & Dinner (Sendai Kokusai Hotel) 17:00~

Reception/Cocktails	
Congratulatory Remarks:	**Takashi YOSHIMOTO** (Former President of Tohoku University)
Nobel Laureate Remarks:	**Heinrich ROHRER** (1986 Physics Nobel Laureate, Chair of International Advisory Board, WPI-AIMR)
Dinner	
Closing Remarks	**Yoshinori YAMAMOTO** (Director of WPI-AIMR)

----------[November 16, 2007]----------

I. Technical Sessions (IMR Lecture Hall etc.) 9:00 ~ 13:00

II. Technical Sessions (IMR Lecture Hall) 14:00 ~16:00

Opening Remarks

Yoshinori YAMAMOTO
Director of WPI-AIMR

Good afternoon everybody. I am Yoshinori Yamamoto, Director of the WPI-Advanced Institute for Materials Research. I would like to extend our hearty welcome to all of you. Thank you very much for your participation. Before introducing President of Tohoku University to deliver the presidential remarks and the distinguished guests to deliver the congratulatory remarks, I would like to say a few words on this happy occasion of Tohoku University WPI Inauguration Ceremony.

First, I deeply appreciate all of you, distinguished guests, foreign guests, professors, researchers, our friends, and ladies and gentlemen, for coming here to attend this Inauguration Ceremony. Secondly, I would like to note that the MEXT conceived this WPI program, that is also called "Top 5 program," a few years ago. We submitted our WPI program last May when it was announced in late April to establish the WPI Research Center for Atom-Molecule-Materials. After many, many screening and very strenuous interview in English on August 30 and 31, we were fortunate to be chosen among five successful projects.

This success was largely due to the past and present scientific achievements of Tohoku University and of course, due to the very high reputation and high scientific achievements of all principal investigators. The success was also due to the very strong support of the president office of Tohoku University and those of the other administrative offices. I would like to thank all of them. Then third thing and last, I would like to say is the followings. Our final goal of this WPI is to establish really a top research center in the world on materials science. And also to produce and to provide innovative and very useful materials to the society which contribute very much to the welfare of mankind.

To make these final goals attainable, I need your continuous support, strong encouragement, and advices. By those strong supports, we will do, and we have to do our best to reach this final goal. Thank you very much.

Presidential Speech

Akihisa INOUE
President of The University & WPI-AIMR Principal Investigator

Nobel laureate Dr. Rohrer, Tohoku University Presidents Abe and Yoshimoto, Distinguished guests, and Ladies and Gentlemen, I would like to welcome all of you to this exciting ceremony.

As President of Tohoku University as well as one of the 30 principal investigators of the newly established WPI research center, I would like to express my sincere appreciation to all of you, some coming all the way from Europe and the USA, for attending the Inauguration Ceremony of Tohoku University's WPI-Research Center: Advanced Institute for Materials Research (WPI-AIMR).

All of us at Tohoku University are extremely happy to be selected by the Japanese Government as one of only five institutions to establish a World-premier-international research center (WPI) over the next 10 to 15 years. We officially started on October 1, 2007 with governmental support of close to a half billion US dollars.

We happily note that this year is our 100th anniversary. When I assumed the presidency last November, I set out the "Inoue Plan 2007" to highlight our goals to firmly establish a 21st century premier-research university.
I coordinated a university-wide effort in order to submit Tohoku University's proposal to establish a synergistic research center by excelling further in materials science, physics, chemistry, mechanical engineering, microelectronics and information science and fusing all these excellent disciplines together.
The government WPI Initiatives clearly state that, with favorable and concentrated funding, we are expected to establish a world-premier international research center which should benefit mankind of the entire world, by innovative research, global human-networking and a creative governing system.

Tohoku University was founded in 1907 as the 3rd National University, following Tokyo and Kyoto. Our university is well-known for three major Innovative Concepts from its earlier days: While Tokyo and Kyoto Universities were initially formulated to produce elite bureaucrats to run the central government.

Tohoku University's aim was research-first (研究第一) from the beginning, rather than importing established knowledge from abroad.
Professor Kotaro Honda, founder of IMR, and the University President, introduced a pioneering policy: basic-research for practical applications (実学主義), namely *Science for the benefit of mankind*, rather than an "Ivory Tower" or "White Elephant" mentality.
An open door policy (門戸開放)for everyone qualified is really unique, but well-publicized by now, admitting a female undergraduate in 1916 for the first time in Japan as well as those from technical schools in 1917.
These unique and innovative concepts are now the perfect base for WPI and our university stands well ahead amongst many national universities, as the Government is telling all academic institutions to do the same.

Upon its approval of our proposal, we named our WPI center the "Advanced Institute for Materials Research (WPI-AIMR)." This Research Institute is headed by Professor Yoshi Yamamoto, a world-renown chemist and Professor Toshi Sakurai, a physicist and my long-time collaborator. 30 principal investigators have been appointed initially, 15 of them are active Tohoku University researchers, four are from other domestic groups and eleven are from abroad, UK, France, Germany, USA and People's Republic of China.

I would also like to note that our administration is very slim. All important decisions will be made by the Executive Committee consisting of Professor Yamamoto, Professor Sakurai, my Chief-of-staff Professor Kitamura and myself.
All PIs are expected to work 120% in research without teaching or administrative burdens.
We are very fortunate to be supported by a seven-member International Advisory Board, chaired by Dr. Heinrich Rohrer, honorary Doctor of Tohoku University, 1986 Physics Nobel Laureate, and founding father of nano-science.

We intend to establish a couple of TU satellite branches around the world to strengthen human-networking and excellence in materials science. We also plan to hire over 100 post-doctors and junior faculty staff in order to quickly reach a 210-manpower plateau by the beginning of the 2009 academic year.
Our aims are very, very high and may not be easy to achieve. However, all of the PIs are eager to work together towards the single mission of establishing a world-premier material science research center. I also intend to work harder and smarter as one of the researchers in this program, in addition to functioning as the head of the host institution.

Based on well-advanced university-wide materials science facilities and personal resources, we will try to further advance in three points

1) Advancements in methods based on atom, molecule level characterization and functional control,
2) Creative functional materials and device development and
3) Eco-friendly material-system integration, all basically for future prosperity.

Tohoku University's solid foundation in theory/simulation, characterization/analysis and fabrication/process technology is the very basic ingredient to achieve this endeavor. By working intelligently and wisely under these principles, we believe that a truly world-premier Research Center for materials will be established upon the completion of this program.

To conclude my speech today, I once again would like to thank all the participants for joining our celebration and for the concerted effort towards excellence in research. We hope to meet you again and again during next 10-to-15 years to witness and share the progress of our program.

Thank you once again.

Congratulatory Remarks

Hiroshi IKUKAWA
Director of Strategic Programs Division, MEXT

Thank you very much for your kind introduction. Good afternoon, ladies and gentlemen and distinguished guests. I am Hiroshi Ikukawa, Director of Strategic Programs Division at the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Mr. Yasutaka Moriguchi, who is Director General of our Science and Technology Policy Bureau, was originally planning to come to attend the ceremony on behalf of our Ministry. However, he was called up by the Diet, Japan's Parliament, which is in session, to be present at the committee meeting this morning. Therefore, he asked me to convey his regret and offer on his behalf a message of congratulations at this Inauguration Ceremony for Tohoku University's WPI Advanced Institute for Material Research.

As you know, recent years have seen a fierce international competition to acquire and secure the world's best brains. To sustain and raise the level of its science and technology amidst such competition, Japan must position itself within a global flow of intellectual mobility. To do so, it would be necessary to build research centers of sufficiently high caliber of excellence to attract outstanding researchers to Japan from all over the world. Cognizant of this urgent/acute need, we, at the MEXT, established this year, the program: World Premiere International Research Center Initiative (WPI). The WPI program, as it is called in short, provides concentrated support to several projects chosen in order to establish research centers that possess own very high quality investigators. These centers have to build up a critical mass of outstanding researchers as well as research environment of high standards to project them with a highly visible presence in the competitive global scientific community. To support building such highly visible research centers, the Ministry will fund each selected center project in a mount of around 1.5 billion yen (~US$14M) annually over the period from 10 to 15 years. Therefore, both in terms of the project funding and duration, this is the largest scale program to be administered by our government to date. This commitment by the government is indicative of the high expectation being placed on several

funded project to succeed.

Our call for proposals this year has yielded 33 applications from 22 institutions. All of them were both, attractive and of a very high quality, making the screening process an extremely difficult task. Ultimately, the Program Committee comprising of top Japanese and overseas authorities selected five projects through a series of hearings with the first-level screening winners. Tohoku University is known to be "the Japan's core research institute" in a field of material science, carrying out highly successful programs that encompass very basic to applied researches. The university has unquestionably contributed to elevating Japan's science and technology standards to the world-highest in a field of material sciences. Tohoku University, indeed, ranks third worldwide in the research-paper citations, which is a clear indicator of high appraisal that the University enjoys internationally. Under Dr. Yoshinori Yamamoto's strong leadership, a research capacity amassed by Tohoku University will be merged with that possessed by the world top researchers participating in the WPI program. As such, I note that steps are taken to realize a top caliber international research center with a high global visibility. Great expectation will be replaced in both in scientific impacts and its role in vanguarding the reform of Japan's science and technology system. Giving the difficulties inherent in Japan's geographical location and language, we recognize that creating highly visible research centers that attract a good number of world front-line researchers will not be an easy task. Nevertheless, both the Ministry and WPI Program Committee recognize that forging success of these center projects will be essential to ensuring the future advancement of Japan's science and technology. As such, we are fully committed to encouraging the further advancements of the WPI Centers through their successful operation. With Tohoku University's president, Dr. Akihisa Inoue, and the Center Director, Dr. Yamamoto, I am sure that all WPI members will be strongly motivated and committed to pushing forward this project to full realization of its tremendous potentials. I look forward to you, creating a greatly visible WPI Research Center, Tohoku University.

Finally, I reiterate my congratulations and wish for the continuous success of Dr. Inoue, the faculty of Tohoku University, and all gathered here today. Thank you very much and congratulations.

Congratulatory Remarks

Motoyuki ONO
President of Japan Society for Promotion of Sciences (JSPS)

Thank you very much for your kind introduction. I am Motoyuki Ono, the president of Japan Society for Promotion of Sciences. I am pleased to be able to say a few words in this Inauguration Ceremony on behalf of JSPS. JSPS supports research driven by the free ideas and initiatives of researchers themselves. As Japan's leading funding agency, JSPS fosters young researchers and promotes international scientific exchange in addition to funding scientific research. With regard to the World Premiere International Research Center Initiatives, JSPS has been commissioned by MEXT to perform the program's application screening process.

Tohoku University has a long history and distinguished tradition of research in the material science. It began when Dr. Kotaro Honda first established University's Institute for Materials Research. The institute has now compiled a world leading record of achievements in this cutting edge field. Carrying forward that tradition, the university's current president, Dr. Akihisa Inoue, is himself a front runner in the Material Science field. He pioneered a revolutional research on amorphous and bulk metallic glasses. As Tohoku University's President, he has created "Inoue Plan 2007" aiming toward a world leading university. It places the university on a firm course for a world-premier academia which contributes to the sustainable society through scientific research. Director of new WPI Research Center, Dr. Yoshinori Yamamoto, has compiled a brilliant record of research in organo-metallic chemistry. He has also made substantial innovations to the university's research management and operational system as the director of major project under the 21 Century COE program. From these various perspectives, we are delighted to know that Dr. Yamamoto is directing the WPI-AIMR at Tohoku University. Under his strong leadership, we are confident that the center will develop rapidly and make cutting-edge advances on the frontiers of Material Science. Material sciences not only have many applications in manufacturing field, but are

also a key technology supporting advances across the entire range of science and technology. Its use in developing energy conversion materials can contribute to a viable solution of global energy supply problems. The development of revolutionary alternative materials can mitigate environmental problems and help to realize an eco-friendly society. And by developing new bio materials, this research can improve people's health and welfare. In myriad of ways, material sciences are the truly vital field in paving the way for the future development of human society.

In closing, I reiterate the great expectations we hold in the new WPI Research Center. We look forward to it taking a world lead in Advancing research in the field of Material Science and to producing superb research result. Thank you. Congratulations.

Congratulatory Remarks

Hiroyuki ABE
Former President of Tohoku University,
Advisor of Japan Science and Technology Agency

I was asked to propose a Toast in this happy ceremonial session. All of you must be hungry and thirsty by now. However, please allow me to say a few words before a toast.

For establishing a world top class research center, it is necessary to realize participation of excellent young researchers and students from overseas countries. For this purpose, I believe that it is most important to enhance the atmosphere of cutting-edge frontier science. I also like to emphasize the importance of the cultivation of its spirits of science and spirits of creativity.

With my elderly advice, ladies and gentlemen, I would like to propose a toast to the successful future of this new program, WPI-AIMR sponsored by MEXT and to the cooperation of all concerned.

Let me propose a toast in Japanese way, saying “Kampai!”

Thank you very much.

Nobel Laureate Remarks

Heinrich ROHRER

“WPI and Luck and Chances”

We heard many congratulations to Tohoku University for being awarded the large WPI grant. On such occasions, I have always my doubts whom to congratulate, the recipient or the donor.

Let me express it the way it is done at weddings. The bridegroom gets the congratulations for his choice, the bride you wish all the luck in the common future.

Let me, therefore, first congratulate JSPS for having selected Tohoku University as recipient of a very large WPI grant. I also congratulate JSPS for the courage and wisdom to entrust to the center this large Material Science grant *in globo* without detailed topical strings and procedures attached. This is perfectly in the spirit of the all over proclaimed holistic thinking and acting in dealing with important complex issues. I have not met alike anywhere else with any other science money agency.

As to the luck, l wish all the scientists a lucky hand in choosing and solving most challenging scientific problems at the forefront of Materials Science, in engaging in new ventures, and in giving Materials Science sort of a face lift. All the responsible ones, line and staff, will need the luck. The trust in them by JSPS obliges.

