

RMW9

The 9th Workshop on Reactive Metal Processing

February 21 (Fri.) - 22 (Sat.), 2014 @ Caltech
Pasadena, California

Organizers

Donald R. Sadoway, *Massachusetts Institute of Technology*

Toru H. Okabe, *IIS, the University of Tokyo*

Sossina M. Haile, *California Institute of Technology*

Tetsuya Uda, *Kyoto University*

<http://www.okabe.iis.u-tokyo.ac.jp/core-to-core/rmw/>

The 9th Workshop on Reactive Metal Processing

February 21 (Friday) - 22 (Saturday), 2014, Caltech, Pasadena, CA

Time:

- 1st day: on Feb. 21 (9:00 - 18:20 and 18:30 - Banquet)
- 2nd day: on Feb. 22 (9:00 - 15:00 and 15:00 - Lab. tour)

Refreshment will be prepared around 8:40 AM in both days on the patio of Beckman Institute.

Venue:

- Beckman Institute at Caltech (for invited lectures)

Beckman Institute Auditorium, Building No.74 on Campus Map,
1200 East California Boulevard, Pasadena, CA 91125

- The Athenaeum at Caltech (for banquet)

<http://athenaeum.caltech.edu/>

Organizers:

Prof. Donald R. Sadoway,

Massachusetts Institute of Technology

Prof. Toru H. Okabe,

Institute of Industrial Science, the University of Tokyo

Prof. Sossina M. Haile,

California Institute of Technology

Prof. Tetsuya Uda,

Kyoto University

Program Coordinators:

Dr. Yu-ki Taninouchi,

Institute of Industrial Science, the University of Tokyo

Mr. Takayuki Onishi and Ms. Sakae Shirayama

Kyoto University

Sponsor:

The workshop is financially supported by the Kyoto University Foundation (<http://www.kyodai-zaidan.or.jp/foundation/outline.html>), the Strategic Young Researcher Overseas Visits Program for Accelerating Brain Circulation by JSPS, the Rare Metal Research Workshop (RC-40: directed by Prof. T. H. Okabe), one of the Special Research Group organized by the Foundation for the Promotion of Industrial Science (FPIS), the funding program for Next Generation World-Leading Researchers (NEXT program by JSPS).

Registration Fee:

\$200 / person (including banquet)

NOTICE: Please prepare to pay the registration fee in cash !

Contact Address:

Yu-ki Taninouchi, *Institute of Industrial Science, the University of Tokyo*

E-mail: taninou@iis.u-tokyo.ac.jp Phone: +81-3-5452-6638

Workshop Program

Day 1

Morning session 1, February 21 (Friday), 2014 @ Beckman Institute Auditorium

9:00 **Opening Remarks**
Prof. Toru H. Okabe, Institute of Industrial Science (IIS), The University of Tokyo

Session Chair: *Prof. Sossina M. Haile*

9:10 – 9:40 **“Bulk Metallic Glasses; Science and Technology”**
William L. Johnson,
California Institute of Technology

9:40 – 10:10 **“A Unique Reactive Metal: Beryllium Extraction and Its Usage”**
James A. Yurko,
Materion Brush Beryllium & Composites

10:10 – 10:40 **“Direct Observation of Marangoni Convection on Molten Salts”**
Takashi Nakamura,
Institute of Multidisciplinary Research for Advanced Materials (IRCSM),
Tohoku University

10:40 – 11:00 **Break**

Morning session 2, February 21 (Friday), 2014 @ Beckman Institute Auditorium

Session Chair: *Prof. Geir M. Haarberg*

11:00 – 11:30 **“Molten Compounds: from Sustainable Metal Extraction to Thermoelectricity”**

Antoine Allanore,

Department of Materials Science & Engineering,

Massachusetts Institute of Technology

11:30 – 12:00 **“Fundamental Study on Anodic Dissolution Process of Platinum Group Metals in Molten Salt (Tentative)”**

Katsuhiko Nose, Toru H. Okabe,

Institute of Industrial Science, The University of Tokyo

12:00 – 13:00 **Lunch Break**

Afternoon session 1, February 21 (Friday), 2014 @ Beckman Institute Auditorium

Session Chair: *Prof. Tetsuya Uda*

13:00 – 13:30 **“Ceria and its Derivatives as Substrates for Solar-driven Thermochemical Fuel Production”**

Sossina M. Haile,

California Institute of Technology

13:30 – 14:00 **“Development of Calcium-based Liquid Metal Batteries”**

Takanari Ouchi, Hojong Kim, Donald R. Sadoway,

Materials Science and Engineering, Massachusetts Institute of Technology

14:00 – 14:30 **“New Approaches for Membrane Based Liquid Metal Batteries”**

Ole S. Kjos,

SINTEF Materials and Chemistry

14:30 – 14:50 **Break**

Afternoon session 2, February 21 (Friday), 2014 @ Beckman Institute Auditorium

Session Chair: *Dr. Yu-ki Taninouchi*

14:50 – 16:20 **3-min short presentation by poster presenters**

16:20 – 18:20 **Poster Session** @ the fountain square “gene pool”