I know luck is not what scientists are looking for. Luck it is not part of the scientific vocabulary. Intellectual mastery, bottomless knowledge, and scientific expertise rank highest in the scientific community. However, luck is very crucial for novelty and for unexpected findings and results. It is, therefore, an important driver of scientific progress. It is not a shame to be lucky in science. Actually, most scientists are lucky now and then, unfortunately only very few are smart enough to notice it. That is how so many big chances are missed, again and again. Missing them is the shame. I consider it as one of the key sins in science.

I will be an advisor to the WPI, but it is hardly appropriate to come up with advice before the WPI has really taken off. Nevertheless, let me share some thoughts with you on the projects and on Materials Science, some thoughts of an outsider.

Besides providing generous funds for about 30 demanding research projects, this WPI on Materials Science offers the chances to rethink some important issues in Materials Science.

Over the years, Materials Science has unfortunately changed from an all embracing scientific activity to a highly fragmented conglomerate of narrowly focused expert interests. Materials Science has lost quite a bit of its drive to new shores. It appears to me that IMR has noticed the signs at the wall and seems to be on good ways to a coherent Materials Science activity. I sincerely hope that the WPI Research Center will considerably enhance this drive back to the future of an adventurous Materials Science. Crucial will be projects, beyond the present interests and activities of the Principal Investigators for which the latter have the full support and encouragement of the responsible WPI political bodies.

With the WPI, Tohoku University gets a third Materials Science Institute on board. In the sense of an all embracing Materials Science, such an Institute cluster appears sort of an artificial construct. Whatever the solution, I like to stress that I do not advocate mergers for the mergers sake and cooperation for the cooperation sake.

What the internal structure of the WPI is concerned, it appears to me a bit complicated with floating responsibilities. It might be difficult to satisfy both the needs of the WPI and those of the Principal Investigators, in particular those of the off site PIs, with their double and triple responsibilities and functions. Whatever worldwide networking, the center of the scientific activities should remain the WPI Research Center at Tohoku University and brains have always priority over structures and procedures.

Let me end with some remarks on my notion of a changing Materials Science. Times have changed and the action takes place now more at the interfaces of the classical expert domains. An interface has two faces in various respects. It is the place where things often fall apart, be it between two different materials, be it between two military divisions of the same army. But it also acts as connection between different ways of thinking and, in materials, between different properties on either side. This makes Materials Science much more demanding but also much more rewarding.

A second remark concerns Materials science on the nm scale which I understand is a key goal of the WPI. Sustainability is a key for science to benefit mankind, the recurrent theme of the WPI, and Nano is a key for sustainability. We do already quite well what nm scale analytics is concerned. Likewise we have already made some progress in nm scale

modification of materials. However, we are nowhere yet what growth of a given nano structure at a given nm position for a given function is concerned. I consider this as the central and most demanding challenge of nm scale Materials Science.

Finally, molecular materials and components are of increasing importance, in particular for nm scale structures, components and systems of them. For handling molecular materials and building structures with them, the solid-liquid interface will be of prime importance. I use to call it the interface of the future. Hopefully, it will not just remain that for ever.

For becoming a World Premier International Research Center in the first ranks of scientific activity, you need all the luck you possibly can get. I wish you all that luck.

Sendai, Nov. 15, 2007 H. Rohrer

Research Prosect

Research Prospect

"Short History and Perspective of Bulk Metallic Glasses"

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Abstract

The widespread enthusiasm for the research of bulk metallic glasses is driven by both the fundamental interest in the structure and properties of the disordered materials and their unique promise for structural and functional applications. Unlike crystalline materials, the disorder and nonequilibrium nature of metallic glasses leads to the underlying mechanisms of bulk metallic glass formation and properties poorly known. In this article, I will brief review the history of bulk metallic glasses and outline a few outstanding questions and critical issues that are believed to be important for further bulk metallic glass research.

Amongst various glasses, metallic glasses are probably the youngest one in the big "glass" family. Metallic glasses possess a number of characteristics, such as high strength and amorphousity, which are shared by other glasses including window glasses (oxide glasses), the one we are familiar with in our daily life. However, the most important feature of metallic glasses along with other glasses, which is distinguished them from amorphous materials, is a glass transition that transforms the glasses into supercooled-liquid states when heated from low temperatures to high temperatures. Thus, **metallic glass** is scientifically defined as an amorphous alloy that exhibits a glass transition where derivate thermodynamic properties such as the heat capacity change abruptly.

The research on metallic glasses is closely related to metallic liquids. It is known that the atomic configurations of molten metals and alloys are disordered. The noncrystalline structures are expected to be retained if the liquids can be quenched with a sufficient high cooling rate to prevent the formation of equilibrium crystalline structures. The critical cooling rates to freeze liquid structures are estimated in the order of 10^5 to 10^6 K/s for alloy systems. This assumption was experimentally proved by a research group at Caltech in 1959. The first reported glassy alloy with a composition of $Au_{75}Si_{25}$ was produced by rapid cooling of liquid droplets. [1]. In this pioneering work, the authors quenched the metallic melt on a cold metal surface, instead of into traditional quenching liquids. The good contact between the

liquid droplets and the cold metal avoids the formation of gaseous layers that limit the heat release during solidification. Moreover, the droplets spread into a thin layer for rapid thermal diffusion when striking the solid and cold metal plate. X-ray diffraction analysis demonstrated disappearance of crystalline structures in the resultant micrometer-sized flakes and formation of a noncrystalline structure in the rapidly solidified alloy. Following this discovery, a large number of metallic glasses were found in various alloy systems and the rapid research progress in searching new metallic glasses was promoted by the invention of a melt spinning method. This state of the art rapid cooling technique can routinely quench liquid metals and alloys into 10-50 μm thick ribbons with a cooling rate of about 10^3 to 10^6 K/s. Most glassy formers found at that time are binary alloys and their glass forming ability was found to strongly rely on alloy compositions. The good glass formers generally have compositions close to eutectic points (**Figure 1**). Practically, searching around deep eutectic points is a shortcut to find good glass formers in binary and ternary systems. Moreover, this result, in principle, coincides with the supposition that metallic glasses are achieved by freezing metallic liquids because an alloy with a eutectic composition generally has a low melting temperature and stable liquid phase.

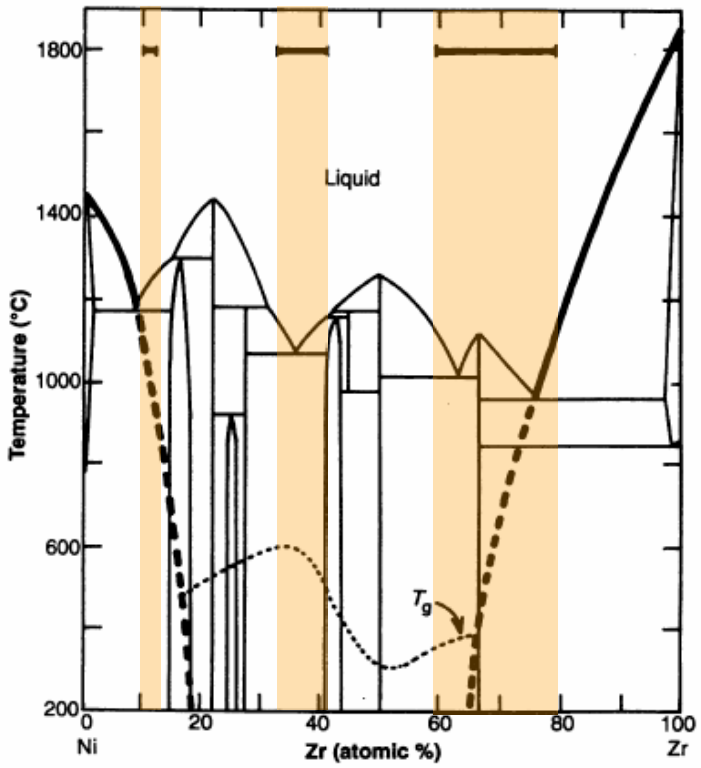

Figure 1. Binary phase diagram of Ni-Zr system. The shadow regions correspond to the composition ranges for the formation of metallic glasses by rapid cooling.[6]

Because of the requirement of high cooling rates for the formation of metallic glasses, glassy alloys can only be produced in the form of small particles or thin ribbons. However, a few exceptions were found in noble metal based alloys, such as Pd-Cu-Si and Pd-Ni-P [2-5]. These alloys have very low critical cooling rates and allow making glassy samples with a large size. The first paper that claims the formation of a bulk metallic glass is, probably, the one with the title "*Bulk formation of a metallic glass:* $Pd_{40}Ni_{40}P_{20}$" published in *Applied*

Physics Letters in 1982 [4]. The authors obtained bulk glassy samples of $Pd_{40}Ni_{40}P_{20}$ with a thickness of about 10 mm and a critical cooling rate of about 1-10 K/s. Unfortunately, these pioneering works on the development of bulk metallic glasses did not make big impacts in materials science community. One of the reasons is that, although the noble metals, such as Pd and Pt, are good for improving glass forming ability, they are too expensive to be used for a wide range of applications.[6] Even for basic research, very few labs in the world can afford the routine use of the expensive metals for casting bulk samples.

The breakthrough of bulk metallic glass research takes place with the discovery of a number of multicomponent bulk metallic glasses by Inoue and his co-workers at Tohoku University around the end of 1980s.[7, 8] The new bulk glassy alloys exhibit excellent glass forming ability and very low critical cooling rates, similar to those of the noble metals based metallic glasses [4, 6, 8]. Significantly, in these new alloy systems noble metals are no longer the essential constituent elements. Some excellent glass formers only contain transition metals, such as the system of Zr-Al-Ni-Cu. In their original papers [7, 8], Inoue *et al* attributed the excellent glass forming ability of the new alloys to the increased packing density by multiple components because the alloy systems have more choices to pick up atoms with a right size to fill the empty spaces in randomly packed disordered structures. Soon after Tohoku group's work, Peker and Johnson at Caltech reported an excellent multicomponent bulk metallic glass

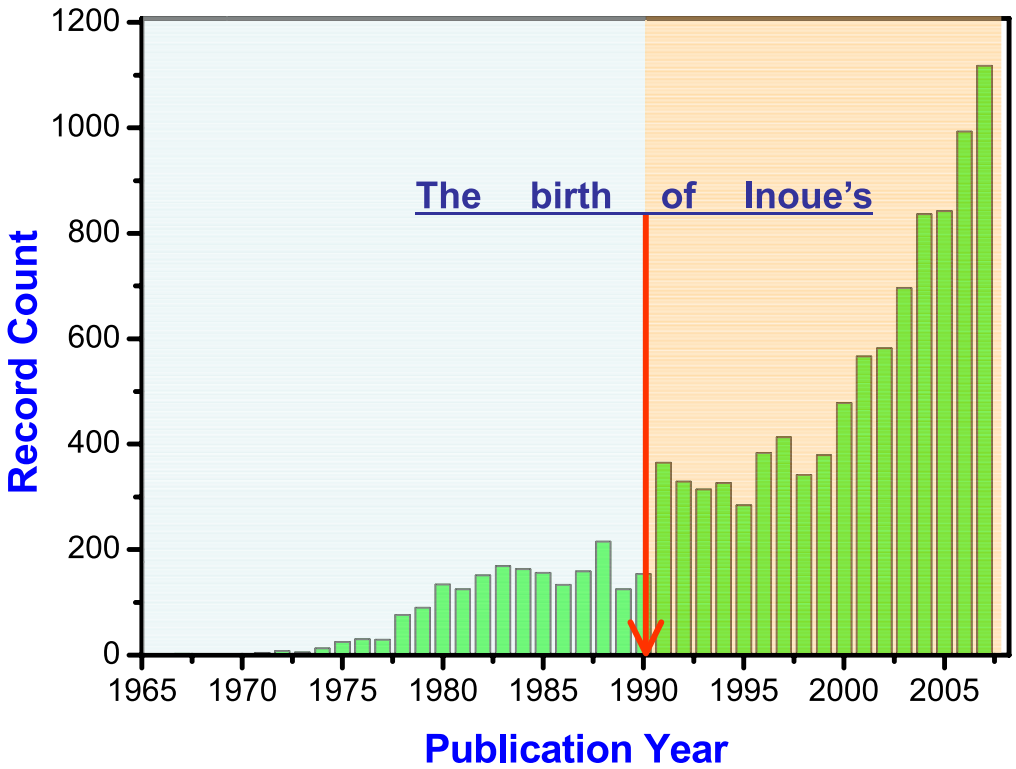

Figure 2. Journal publication profile of metallic glasses, searched by using "metallic glass" as the "topic" at http://portal.isiknowledge.com/.

with a composition of $Zr_{41.2}Ti_{13.8}Cu_{12.5}Ni_{10.0}Be_{22.5}$.[9] It's worthy to note that this alloy contains 22.5 at. % beryllium, the smallest metallic atom, which is expected to fill empty spaces more efficiently. Until now, this alloy is still one of the best glass formers and probably puts the effect of multicomponent for dense packing to an utmost in Zr-based bulk metallic glasses. Besides the explanation of the improved dense packing by multiple components, the improved glass forming ability by the multiple components is also associated with the reduced free energy of the alloy systems due to chemical mixing entropy effect. This can be explained by "confusion principle", *i.e.,* "*the more element involved, the lower the chance that the alloy can select viable crystal structures, and the great chance of glass formation*".[10] The findings of these new bulk metallic glasses with multiple components stimulate the extensive enthusiasm for metallic glass research in recent years. As pointed out by Greer in one of his review articles [6], "*the ability to form metallic glass very easy, in large cross sections, from common elements has naturally arouses much interest and leads to rapid development*". This viewpoint is supported by the journal publication profile of metallic glass research based on ISI database (**Figure 2**). Right after the birth of the multicomponent bulk metallic glasses, the publications on metallic glass research dramatically increase with each passing year, in particularly after the year of 2000.

As discussed before, deep eutectic points in binary and ternary alloys systems have been widely used as the indications for searching good glass formers. However, it is not possible to represent more than three components on a phase diagram and the eutectic transitions in quaternary and higher systems are rarely known. Therefore, it's extremely difficult to locate the compositions for best glass formers in multicomponent alloy systems. So far, most of new multicomponent metallic glasses were found after a large number of attempts. It thus has a compelling demand to uncover the underlying regularity for the formation of bulk metallic glasses. By statistically analyzing hundreds of alloys that have excellent glass forming ability, Inoue suggested three empirical rules for the formation of bulk metallic glasses, i.e. *(1) multicomponent systems consisting of more than three elements; (2) significant difference in atomic size ratios above about 12% among the three main constituent elements; and (3) negative heats of mixing among the three main constituent elements.* Although there are a few exceptions, most of the best glass formers follow those rules, implying certain physical principles, associated with the statistical mechanics, topology and multi-body quantum mechanisms, play an important role in the formation of bulk metallic glasses in multicomponent systems. However, the definite physical picture remains unknown and the laws for quantitative composition design of bulk metallic glasses are still missing.

One important clue for understanding the underlying mechanisms of bulk metallic

glass formation is that the best bulk metallic glass formers in each alloy system generally have a narrow composition range. Slightly changing the compositions or replacing constituent elements can lead to obvious loss of glass forming ability. This characteristic is very similar to some crystalline and quasicrystalline compounds with complex atomic configurations, such as Laves phases and icosahedral phases. Therefore, the exact composition requirements for best glass formers certainly indicate an inherent correlation between glass forming ability and atomic configurations of bulk metallic glasses. Understanding the atomic structures of best glass formers is probably a viable way toward the destination for quantitatively designing new bulk metallic glasses with ultra-high glass forming ability and excellent properties in physics, chemistry and mechanics.

As an empirical rule, the most appropriate compositions for glass formation are those stabilizing liquid phases relative to crystalline phases, such as the compositions close to deep eutectic points where the metallic liquids can be deeply supercooled. Thus, the atomic structures of metallic glasses have first been thought to be similar or even the same as those liquids. To explain the stability of simple metallic liquids at a temperature far below their molting points[11], Frank suggested that local icosahedral order might be responsible[12] because icosahedra are highly close packed, lack of the translational periodicity and difficulty for growing up comparing to the crystal counterparts. This idea was subsequently pursued by numerous experimental and computational investigations. However, it was found that for a simple metallic liquid, the stability of icosahedra for finite clusters is largely relate to a surface effect and thus it does not imply that local icosahedral structure is favorable for a bulk liquid[13]. The most appreciate structural model for metallic glasses is Bernal's dense random packing model in which the glasses is assumed as the frozen metallic liquids and the atomic arrangement is considered from purely geometrical sphere packing such as the ratios of atomic radii[14, 15]. Bernal's idea can satisfactorily model the systems of monatomic metals and alloys with constituent species having comparable atomic sizes. However, it does not provide structure favorites on short- and medium-range ordering observed in real, multicomponent glassy systems that have very low critical cooling rates. Moreover, it has been found that this model fails to describe metal–metalloid based alloys in which the chemical short range ordering is pronounced. [16-19] In light of this, Gaskell proposed a stereochemically defined model that stipulates the local unit with nearest neighbors in amorphous metal–metalloid alloys to have the same type of structure as their crystalline compounds with a similar composition [16-18]. However, this model has not been proved by metal-metal based metallic glasses. Regardless of the atomic configurations, it has been generally accepted that the disordering of metallic glass can only be preserved down to a certain length scale. Atoms in metallic glasses prefer to form short-range orders (SROs) in

which the local nearest-neighbor environment of each atom is similar to other equivalent atoms, but this regularity does not persist over an appreciable distance. With the fact that good glass formers have higher density and thereby more packed atomic configurations than ordinary amorphous alloys with high critical cooling rates, it has been suggested that the higher packing density is essential to achieve the high glass-forming ability [7-9, 20]. Although face-centered cubic (f.c.c.) and hexagonal close-packed (h.c.p.) packings have high packing efficiency, those structures fail to explain the excellent stability of metallic glasses in a supercooled state. As an alternative model for dense packing, the highly packed icosahedral orders have been widely considered as a possible structure unit of bulk metallic glasses. A number of simulations and experimental observations have suggested that icosahedron is an energetically favorable atomic structure in some metal-metal based metallic glasses.[8, 20-22]. However, the metallic glasses that can be the formers of icosahedral quasicrystals during annealing generally have marginal glass-forming compositions and are not the best glass formers. This fact indicates that the icosahedron may not be the only favorable structure unit in metallic glasses. Therefore, the existence of a universal atomic model that possesses general applicability to all metallic glasses appears highly impossible.

The densely packed atomic structure of metallic glasses is required to extend to the macroscopic scale in a real material. Thus, the knowledge of SROs is far not enough to determine the overall structure of a disordered solid, which is dramatically different from a crystal where it is only necessary to solve the structure for a subunit that can be repeated periodically to produce the whole structure[23]. The efforts to define the structure of metallic

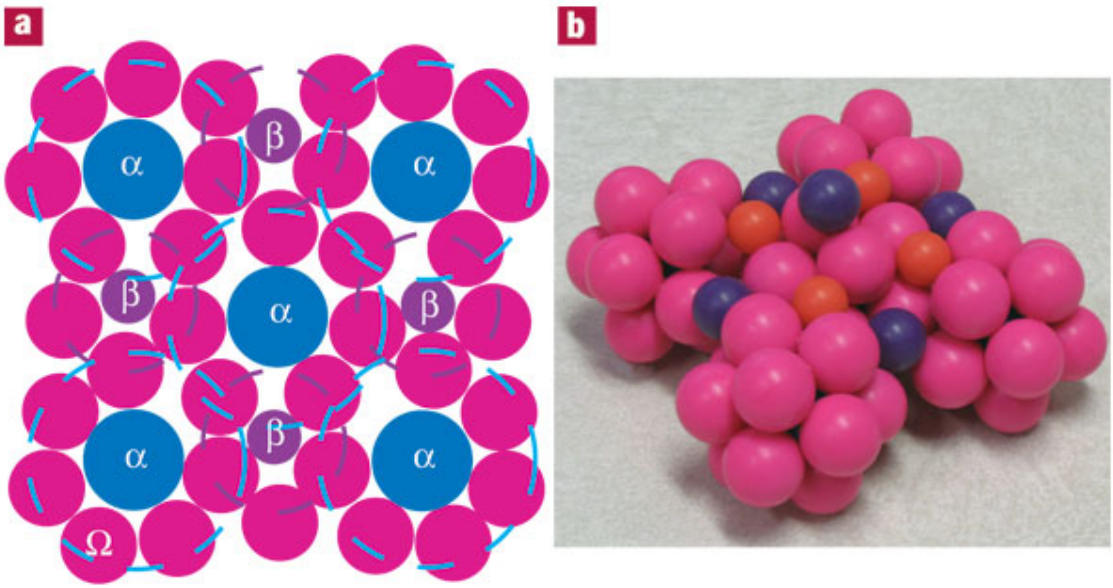

Figure 3. Illustrations of portions of a single cluster unit cell for the dense cluster packing model.[24]

glasses beyond the nearest-neighbor SROs have been one of the most outstanding questions in metallic glass research. Recently, Miracle suggested a scheme to model the medium-range ordering in metallic glasses.[24] In his model, efficiently packed solute-centered atomic clusters are retained as local structural units. An extended structure is produced by idealizing these clusters as spheres and efficiently packing these sphere-like clusters in f.c.c. or h.c.p. configurations to fill the three-dimensional space (**Fig. 3**). Because of the internal strains and packing frustrations, the order of the cluster-forming solutes cannot extend beyond a few cluster diameters and thus the disorder nature of metallic glasses can be retained beyond nanoscale. Based on experimental measurements and computational simulations, Sheng, *et al* proposed an alternative cluster packing scheme to resolve the atomic-level structure of amorphous alloys. By analyzing a range of model binary alloy systems that involve different chemistry and atomic size ratios, they elucidate the different types of short-range ordering as well as the nature of the medium-range ordering. Their results suggest that the icosahedral fivefold packing is a more realistic ordering pattern for SRO cluster–cluster connection in metallic glasses, rather than f.c.c or h.c.p cluster packing. With the schemes of cluster-cluster packing, the dense structures without an appreciable translational symmetry can be extended to 1-2 nm scale in metallic glasses. Although the research on the structure of metallic glasses is the topic of recently intense discussion, the atomic configurations, in particular in multicomponent alloys, remains to be an unsolved mystery. It is still a dream to design bulk metallic glasses based on atomic packing laws.

One of the most notable properties of bulk metallic glasses is their extremely high hardness and strength, which makes them attractive for applications where strength and weight are critical. Nevertheless, the underlying deformation micro-mechanisms that control the strength and ductility of bulk metallic glasses are poorly known. For crystalline metals and alloys, the controlling factors of their mechanical properties have been well investigated with the development of dislocation theory and electronic theory, which can explain, in general, the atomic and electronic origins of the strength and ductility of crystalline materials. For disordered materials, such as metallic glasses, the definite correlation between mechanical behavior and their atomic and electronic structures has not been properly established. However, it has been realized for long time that the mechanical properties of metallic glasses are closely related to the chemical and physical possessions of their component elements [2]. The significant difference in mechanical performances, such as strength and ductility, varying with the chemical compositions of metallic glasses, indicates the existence of an intrinsic correlation between the mechanical properties and the atomic and electronic structures of metallic glasses. However, the underlying mechanisms have not been well understood and the physical picture appears to be much more complicate than those of crystalline materials. The

plastic deformation of metallic glasses at temperatures far below Tg is known to be inhomogeneous both spatially and temporally and carried by highly localized shear bands. Inspired by the increasingly intense scientific and technological interests of metallic glasses and the efforts of improving their mechanical properties, it is essential to identify the underlying mechanisms responsible for ductility and strength of metallic glasses. Historically, several theories have been developed to describe the heterogeneous plasticity of metallic glasses. These models are mainly based on two atomic-scale mechanisms, i.e. deformation-induced dilatation or free volume and local events of cooperative shearing of atomic clusters termed shear transformation zones (STZs)[25, 26]. Unambiguously, the free volume and STZ models provide simple and clear-cut explanations on the strain softening and thereby heterogeneous deformation of metallic glasses. They have been widely cited to qualitatively explain various mechanical properties of metallic glasses. However, carefully considering the physical process of metallic glass deformation, one can find that both the free volumes and STZs could be the origins and the results of plastic deformation, but not the deformation process. The motion and re-arrangement of constitute atoms within shear bands during plastic flow have not been made clear by the models. Moreover, they cannot provide quantitative explanations on the strength and ductility of various bulk metallic glasses. The appearance of a multidimensional potential energy surface, or potential energy landscape, of a disordered material can be related to the form of the interatomic or intermolecular potential. Combining with catastrophe theory, it enables to describe how the geometry of the surface changes with parameters in the potential, and provides universal scaling relations that can explain an unexpected connection between barrier heights, path lengths, and vibrational frequencies, with applications to a wide variety of problems, for examples, mechanical behavior of metallic glasses.[27] Derived from the energy landscape theory and Frenkel scheme for the shear deformation of defect-free crystals, Johnson and Samwer recently proposed a cooperative shearing model of STZs.[28] Although the Johnson-Samwer model is originally introduced to elucidate the temperature dependence of yield strength in a form of $T^{2/3}$, it has been shown to provide an effective interpretation of ductility and strength of metallic glasses, which may pave a new way to get a quantitative insight into the atomic-scale mechanisms of bulk metallic glass mechanical behavior.[27]

With the last twenty years' efforts, a large number of bulk metallic glasses in various alloy systems have been developed, which rouses the intense research interest in finding novel physical and chemical phenomena in the non-equilibrium, disordered and multicomponent solids. As outlined in this paper, many fundamental questions remain to be elucidated and the comprehensive understanding in the properties and structures of bulk metallic glasses is far from complete. Searching for new bulk glassy alloys with advanced properties and exploring

atomic-scale mechanisms of bulk metallic glass formation and properties will continue to be exciting areas in future research.

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"Atomically Precise Assemblies, Tools and Analyses"

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It is a great honor to be a part of the new Advanced Institute for Materials Research (AIMR). Having the long-term support to look beyond the horizon at materials and measurements, and to see how we can impact the world around us is indeed an awe-inspiring task and opportunity. In our science, at the satellite center at Penn State and in our collaborations throughout the Institute, I see two drivers that will enable us to succeed in this mission.