18:30 – **Banquet** @ the Athenaeum

Day 2

Morning session 1, February 22 (Saturday), 2014 @ Beckman Institute Auditorium

9:00 **Opening Remarks**
Prof. Tetsuya Uda, Kyoto University

Session Chair: *Prof. Georges J. Kipouros*

9:05 – 9:25 **“Possibility of Nickel/Cobalt Separation by Aqueous-Aqueous Solvent Extraction”**
Sakae Shirayama, Tetsuya Uda,
Department of Materials Science and Engineering, Graduate School of Engineering, Kyoto University

9:25 – 9:55 **“Phase Diagrams and Intrinsic Defects in Thermoelectric Alloys”**
Jeffery G. Snyder,
California Institute of Technology

9:55 – 10:25 **“Recycling of Rare Earth Magnet Alloy Using Molten Fluoride”**
Osamu Takeda, Kiyotaka Nakano, Yuzuru Sato, Hongmin Zhu,
Department of Metallurgy, Graduate School of Engineering, Tohoku University

10:25 – 10:40 **Break**

Morning session 2, February 22 (Saturday), 2014 @ Beckman Institute Auditorium

Session Chair: *Dr. Adam C. Powell IV*

- 10:40 – 11:00 **“Evaluation of Cathode Overpotential of Fuel Cell with Y-doped BaZrO₃ Electrolyte”**
*Takayuki Onishi*¹, *Yohei Noda*^{1,2}, *Donglin Han*¹, *Naoyuki Hatada*¹, *Masatoshi Majima*², *Tetsuya Uda*¹,
1: Department of Materials Science and Engineering, Kyoto University
2: Sumitomo Electric Industries, Ltd.
- 11:00 – 11:30 **“Liquid Metal Batteries: Past, Present, and Future”**
*Hojong Kim*¹, *Donald R. Sadoway*²,
1: Materials Science and Engineering, Penn State University
2: Materials Science and Engineering, Massachusetts Institute of Technology
- 11:30 – 12:00 **“A New Electroplating Method Using Water-soluble Molten KF-KCl Systems”**
*Kouji Yasuda*¹, *Kazuma Maeda*¹, *Toshiyuki Nohira*¹, *Rika Hagiwara*¹, and *Takayuki Homma*²,
1: Graduate School of Energy Science, Kyoto University
2: Faculty of Science and Engineering, Waseda University
- 12:00 – 12:20 **Photo Session** @ Beckman Auditorium
- 12:20 – 13:20 **Lunch Break**

Afternoon session, February 22 (Saturday), 2014 @ Beckman Institute Auditorium

Session Chair: *Prof. Antoine Allanore*

13:20 – 13:50 **“Mechanisms for Current Efficiency for Aluminium Deposition from Cryolite-alumina Melts”**

Geir M. Haarberg,

Norwegian University of Science and Technology

13:50 – 14:20 **“A Breakthrough in the Boron Removal from Silicon by Combining Slag Treatment and Solvent Refining”**

*Kazuki Morita*¹, *Xiadong Ma*¹, and *Takeshi Yoshikawa*²,

1: Department of Materials Engineering, The University of Tokyo

2: Institute of Industrial Science, The University of Tokyo

14:20 – 14:50 **“Electrodeposition of Nickel-Phosphorus for Wire Bonding Applications from a Highly Conductive Citrate Bath”**

*Nazila Dadvand*¹, *George Jarjoura*², *Georges J. Kipouros*³,

1: TE Conectivity (TYCO Electronics)

2: Dalhousie University

3: College of Engineering, University of Saskatchewan

14:50 – 15:00 **Information for the Next RMW**

Prof. Toru H. Okabe, Institute of Industrial Science, the University of Tokyo

Closing Remarks

Prof. Sossina M. Haile, California Institute of Technology

15:00 – **Laboratory Tour (for applicants)**

Dr. Yoshihiro Yamazaki, California Institute of Technology

List of Poster Presentations

- 1. “Phase Formation of the Clathrate BaGe₅”**
*Umut Aydemir*¹, Michael Baitinger², Yuri Grin²,
1: Koc University
2: Max Planck Institute for Chemical Physics of Solids
- 2. “Recovery of Magnesium from Scrap”**
Subodh K. Das,
Phinix, LLC.
- 3. “A Study on the Solubility Limit of Iron in Ceria and Ceria-Zirconia Solid-Solutions”**
Hari P. Dasari, Ian Koss, Sossina M. Haile,
California Institute of Technology
- 4. “Thermodynamics of Ce_{0.9}Pr_{0.1}O_{2-δ} for Thermochemical Water Splitting”**
Timothy C. Davenport, Michael J. Ignatowich, Benjamin W. Slone, Stephen K. Wilke,
Yong Hao, Sossina M. Haile,
California Institute of Technology
- 5. “Characteristics of Particulate Emissions from Aluminium Electrolysis Cells”**
*Heiko Gaerther*¹, Arne Petter Ratvik², Thor Anders Aarhaug²,
1: Department of Materials Science and Engineering, Norwegian University of Science and
Technology
2: Materials and Chemistry, SINTEF
- 6. “An Innovative Electro-winning Process for Titanium Production”**
Guiseppa Granata, Ryota Sumiuchi and Yoshinao Kobayashi, Akio Fuwa,
School of Creative Science and Engineering, Waseda University
- 7. “Recycling of Titanium Metal Scrap through Chlorination by Using Reaction Mediator”**
Yuki Hamanaka, Yu-ki Taninouchi, Toru H. Okabe,
Institute of Industrial Science, The University of Tokyo