Our first thrust will be to find the means to bridge between the scale of synthetic molecular chemistry, *ca.* 1 nm, and the scale of conventional nanolithography, currently ~50 nm. Tremendous possibilities open if we are able to go beyond simply carving up silicon, turning it into metal or insulator or doped semiconductor. We will not only expand the range of materials addressed, but will also tailor the chemical, physical, biological, and functional properties of exposed surfaces in order to enable new possibilities and applications for materials. We will develop capabilities to gain this control down to the sub-nanometer scale through the patterning and control of single molecules in tailored environments (Figure 1).[1-6]

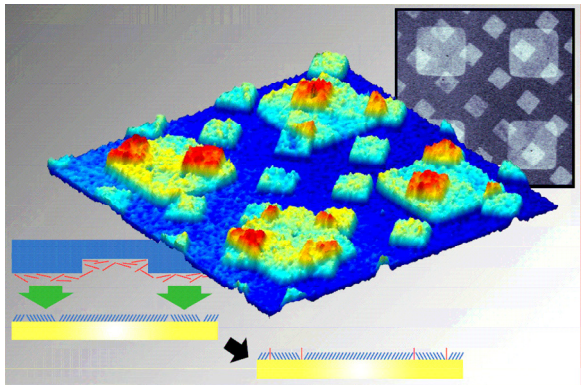

Figure 1. New patterning and assembly methods will be developed that go far beyond today's nanolithographic methods. We will be able to place single molecules and assemblies in precisely defined chemical environments.[5]

Our second thrust will be to develop new tools that simultaneously measure structure, function and properties with atomic resolution. These will enable us not only to optimize our materials but also to enter a tight feedback loop of design, synthesis, assembly, and measurement that has served us so well in the a recent series of measurements on molecular devices.[7-10] These tools will combine scanning probes with spectroscopies from the microwave to the ultraviolet (Figure 2), as well as measurements of motion, actuation, polarizability, and many others.[11-15] We will not only manipulate atoms, molecules,

nanoclusters and larger assemblies to make atomically precise nanostructures, but we will measure the energetic and other requirements of doing so.[16-20] This will give us the insight required when we target high-value structures for synthesis, and for self-, directed and hierarchical assembly. In addition, we will develop new methods of parallel analyses that enable single-atom/molecule/assembly measurements on the one hand, and sufficient statistics, comparable to ensemble-averaged measurements, on the other (Figure 3).[21,22] By preserving the information related to the heterogeneity of the systems studied, we will be able to elucidate the key control parameters of these nanoscale systems and assemblies.[21-24]

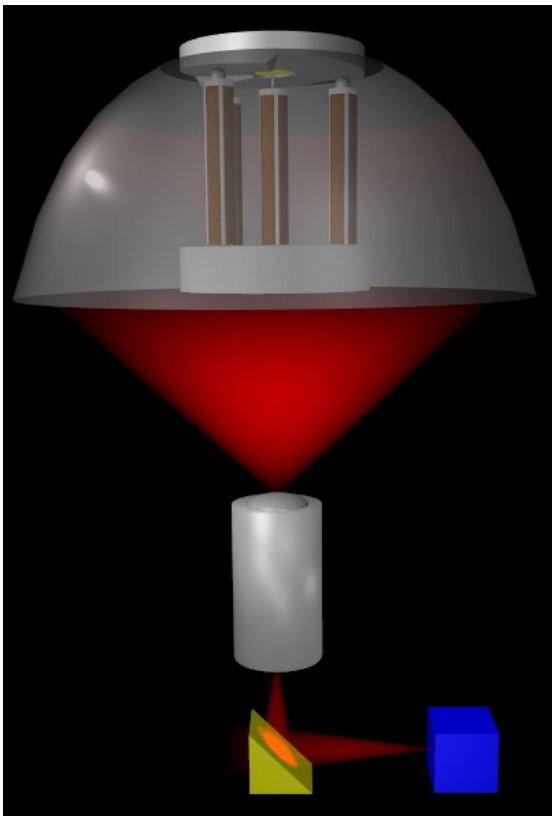

Figure 2. New atomic-resolution absorption and emission spectroscopies will be developed to determine the properties of precise assemblies with unprecedented definition.

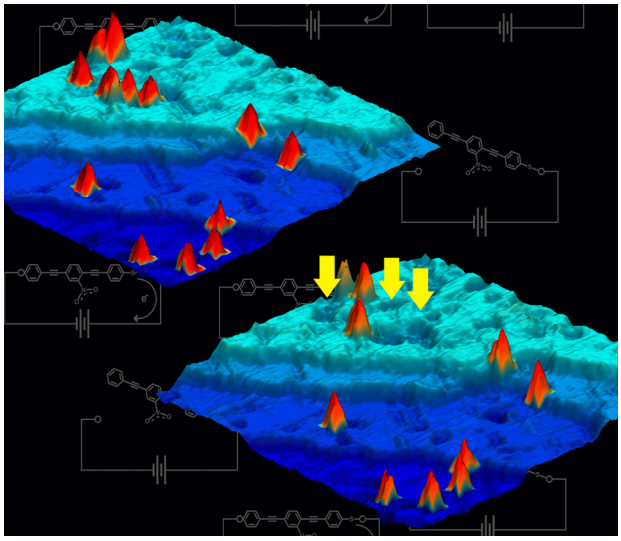

Figure 3. New methods will be developed to record many thousands of single atom/molecule/assembly measurements while retaining all the heterogeneous information due to the specific environment and condition of each. This will yield unprecedented insight into control of structure and function at the atomic scale.

Self-, Directed and Hierarchical Assembly to Create Precise Structures and Chemical Patterns

One of the keys to creating atomically precise assemblies is to employ non-covalent interactions. These have been used to exquisite effect in nature, but their exploitation in artificial structures has only just begun. We need to understand and to tailor these interactions in order to control self-, directed and hierarchical assembly. Such interactions can be exploited to stabilize one or more of several states of an assembly.[7,8] Likewise, they can be used to control which functions can be exercised at any given time.[25] Ultimately, we

will use them to assemble precise structures in the 1-50 nm range.

This is largely unexplored territory.[26] The tools to test the structures assembled do not exist elsewhere. Adding this capability to the ability to measure the assemblies' functions at the atomic scale will open up new worlds for exploration and control. Our first glimpses of this have already yielded surprises (Figure 4).[27] We will work closely with the theory groups of the AIMR in order to understand and to exploit what we find.

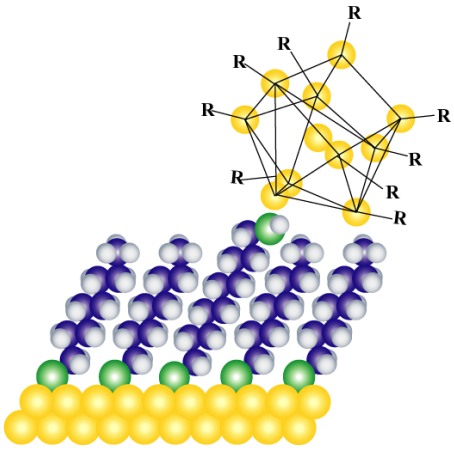

Figure 4. An atomically precise assembly of a single Au_{11} cluster attached through a single alkanedithiolate tether molecule to a substrate with a precisely defined chemical environment has surprisingly unstable electronic structure at 4 K and 10^{-14} torr.[27] We will learn how to stabilize and to predict the properties of these as well as precise assemblies with much greater complexity.

Atomic-Scale Manipulation

We will use our ability to manipulate atoms to target high-value nanostructures with atomic precision.[16-20,28] This enables us to make a series of structural variations efficiently (*i.e.*, without having to synthesize each member of a family). Then, we can target the optimized structures for synthesis and assembly with enormous economies of scale. We have already shown that we can move atoms on and sometimes even *underneath* surfaces![16-20] When we do this, we can determine the energetics of motion, and the potential energy surfaces of chemical reactions and supramolecular assembly rearrangements. With this information in hand, we can learn to manipulate potentials so as to *guide* the dynamics and assemblies.[18,29,30]

New Nanoscale Tools and Analyses

The new tools and methods that we develop will be enabling in the sense of allowing us to associate structure and environment with function and control. The goal is to retain atomic resolution and to gain additional capabilities. These will include spectroscopies from the microwave through the infrared into the visible and beyond. These will also measure functions, such as actuation and coordinated motion.

These tools will enable us to measure the intrinsic properties of molecules and assemblies, such as the photoconductivity of specially tailored donor-acceptor complexes. We will engineer function into and out of the complexes, thereby verifying our predictive design capabilities and understanding. With this understanding, and tested by measurements, we will optimize the molecular designs, the environment in which the assemblies function and

their attachment to contacts and interfaces. This will enable rapid advances in the design and application of these assemblies.

Critical to this tight feedback loop of design, assembly and measurement is the ability to do many parallel single atom/molecule/assembly measurements. We will continue to develop and to apply advanced tools for this purpose.[21-24] This will enable objective and statistically significant assessments, and therefore to come to meaningful assessments of function.

Prospects

In our satellite center at Penn State, in the chemistry and physics thrusts, and with our experimental and theoretical collaborations throughout the AIMR, we will push forward in these areas, to open up unexplored territory, and to enable new science and new opportunities. We will take inspiration from the measurements and approaches of chemistry, physics, biology and engineering, merging these disciplines to create unprecedented understanding and opportunities. In doing so, we will cross-train a new generation of scientists to take us to new levels of complexity, function, and precision.

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“Polymer Science”

(Lecture summary at Inauguration Ceremony of TU WPI-AIMR)

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1. Introduction

As one of the Principal Investigators (PI) at the newly founded institute, WPI Advanced Institute for Materials Research (AIMR) at Tohoku University, I in this report will describe the current status and the future prospect of polymer science that would be very much related to our research goal aimed during about five years in our project.

Recent demands for polymeric materials require them to be multi-functional and high performance. Therefore, the development and research of polymer blends, alloys, and composite materials have become quite important since single polymeric materials can never satisfy such broad requirements over multiple length scales. Polymeric nano-materials, [1)] including nano-alloys and nano-composites, are emerging as key elements to meet these demands. In case of nano-alloys, more than two different polymeric materials are used to generate materials structured over multiple length scales by reactive processing techniques, for example. For nano-composites, the spatial arrangements of nano-scale particles, from 0th to 3rd dimensions, are dispersed in polymeric materials, to realize much improved properties or unexpectedly new functions. As structures get smaller and smaller, the surface to volume ratio increases significantly and, as such, the interfacial behavior of materials become increasingly important. Enabling nanotechnology, utilizing the remarkable advances in generating polymeric nano-materials in actual applications, as a consequence, requires a quantitative understanding of the interfacial behavior of materials. Gaining this understanding will allow nanotechnology to markedly impact our lives.

The emergence of polymeric nano-materials has accelerated the development of characterization tools with nanometer-level resolution. I, as one of group leaders, have been developing for seven years unique tools to evaluate polymeric nano-materials for the Japanese national project on “Nanostructured Polymer Project” by the Ministry of Economy, Trade, and Industry (METI), New Energy and Industrial Technology Development Organization (NEDO) and Japan Chemical Innovation Institute (JCII) that will last until the end of March, 2008.

The characterization of polymeric nano-materials encompasses three- dimensional (3D) structural analysis, nano-scale physical properties evaluation, and nano-scale spectroscopy

(material identification). [2] We have already been in strong position for the former two technologies developed in the above-mentioned project. Thus, the original idea in my mind was placing them into the core of our new project and further extension of the success of this endeavor to the maximum extent in order to make them much more applicable to realistic materials research. See Figure 1 for more detail.

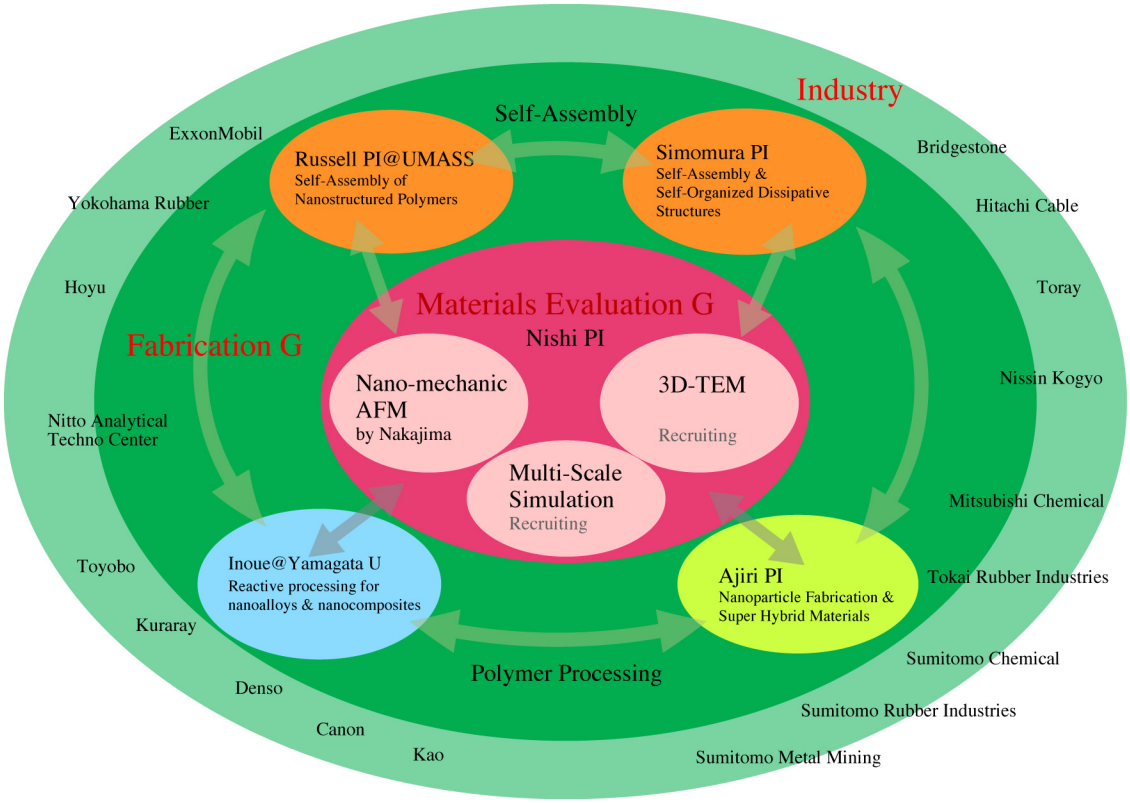

Figure 1. The organization structure of WPI-AIMR polymer group

The first effort would be the development of physical property measurements, based on the modification of an atomic force microscope (AFM). [3] We have developed nano-mechanical mapping technique equipped with AFM (nano-mechanic AFM) where we can reconstruct the true surface topography and Young's modulus image of polymeric materials with nanoscopic lateral resolution. [4-7] Dr. K. Nakajima is in charge of this development and, therefore, he will continue his research among the WPI-AIMR framework. Using the methods Nakajima has and will develop, new information on the physical properties of the interface of nano-composites, the dispersion of nano-particles in polymers and the consequent effect on mechanical properties. The method has proven to be very powerful in understanding the mechanism of reactive processing, since even 3D structural information is not enough to answer questions about specific functions of polymeric nano-materials. I will describe more detailed research subject in the following sections.

As for 3D structural analysis, polymer-oriented energy-filtered 3D transmission

electron microscopy (3D-TEM) was first developed by Assoc. Prof. H. Jinnai at Kyoto Institute of Technology. I will continue to keep a strong connection with him during this project. We have succeeded in analyzing micro-phase separated block copolymers, [8-10] injection-molded plastic/thermoplastic polymer alloys, [11] carbon black/ silica filled elastomers, [12] polymer clay nanocomposites, [13] and even metal nano-particles supported by porus polymer substrates useful for fuel cells. [14] Jinnai recently succeeded in creating a double-helix morphology using self-assembling process of three-component terpolymers in collaboration with Prof. Dr. Volker Abetz at GKSS Research Centre Geesthacht GmbH Institute of Polymer Research in Germany. The intriguing, yet complex, 3D morphology, that can only be imaged by 3D-TEM, may be utilized for various applications such as high-precision separation membranes and nano-coil, shielding material for electromagnetic waves. 3D-TEM revealed new and quantitative insights that could never have been obtained by conventional TEM. In the WPI-AIMR project we propose to develop the "missing wedge", *i.e.*, distortion-free perfect 3D-reconstruction by rod-shaped specimens. The combination of 3D-TEM, electron energy loss spectroscopy (EELS) and cryogenic-techniques while in the development stage is already yielding some fascinating results and will be completed within the research period. In addition, the development of four-dimensional (4D) microscopy, where time is the fourth dimension, will be developed and will be the key, in our opinion, in harnessing and trapping non-equilibrium structures.

Nano-mechanic AFM and 3D-TEM have been the most successful results that have emerged in the above-mentioned national project and have pioneered the field world-wide. Within WPI-AIMR we want to expand these efforts to include multi-scale simulations of soft materials, which can provide insights into the "holy grail" of materials science, namely structure-property relationships where the structure spans from the nanoscopic to the microscopic to the macroscopic size scales. "OCTA" is such a simulation tool, which is still growing and spreading internationally. [15] The combination of the computer-simulation technique with 3D imaging should open a new research field in which fundamental problems, like the conformation of polymer chains confined within nanoscopic structures, can be addressed using the advanced computational techniques.

In summary as in Figure 1, I will lead the materials evaluation group and the group must be composed of three main techniques, nano-mechanic AFM, 3D-TEM and multi-scale simulation. To promote polymer nanotechnology, we need to collaborate with the polymer fabrication group. I placed three PIs (Prof. Russel at University of Massachusetts, Prof. Simomura, and Prof. Ajiri) and a joint research (Prof. Inoue at Yamagata University) together with the list of collaborating companies into Figure 1 as research networks to bring our polymer nanotechnology as more realistic materials research tool. We have already talked several times about the possible collaboration topics, including photovoltaics, fuel cells, water

desalination and delivery systems for health related fields. These are the key areas of research that can have the most significant impact on a world-wide setting. Figure 2 shows the summary of five-years roadmap of our group.

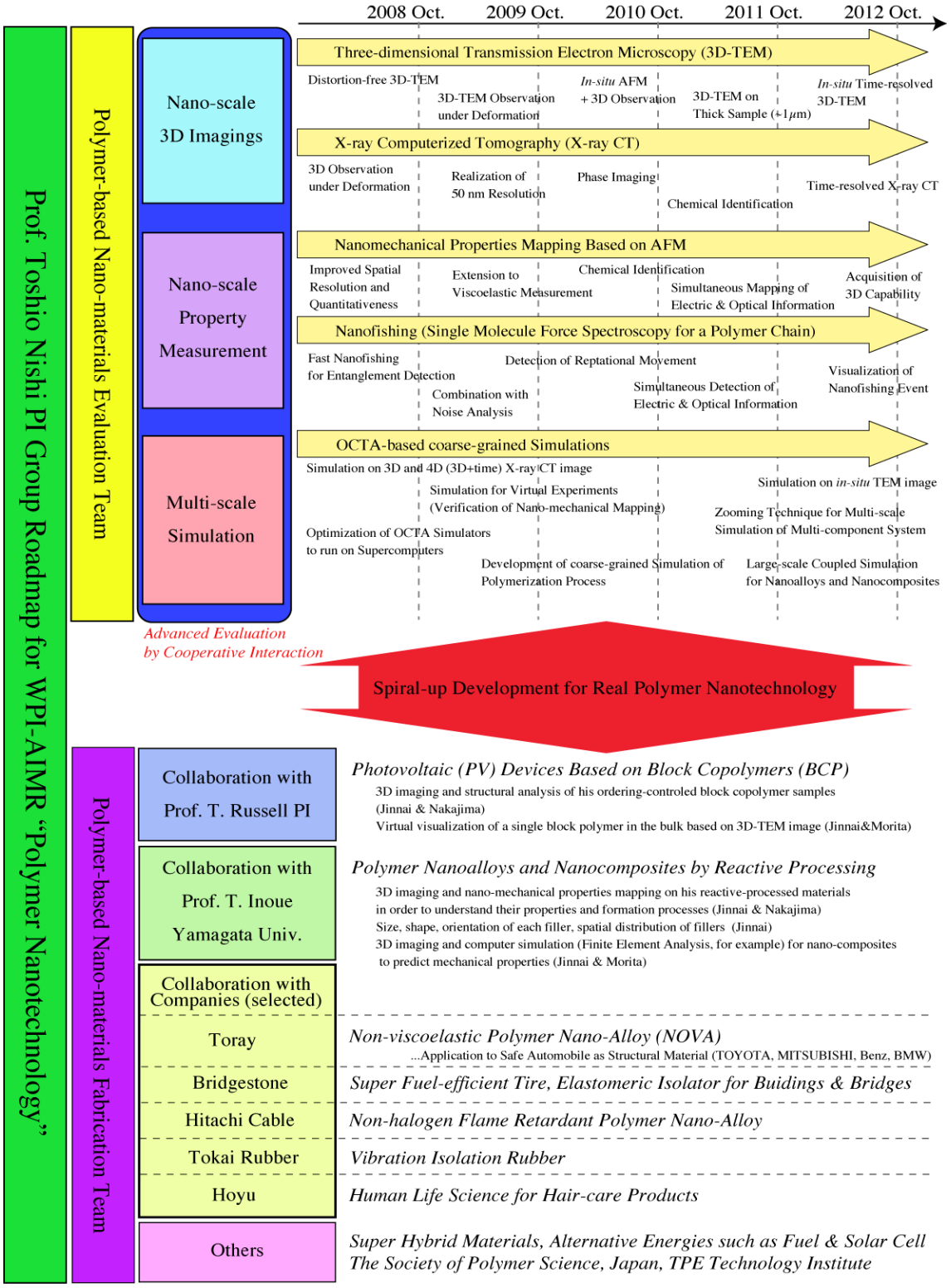

Figure 2. Five-years roadmap of Nishi PI's group

2. Nano-Palpation

The mainstay of polymer industry is composed of three articles, *i.e.*, textile, rubber and plastic. It is no doubt for these articles to be of great importance among the whole industrial circles. Polymeric materials have a lot of interesting electronic or optical characteristics, while SPM techniques do not contribute to these properties much far beyond other characterization tools at least at this moment. Instead, the advantage of SPM, AFM, has been properly recognized when polymers as structural materials has to be investigated. Therefore, our emphasis in this research will be placed on nano-mechanic AFM from the point of view of material scientists as shown in Figure 3. [16)]

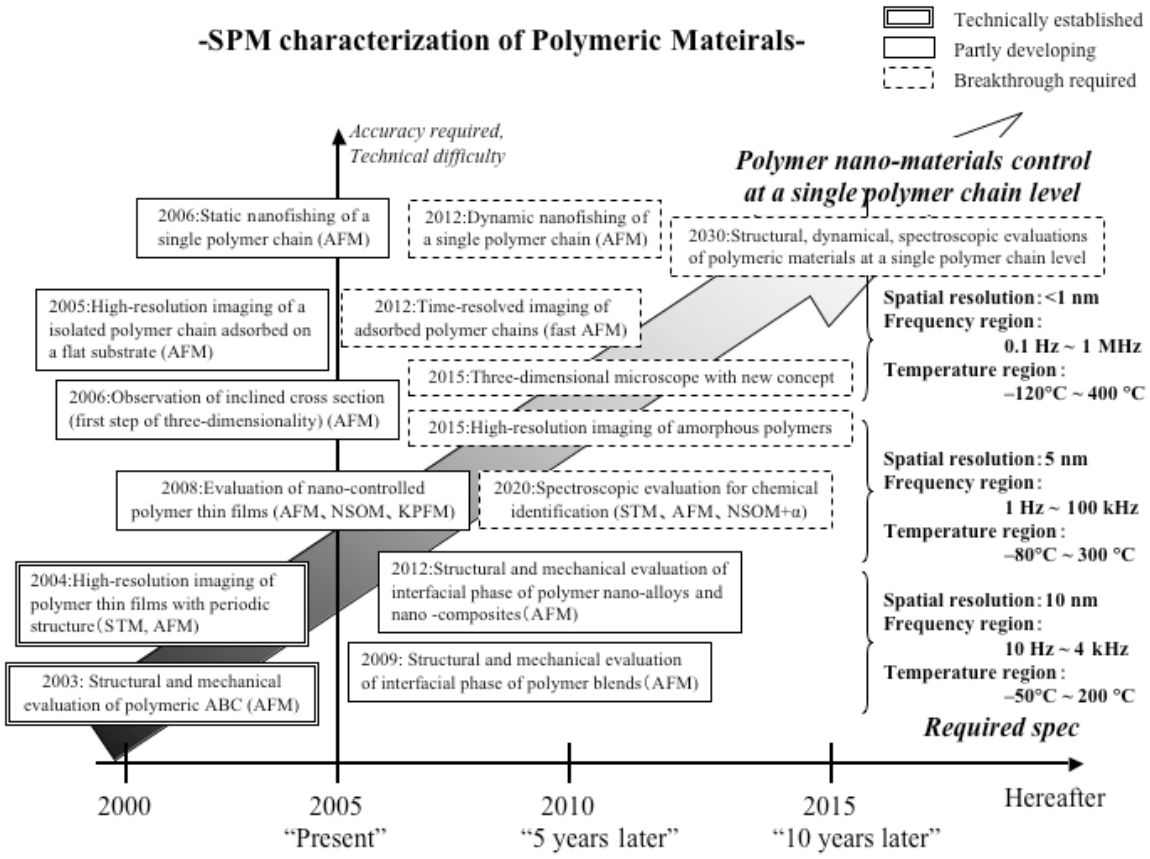

Figure 3. AFM roadmap for the characterization of polymeric nano-materials [16)]

Nanotechnology is also on the upward trend in polymer industry. In fact, the structures in nm-scale are exceedingly essential in treating polymeric structures and properties, for example, amorphous polymers, the lamellar thickness of crystalline polymers, micro-phase separated structures of block or graft copolymers, crosslink point of rubbers, the interfacial phases between polymer alloys, blends and composites (polymer ABC). Polymer nano-composites, where the size of composite materials is in the range of nm-scale, have also drawn much attention in the recent studies. These structures, as well as their molecular-level

dynamics, are the control parameters in order to realize polymeric nano-materials. The social demands to these materials at present and in the future can be widely spread; lightweight, high-strength, highly-elastic materials, surface functional materials, thermoplastic elastomers, fuel-efficient or wear-resistant tires, separation membranes, medical biomaterials, sensor materials can hardly be realized by homogeneous materials. Thus, polymeric nano-materials, which is essentially heterogeneous materials, have drawn much attention these days and furthermore AFM has been recognized as a very powerful tool to perform structural analyses on such materials.

However, researches to date have mainly focused on structural observations, or at most qualitative characterization of mechanical properties. Quantitative analyses must be a key to expand the marketing share, especially on the interfacial structures and mechanical properties for heterogeneous constituents. Since many polymers are in glassy or fluid states except for some specific conditions, and thus amorphous, any high-resolution imaging is not possible or required in many cases, although such a technology has to be established in the future to increase the AFM ability. In addition, different from other materials, the elastic moduli of polymers are extremely low, resulting easily in the deformation by nN or pN-level forces. One might feel that this is a serious disadvantage, while we turn this disadvantage into an advantage with developing characterization methodologies of sample elasticity in quantitative ways (nano-palpation). Three items are important in this point; an adequate selection of mathematical models to describe contact mechanics, a precise determination of cantilever spring constant, and a sufficient estimation of probe tip shape. As for the latter two, there have been many different techniques developed in recent years. Especially, it was reported that the tip shape must be treated as hyperboloid instead of simple spherical or conical shapes to perform better quantitative measure. [17] In any case, the most important factor is the former item, *i.e.*, the selection of mechanical models. Several models have been widely used for the purpose such as Herzian, [18] or Johnson-Kendall-Roberts (JKR) [19] theories. Furthermore, a guiding principle have been established which models are the most appropriate, depending on the degree of load, sample elasticity, and the existence of adhesive interactions. [20] Any new design for non-classical model may be necessary in the future, however, which must be preceded by checking the applicability of these classical models at least for a few years.

As easily understood, the AFM images for polymeric materials in many cases do not represent real topographic features due to sample deformation neither in contact mode nor in tapping mode. Even if quantitative analyses on surface elastic properties were successfully made by the above-mentioned methods, the failure in obtaining real topography causes the misleading interpretation because both unreal apparent topographic and mechanical images would contradict to each other. Recently, a method was developed where a sample deformation image was obtained from force-distance curve anaysis and it was used to

compensate an apparent topographic image into a real topographic image (nano-mechanic AFM). [5] The method must urgently be applied to the study on nano-alloy and nano-composite systems.

The formulation of tapping-mode operation increasingly becomes important in conjunction with the argument of energy dissipation. As recognized by many researchers, the problem has arisen in the interpretation of phase images because phase shift should occur not only in the case of viscous contribution but also in the existence of adhesive hysteresis. [21] Since polymeric materials have elasticity and viscosity at the same time, in other words, viscoelasticity by nature, the interpretation becomes more complicated. Thus, a certain investigation is really required whether a sample viscosity is properly observed or not. Polymers in general obey time-temperature superposition principle as the resultant effect of viscoelasticity. Soft materials can behave as hard materials by temperature lowering or frequency increase (shortening of characteristic time scale). [4] It has become possible to purchase a commercially available AFM instrument with superior temperature control, while it is required to develop a novel instrument capable of wide-range frequency sweep to provide complementary information. It is difficult to use cantilever resonant frequency for the purpose. A certain breakthrough is inevitable. Figure 3 shows regions of temperature and frequency required in the near future.

It is necessary to realize a single polymer chain experiment for the future prospect (nano-fishing). It is a dream in the field of polymer science to characterize and to precisely control a single polymer chain for the purpose of achieving better macroscopic properties. The acquisition of three-dimensionality in SPM imaging must be realized within ten years. The observation of inclined cross-section can possibly be the first step toward the direction. [6] In the following two sections. I will show recent progresses of two nano-palpation examples, nano-mechanic AFM (§3) and nano-fishing (§4).

3. Nano-mechanic AFM

As discussed, AFM is widely used in the world as an *imaging tool* for elastic samples like polymers and biomaterials. Contact and tapping mode operations are known as major imaging modes. Samples are scanned over their surfaces with mechanical contact in both modes. Thus, it has been said that topographic images from both modes are affected by contact or tapping forces. One could qualitatively understand the influence of a contact or tapping forces for the obtained topographic images in the past. However, Jiao *et al.* reported recently that imaging setpoints of contact or tapping modes affected the obtained topographic image of chromosome. They claimed that force mapping mode should be used whenever the height or volume of soft samples are needed to be determined accurately. [22]

Now, the quantitative method, nano-mechanic AFM, to obtain accurate topographic

images of elastic samples together with Young's modulus distribution images will be introduced. Especially, the emphasis may be placed on rubbery or melt states of polymeric materials that are commonly difficult for AFM to deal with. The thin film of polymer blend sample as a model system are investigated, which consists of polystyrene (PS) (M_n = 43,900, M_w/M_n = 1.01) as a stiff material (3 GPa) and polyisobutyrene (PIB) (M_n = 200,000, M_w/M_n = 2.50) as elastic one (3 MPa). Their glass-transition temperature, T_g, are 100°C and –76°C, respectively. These polymers are immiscible at room temperature. Thus, this system is suitable for comparing influences of elasticity on topographic images because this blend sample should have "sea-island" phase separating structure and they have very different Young's modulus from each other. The procedure to rebuild a "real height image" from an original "apparent height image" and a sample deformation image obtained from force-volume measurement will be also described.

The value of a cantilever spring constant is an important factor to detect mechanical properties from a sample surface. If the spring constant is very small, the cantilever approaching to the surface cannot deform the sample. If the spring constant is very large, instead, the cantilever can deform the sample, without any deflection. Therefore, necessary information about the sample is lacking. Thus, it is necessary to choose a cantilever with an appropriate spring constant. As will be shown later in detail, in the PS/PIB blend sample, the cantilever used in this study can largely deform PIB rich island part, while PS rich matrix hardly deforms. Although several calibration techniques have been established to date, [23-25] a nominal value (0.58 N/m) is used for the spring constant in this study.

To obtain the mapping of the local mechanical properties of polymer blend, force-volume measurement is performed. In this mode, force-distance curve data are recorded until a given cantilever deflection value (trigger setpoint) is attained for 64 × 64 points over two-dimensional surface. At the same time, z-piezo displacement corresponding to the trigger setpoint deflection is recorded to build a topographic image. The topographic image taken in this mode is basically the same from that by conventional contact mode if contact force setpoint and trigger setpoint are identical. If all the points over the surface are stiff enough, the set of recorded displacements represents the topographic feature (real height) for the sample. However, if the surface deforms as shown in Figure 4(a), it is no more valid to regard an obtained data as the real topographic information. It will be demonstrated that "real height image" can be reconstructed even for such elastic samples if a curve fitting technique is employed for the obtained force-distance curves.

There have been a variety of theoretical models to describe the mechanical contact between the two bodies under external load and many of such theories have been used to analyze force-distance curves as described. [19] Among them, Hertz theory [17] has been most

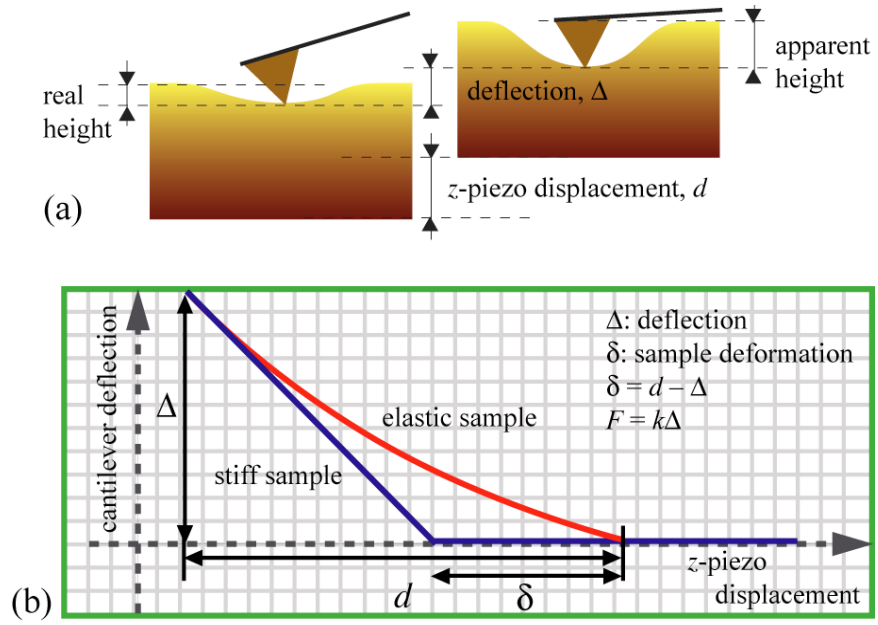

Figure 4 (a) The schematic drawing of sample deformation for an elastic sample. (b) The comparison between force-distance curves for stiff and elastic samples.

widely used because of its simplicity, where the absence of adhesion is assumed. One can adopt some theories such as JKR model [18] in order to treat adhesive interaction. However, Hertz contact is used for the study to make the discussion clear. For the purpose of increasing the validity of Hertz model, our attention is only placed on approaching process in a liquid circumstance.

A force-distance curve gives the relationship between the z-piezo displacement and the cantilever deflection as shown in Figure 4(b). When a cantilever approaches to a stiff sample surface, cantilever deflection, Δ, is equal to the z-piezo displacement, *d*. On the other hand, z-piezo displacement becomes larger to achieve the preset trigger value of the cantilever deflection in the case of an elastic sample due to the deformation of the sample itself. In other words, we can obtain information about a sample deformation, δ, from the force-distance curve of the elastic surface by the following equation (nano-palpation).

$$\delta = d - \Delta, \tag{1}$$

$$F = k \cdot \Delta, \tag{2}$$

where F is force and k is the spring constant of the cantilever. The Young's modulus can be obtained from the force-distance curve by analyzing the sample deformation under external loads, F. In the case of a cantilever having a stiff and conical (not hemispheric) tip, Hertz model predicts the following equation, [5]

$$d = \frac{F}{k} + \sqrt{\frac{\pi}{2}\frac{F\left(1-\nu^2\right)}{E\tan\alpha}} \tag{3}$$

where α is the half-angle of the conical tip (35°). Here the Poisson's ratio, ν, is fixed at 0.5 for simplification.

Figure 5 shows the height image of a PS/PIB blend thin film on a glass substrate in tapping mode. The scan size is 10 μm. PIB-rich island structures are spread over a PS-rich matrix. These islands sometimes appear as depressions, while some protrusive islands are also observed. The height image obtained by a force volume measurement on the same sample is shown in Figure 6. [5] Trigger setpoint (maximum limit of cantilever deflection) is 150 nm. Contrary to the tapping height image, all of the PIB rich phases are observed as depressions. For each 64 × 64 pixels, a force-distance curve was incorporated. Guided by the idea shown in Figure 4(b) and Eq. (2), it is possible to plot a

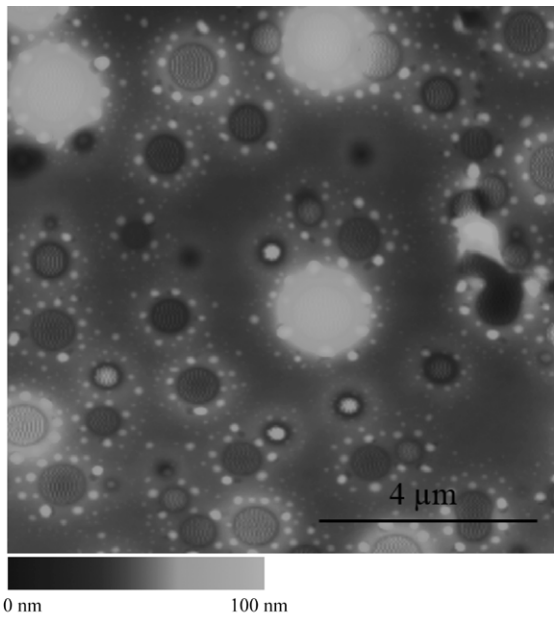

Figure 5 The height image of a PS/PIB blend thin film on a glass substrate in tapping mode.

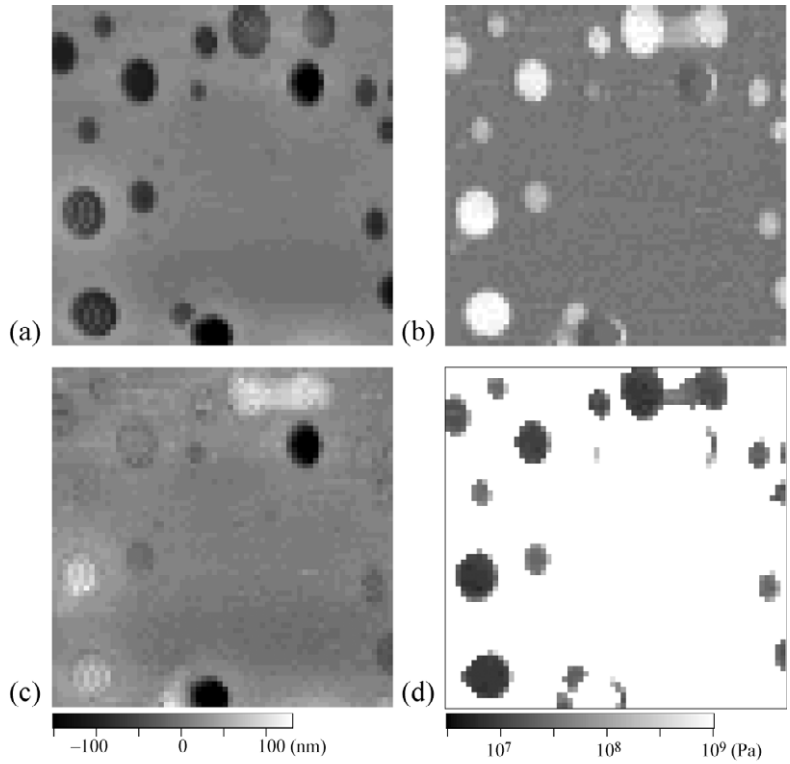

Figure 6 The result of a force volume measurement on the same sample. (a) The force volume (apparent) height image, (b) the sample deformation image, (c) the reconstructed real height image and (d) the Young's modulus distribution image. [5]

sample deformation image as shown in Figure 6(b).

Then, the reconstruction of the “real height image” is performed by adding the force volume “apparent height” and the sample deformation images. The result is given in Figure 6(c). At a glance, this reconstructed image at least qualitatively resembled to the tapping height image in Figure 5. There are protrusions together with depressions. In short, obtained force volume height image is an artifact caused by the very small elastic modulus of PIB-rich phase. In contrast to the fact that many of depressions became shallower, it was also found that there existed two “real” deep depressions of which depth was unchanged by the reconstruction procedure (upper-right and lower-middle islands). Such depressions have a depth of around 200 nm where the sample deformation is almost zero. They are thus attributed to the bare glass substrate due to the film thickness.

Next, the Young's modulus is calculated by the curve fitting of a set of force-distance curves. The experimental data are fairly fitted to Eq. (3) for PIB-rich phase. Because the stiffness of PS-rich phase is sufficiently large, the part cannot be deformed like PIB-rich one for the cantilever used here (k = 0.58 N/m). Then, the curve fitting to Hertz model always fails. Therefore, such parts are automatically excluded by judging a mean square-root error. The mapping of the Young's modulus distribution is shown in Figure 6(d). Non-calculated parts are painted by the white color. The depressions where bare glass substrate appeared are hard as expected, while their surroundings are somewhat softer. In the upper part of the image, a region between the two protrusions seems to be soft, while such information is hardly obtained from Figure 6(a). Thus, it must be claimed that Young's modulus images should be compared with the “real height” images if one want to make a clear correlation in-between.

We have already extended the above-mentioned technique to several polymeric systems such as elongated elastomers, [26,27] carbon black reinforced natural rubber, [28,29] carbon nanotube reinforced natural rubber (in collaboration with Nissin Kogyo, Co.), nano-alloy of nylon and a certain kind of rubber produced by twin-screw extruder with L/D = 100 (in collaboration with Prof. Inoue and Toray, Co.). One of the best examples would be the application of this technique to human hair cross-section (in collaboration with Hoyu, Co.). [30]

The hair has a complicated hierarchical structure which is composed of hydrophobic and hydrophilic components. It is important to understand mechanical properties of each component in micro level in order to understand a texture of hair in macro level and develop hair care products. Nano-mechanic AFM using stiff cantilevers in order to deform a sample by AFM enable us to evaluate Young’s modulus and a fine structure simultaneously at the same point. In this study, we applied this method to hair cross section in order to evaluate the degree of hair damage.

The Yong’s modulus mapping images of hair cross section are shown in Figure 7. As for the damage hair (B), the Young’s modulus at the whole area was lower than virgin hair (A)

and intermacrofibrilar matrix among the macrofibrils was weakening site specifically. We found that the Young's modulus was improved when the damage hair was treated by L-teanine solution (C) and especially Young's modulus of macrofibril was recovered. In this way, this method is very useful to appraise the effectiveness of hair care components.

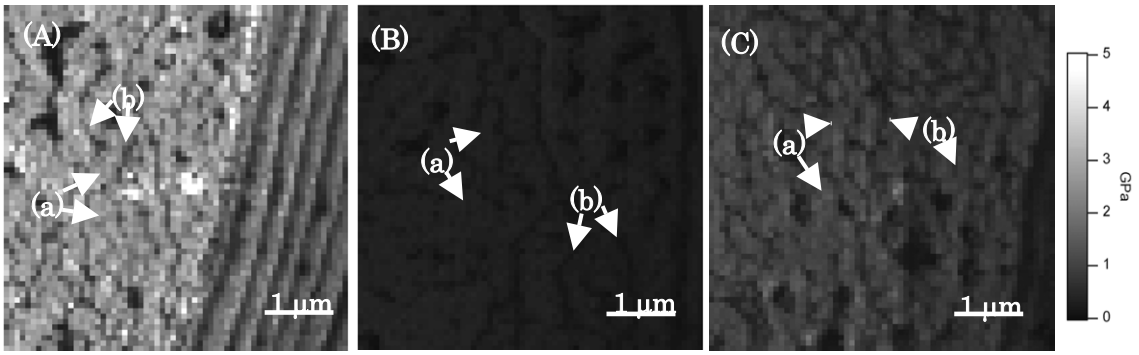

Figure 7. Young's modulus mappings of hair cross section in water. (A) Virgin hair (B) damaged hair and (C) damaged hair treated with 2% L-teanine aqueous solution. (a) macrofibril and (b)macrofibrilar matrix

4. Nano-fishing

Nnano-fishing enables us to stretch a single polymer chain using force-spectroscopy mode of AFM. We can say that nano-fishing is the second and ultimate nano-palpation technique for polymeric materials. A stress-strain curve obtained for a polystyrene (PS) polymer chain with thiol termini in θ solvent showed a good agreement with a worm-like chain model, and thus gave microscopic information about entropic elasticity. The information obtained by this measurement does not give any energy dissipative interaction between polymer chains and liquid medium, while dynamic measurement reveals such information. A sinusoidal excitation was exerted mechanically on a cantilever in liquid condition to investigate single polymer chain viscosity, which is mainly attributed to monomer-solvent friction. We could conclude that the method was a powerful tool to reveal a basic concept in polymer physics.

4.1 Static Nanofishing

AFM has enabled us to visualize a small world consisting of atoms and molecules. The visualization of individual single polymer chains has been also already reported. [31] Furthermore, dozens of researchers have placed their attention on the expanded capability of AFM as force spectroscopy. With this technology, the relationship between force and deformation of a single molecule sandwiched has been measured. Our "nano-fishing" comes under this category. We have obtained a novel method for experimentally verifying the

statistical mechanics of a single polymer chain, which is indeed the basis of polymer physics. As in the case of strain-stress curves of rubber, we can now investigate such curves for single polymer chains like the conceptual experiment appeared in the textbook by Prof. P. G. de Gennes. [32] However, these trials have been especially dedicated to studies of "single protein unfolding" events, physisorbed macromolecules. From a comparison of such cases, synthesized polymers have many disadvantages. For instance, it is difficult to attach any reactive groups at their ends in general. Thus, the force-distance curve data obtained in uncontrolled experiments contain many complicated factors such as that the adsorptions occur not only at the tails but also at the loops. As described, however, successful nanofishing results on PS chains with chemically active termini were obtained and thus several statistical analyses could be conducted. [33]

An SH-terminated PS was used as a sample. It was based on a living polymerized COOH-terminated PS with M_n = 93,800 and M_W = 100,400. Its contour length was about 220 nm. The thiol groups were substituted for the COOH ends using 1,10-decanedithiol by means of thiolester bonding, anticipating the preferential interaction between thiol and gold. The polymer was dissolved in θ solvent, cyclohexane and the solution was cast on a Au(111) substrate. So as to pick up the SH-modified terminal, a gold-coated cantilever was used. The nominal value of its spring constant k_1 was 30 pN/nm. A typical force-extension curve measured in cyclohexane is shown in Figure 8. [33] The solvent temperature was kept at about 35°C, which corresponded to its θ temperature for PS chains. The initial slope was observed which should be attributed to single polymer chain elasticity caused by entropic contribution. As for further analysis, curve fitting against the worm-like chain (WLC) model was conducted:

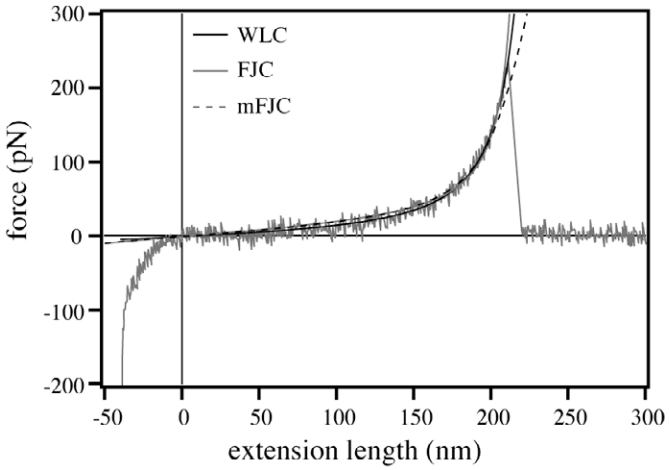

Figure 8. Static nanofishing of a single PS chain in cyclohexane. The solvent temperature was about 35°C. WLC (solid black line), FJC (solid grey line) and mFJC (dashed line) models were used to obtain fitting curves.

$$F(x) = \frac{k_B T}{l_P}\left[\frac{1}{4(1-x/L)^2} + \frac{x}{L} - \frac{1}{4}\right] \qquad (4)$$

where x is the extension length at an external load of F. l_p and L are persistence and contour

lengths, respectively. The fitting results were l_p = 0.24 ± 0.01 nm and L = 244.9 ± 0.6 nm. The persistence length almost corresponded to the length of a single monomer. We also checked the validity of other models such as freely jointed (FJC), modified FJC models. Thus, nanofishing could be used to judge the ever-present basic theories of polymer physics. Further examinations by changing solvent temperature proved to be useful in order to reveal statistical mechanical properties such as the second virial coefficient on a single polymer chain basis. [33,34] The results were explained well by Flory's lattice model, at least as the first approximation.

4.2 Dynamic Nanofishing

Static nanofishing merely gives static information about polymer chains. Therefore, viscoelasticity, which is a quite important property of polymers, seldom appears. Here, we describe the technique of revealing monomer- solvent friction for a single polymer chain. [35,36] The experimental setup was almost the same as that for the static measurement, while the cantilever was now vibrated at its resonant frequency ($f_1 = \omega_1/2\pi$ = 9.0 kHz). The oscillation amplitude was A = 6.0 nm when free oscillation was reached. In the case of successful nano-fishing, the amplitude decreased as in the case of the tapping-mode operation. The phase shift between input and output signals also deviated from 90°. The change in boundary condition by polymer chain attachment caused a change in the free oscillation of the cantilever.

To obtain information about the mechanical properties of a single polymer chain, we analyzed the separation-dependent amplitude and phase shift changes based on the phenomenological double Voigt model. Although detailed calculation is omitted, effective spring constant of a single polymer chain, k_2, and frictional coefficient, η_2, could be calculated as follows:

$$k_2 = \frac{A_1}{A}\left\{(-m\omega_1^2 + k_1)\cos\psi + \eta_1\omega_1 sin\psi\right\} - (-m\omega_1^2 + k_1) \qquad (5)$$

$$\eta_2 = \frac{A_1}{A\omega_1}\left\{\eta_1\omega_1\cos\psi - (-m\omega_1^2 + k_1)sin\psi\right\} - \eta_1 \qquad (6)$$

where A_1 is the oscillation amplitude without the polymer chain and ψ is the difference in phase shift with and without the polymer chain. m is effective mass of cantilever and η_2 is frictional coefficient measured without polymer chain. Figure 9 shows the obtained result. The stiffness of a single chain k_2 increased abruptly with stretching. This is commonly observed in conventional simple stretching experiments on polymers, as in Figure 8, *i.e.*, an almost constant value for spring constant at low extension and an apparent increase due to the fully stretched effect caused not only by entropic contribution but also by enthalpic contribution. A new result, only available by dynamic nanofishing for the frictional coefficient,

which might be related to viscosity, was obtained. At first glance, almost zero viscosity was observed in the low extension region. However, viscosity had a certain value in this region. The viscosity η_2 in the region (30-150 nm) averaged 2.62 × 10^{-9} kg/s. Note that this value is the first estimation of viscosity on a single polymer chain basis in a low extension region. We also found an interesting phenomenon in that viscosity also increased in the same manner as in k_2. This means that the experimental observation does not support free-draining model which was submitted to explain polymer-solvent friction in the past, [37] because the increase in viscosity in the higher extension region was never explained by this simple additivity. The increase might be related to an increase in the number of constituent molecules exposed to solvent friction. During the stretching event on simultaneous two polymer chains, measured viscosity showed a stepwise change as shown in Figure 10, that also support our idea.

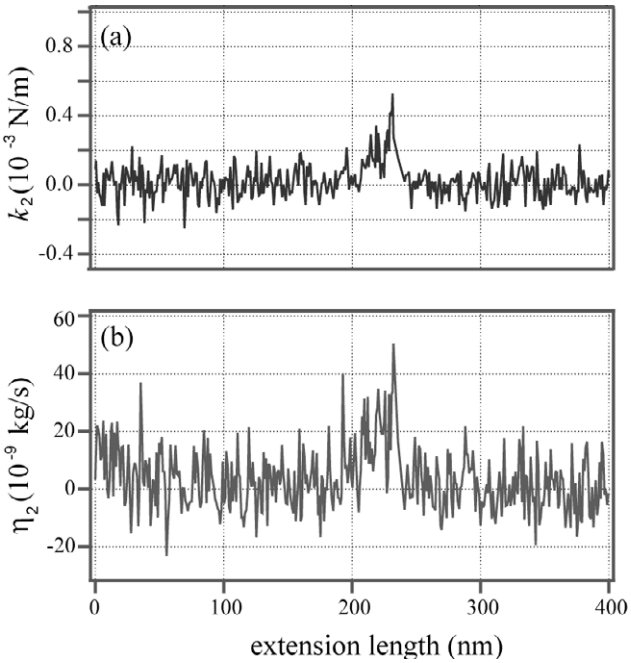

Figure 9. The behavior of (a) chain stiffness, k_2 and (b) viscosity of the chain, η_2 against the extension. The values were calculated by a double Voigt model.

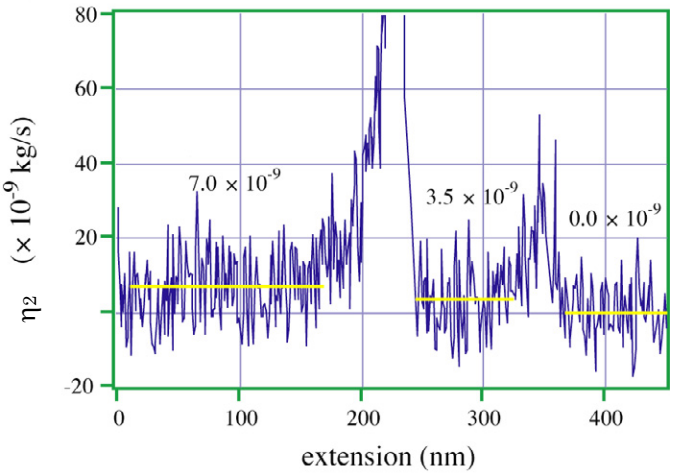

Figure 10. Quantized frictional coefficient during stretching two polymer chains at the same time.

5. Polymer Megatechnology

This is my personal opinion that nanotechnology, which has no example application for our daily-life size-scale, is barren technology. We do not forget about the comment made by Prof. Whitehouse, The University of Warwick, UK, who is one of the founders of nanotechnology: "You cannot drive a nano-car on the road." I dare say "You can drive a super car based on nanotechnology." All of the materials developed in "Nanostrucured Polymer Project" are not nano-materials merely for nano-scale world but much realistic nano-materials. For example, non-viscoelastic alloy (NOVA), fabricated by Prof. Inoue,

Yamagata University, is one of the best candidates for future big market. Several newspapers had reported the material as “hard but soft plastic at the same time,” “plastic with large deformation like rubbers by impact.” The key of the material’s specific feature is caused by nano-scale dispersion technique. Along this context, seismic isolators, that I am very much involved in its ISO standardization, would be an ultimate technology. One might think seismic isolators have nothing to do with nanotechnology, while its durability, dumping capability and adhesion condition between steel and rubber plates are the serious concern of nanotechnology after all. I call this technology as “megatechnology” because the maximum load that a single seismic isolator withstands reaches thousands tons, namely, 25 MN. A single polymer chain has pN-level elasticity. Then, this is very surprising thing that layer-built rubbery materials can endure MN loads. It is my dream to open a new era by bridging between nano and mega.

More than thirty years ago, I published my own work done in Bell Laboratory, Murray Hill, N.J., in the famous journal, *Macromolecules*. The title was “Melting-Point Depression and Kinetic Effect of Cooling on Crystallization in Poly(vinylidene fluoride)-Poly(methyl methacrylate) Mixtures.” The editorial office of *Macromolecules* recently announced the 10 most cited papers as one of its 40-years anniversary events and my paper was nominated as 5th one. The paper is the basis of impact resistant plastic bumbers used almost all cars in the world. I am very happy to announce this news to all of you involved in WPI-AIMR and would like to encourage you. Every thing necessary for your research has been already in your hand. Indeed, my paper is merely based on differential scanning calorimetry (DSC). What is necessary would be your own dream and bravery.

Acknowledgment

Nano-mechanic AFM is one of the main fruits obtained by “Nanostructured Polymer Project” by the Ministry of Economy, Trade, and Industry (METI), New Energy and Industrial Technology Development Organization (NEDO) and Japan Chemical Innovation Institute (JCII). Dr. Nakajima have developed nano-fishing techniques partially supported by a Grant-in-Aid for Young Scientists (A) (#18685028) from the Ministry of Education, Culture, Sports, Science and Technology.

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Job Recruitment

WPI Advanced Institute for Materials Research
Recruitment of Researchers

Outline of WPI Advanced Institute for Materials Research:

The proposal on the WPI research center for Advances Institute for Materials Research (WPI-AIMR) of Tohoku University was accepted by MEXT as one of the top 5 WPI research centers. Based on this proposal, Tohoku University established WPI Advance Institute for Materials Research on October 1, 2007.

The main objective of the Center is to promote the development of new materials under a world-leading organization for interdisciplinary research in functional materials, by use of an innovative method of atom and molecular control, departing from the typical approaches and moving towards the next generation. The center will pursue (1) the creation of new compounds and materials with innovative functions which exceed existing ones, (2) the construction of devices based on a new fundamental paradigm, and (3) the promotion of applied research projects on materials and system architecture that will generate direct social impacts (http://www.wpi-aimr.tohoku.ac.jp/en/index.html).

Number of positions:

More than 10 people for each position will be hired at the rank of Associate Professor, Assistant Professor, and Postdoctoral Research Fellow.

Starting date: as soon as possible

Employment conditions:

(1) Salary:
Associate and Assistant Professor: an annual income system is employed according to the rule of Tohoku University
Postdoctoral research fellow: competitive in a range of 4500000 and 6000000 yen.
(2) Research fund:
Cooperative research together with PI who manages the research fund is recommended, but independent research proposals for associate and assistant Professors are also encouraged.
(3) Tenure:
Associate and Assistant Professor: in principle 5 years term but every 2 years there is review process.
Postdoctoral research fellow: one year, but renewal is possible through review.

Documents for application:

(1) complete CV
(2) Publication list, including citation data
(3) Outline of past research accomplishments, and research proposal to be performed at WPI

The files of the above documents (pdf) should be sent to the following E-mail address; wpi-office@bureau.tohoku.ac.jp, or the print-out documents should be sent via regular mail to the following address; WPI Advanced Institute for Materials Research, Tohoku University, 980-8577 Katahira 2-1-1, Aoba-ku, Sendai, Japan

Deadline for applications: The deadline for first round recruitment is the end of January 2008..

(Physics Today Advertisement)
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WPI-AIMR

Effective October 1, 2007, Tohoku University created a new Research Institute, the Advanced Institute for Materials Research (AIMR), based on an initiative of the Japanese Department of Education (MEXT) for World Premier International Research Center Initiative (WPI) to bring together scientists involved in research on nano-science and technology.
In the 21st century, material science, broadly defined as the study of how complex/novel properties arise in matters/materials from the interactions of individual components, will comprise of inter-discipline collaboration.
(HTTP://WWW.WPI-AIMR.TOHOKU.AC.JP).
Over the next few years, as many as one hundred new appointments at the levels of post-doctoral fellows and junior faculty will be available. All innovative researchers are welcome as active promoters of basic/applied sciences in the fields of physical metallurgy, physics, chemistry, precision mechanical engineering and electronic / informational engineering..

We are particularly interested in applications for assistant professor positions (tenure track), but will consider exceptional candidates for other positions as well.
Applications are due by **January 31, 2008**.
Please submit

1) **a curriculum vitae,**
2) **research proposal (<3,000 words),**
3) **summary of previous research accomplishments (<2,000 words),**
4) **copies of 5 significant publications, and**
5) **2 letters of recommendation**

by email to **sakurai@imr.tohoku.ac.jp,** and **wpi-office@bureau.tohoku.ac.jp**.
All files must be submitted electronically in pdf or Word format.

Applications from, or nominations of, women and minority candidates are encouraged. Tohoku University WPI-AIMR is an affirmative action / equal opportunity employer

Graduate Student scholarship
In Materials Science/Engineering

WPI-AIMR
Graduate Student scholarship

Effective October 1, 2007, Tohoku University created a new Research Institute, the Advanced Institute for Materials Research (AIMR), based on an initiative of the Japanese Department of Education (MEXT) for World Premier International Research Center Initiative (WPI) to bring together scientists involved in research on nano-science and technology.
In the 21st century, material science, broadly defined as the study of how complex/novel properties arise in matters/materials from the interactions of individual components, will becomes an essential and most important research topics
(HTTP://WWW.WPI-AIMR.TOHOKU.AC.JP).
TU WPI-AIMR is now looking for young motivated Ph.D. graduate student candidates in the fields of physical metallurgy, physics, chemistry, mechanical engineering and electronic / informational technology. All innovative M. S. students are welcome as active promoters of basic/applied sciences in these fields.

Applications are continuously screened throughout the year.
Please submit
1) a curriculum vitae,
2) research proposal (<1,000 words),
3) 2 letters of recommendation,
by email to
yoshi@mail.tains.tohoku.ac.jp,
sakurai@imr.tohoku.ac.jp, and
wpi-office@bureau.tohoku.ac.jp.
All files must be submitted electronically in pdf or Word format.

Workshop Guideline

WPI-AIMR

Workshop Guideline

Tohoku University's new Research Institute, the Advanced Institute for Materials Research (WPI-AIMR) solicits several applications per year for International Workshops in the field of "broadly defined Materials Science."

Guidelines:

1) Organizers

Qualified research staff of academic institutions and public or private research establishments can submit the application for an international workshop to be held at WPI-AIMR or its Satellite branches, jointly with the WPI-AIMR principal investigator(s) whose research interest overlaps with the scope of the workshop..

2) Financial support

Under normal circumstances, WPI-IMR supports up to 2/3 of the workshop budget, while the organizer is expected to cover the rest.

3) deadline

The application must be received at least four months in advance

to

yoshi@mail.tains.tohoku.ac.jp,
sakurai@imr.tohoku.ac.jp, and
wpi-office@bureau.tohoku.ac.jp.

All files must be submitted electronically in pdf or Word format.

Appendix

Inauguration Ceremony snapshots


東北大学
TOHOKU UNIVERSITY

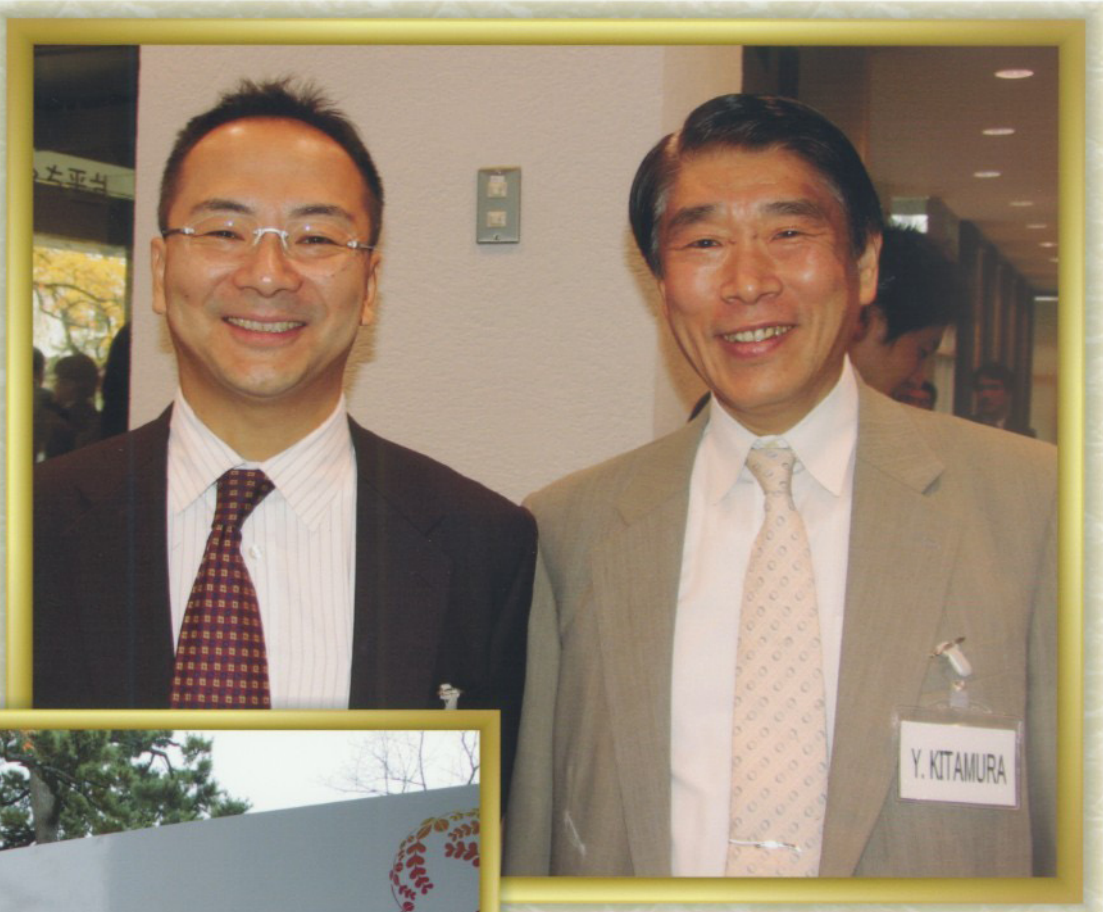

H. ABE
H. ROHRER


Y. YAMAMOTO


M. KAWASAKI
T. HASHIZUME

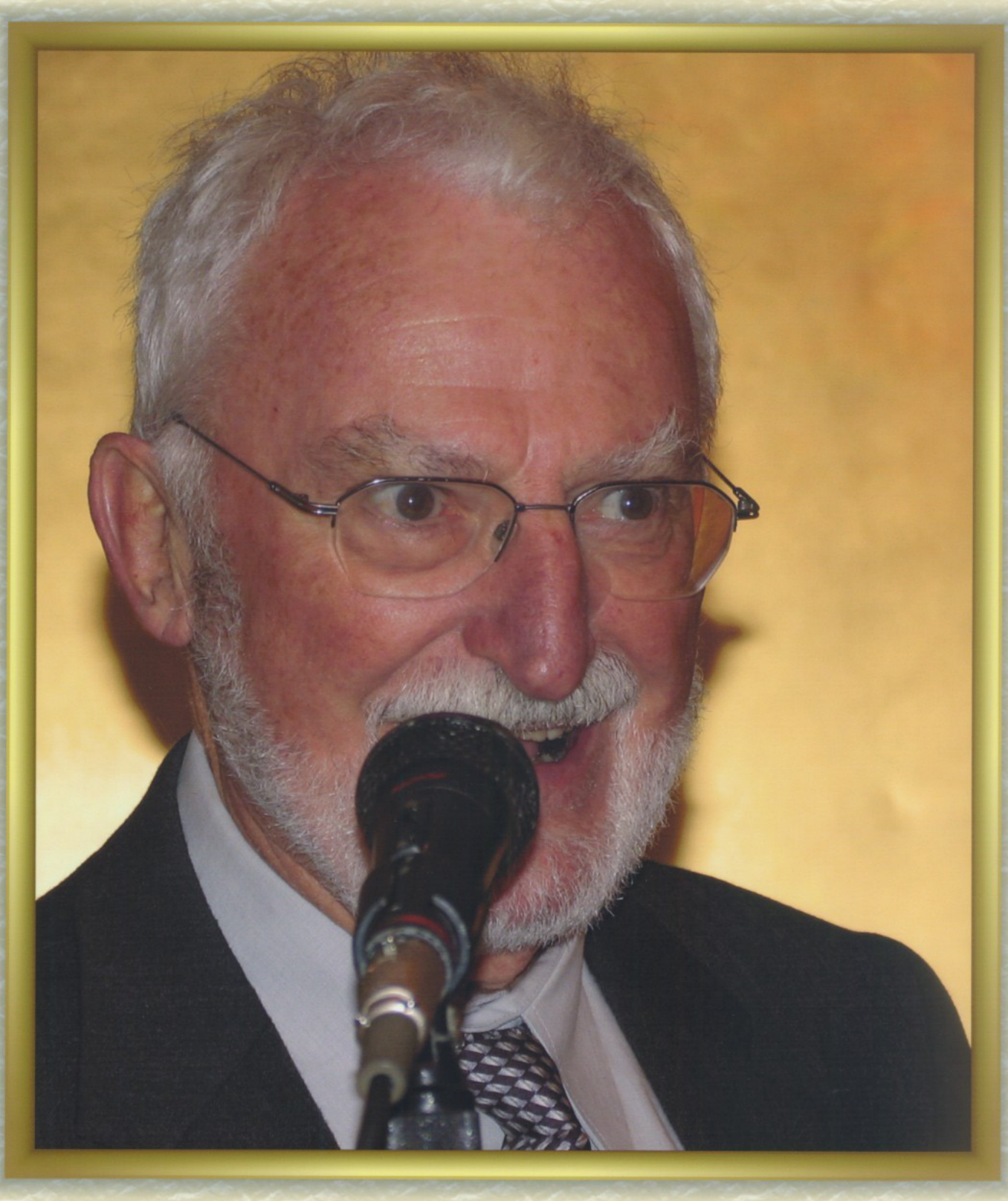

Y. TAKAMURA
H. ROHRER


S. HYODO


Y. KITAMURA


TOHOKU
UNIVERSITY
Inauguration Ceremony
of
WPI Advanced Institute for Materials Research
Tohoku University
I. 12:00 noon~
Inauguration Ceremony (Katahira Sakura Hall)
II. 2:00 pm~
Technical Sessions (Katahira Sakura Hall)
WPI-A
TOHOKU UNI


R. M. TROMP




Y. KITAMURA


A. INOUE
Asahi


S. HYOU


T. HASHIZUME
Y. KITAMURA


R. M. TROMP
Y. YAMAMOTO


T. SAKURAI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