8. **“Investigation of Samarium Doped Ceria as a Catalyst for Thermochemical Fuel Production”**
Mike Ignatowich, Timothy C. Davenport, Sossina M. Haile,
California Institute of Technology

9. **“Nanostructured Thermoelectric Materials via a High-energy Nonequilibrium State”**
Teruyuki Ikeda,
Department of Materials Science and Engineering, Ibaraki University

10. **“Phase Relations for the Ce₂O₃-Al₂O₃-CaO System at Steelmaking Temperatures”**
Makoto Ishi, Ryo Kitano, Kazuki Morita,
Department of Materials Engineering, The University of Tokyo

11. **“Production of High-grade TiO₂ Feed from Ti Ore through Selective Chlorination Using TiCl₄”**
Jungshin Kang, Toru H. Okabe,
Institute of Industrial Science, The University of Tokyo

12. **“Thermodynamic Measurement by Double Knudsen Cell Mass Spectrometry for Metals”**
Yoshifumi Kobashi, Hideaki Sasaki, Masafumi Maeda,
Institute of Industrial Science, The University of Tokyo

13. **“A New Instrument to Discover Catalysts for Fuel Cells”**
Chris Kucharczyk, Rob Usiskin, Sossina M. Haile,
California Institute of Technology

14. **“Rare-earth Metals Extraction from Molten Oxides”**
Guillaume Lambotte, Rachel DeLucas, Tessa Green, Andrew Liotta, Antoine Allanore,
Department of Materials Science & Engineering, Massachusetts Institute of Technology

15. **“Effect of Current Density and Impurities on Current Efficiency in Aluminum Electrolysis at High Current Densities”**
Rauan Meirbekova^{1,2}, Geir Martin Haarberg², Jomar Thonstad², Gudrun Saevarsdottir¹,
1: School of Science and Engineering, Reykjavik University
2: Department of Materials Science and Engineering,
Norwegian University of Science and Technology

16. **“Recovery of Rare Earth Metals from Wasted Magnet”**
Takashi Nagai, Tatsuki Uzawa,
 Chiba Institute of Technology
17. **“Pure Oxygen Anodes for Efficient Clean Production of Reactive Metals”**
Adam C. Powell IV, Matthew Earlam, Salvador Barriga,
 INFINIUM, Inc.
18. **“Zinc Vapor Pretreatment for Acid Leaching of Precious Metals from Automotive Catalyst Converters”**
Hideaki Sasaki, Masafumi Maeda,
 Institute of Industrial Science, The University of Tokyo
19. **“Behavior of Uranium and Other Actinide Elements in the UO₂-ZrO₂ System for Fuel Debris Treatment”**
*Nobuaki Sato*¹, Akira Kirishima¹, Takayuki Sasaki²,
 1: Institute of Multidisciplinary Research for Advanced Materials, Tohoku University
 2: Department of Nuclear Engineering, Kyoto University
20. **“Separation of Iron and Titanium by Liquid Phase Oxidation”**
*Hidehiro Sekimoto*¹, Shuhei Yahaba², Katsunori Yamaguchi¹,
 1: Department of Materials Science and Engineering, Iwate University
 2: Frontier Materials and Function Engineering, Graduate school of Engineering,
 Iwate University
21. **“Understanding Anode Performance”**
*Camilla Sommerseth*¹, Rebecca Thorne¹, Ann Mari Svensson¹, Stein Rørvik²,
 Arne Petter Ratvik², Espen Sandnes³, Lorentz Petter Lossius³, Hogne Linga³,
 1: Department of Materials Science and Engineering,
 Norwegian University of Science and Technology
 2: SINTEF Materials and Chemistry
 3: Hydro Aluminium
22. **“New Upgrade Process for Autocatalyst Scrap to Recover the Platinum Group Metals”**
Yu-ki Taninouchi, Akinari Suzue, Toru H. Okabe,
 Institute of Industrial Science, The University of Tokyo

23. **“Direct Precipitation of Sr-doped LaP₃O₉ Thin Film Electrolytes for Intermediate-Temperature Fuel Cells in Condensed Phosphoric Acid Solutions”**
Kota Takahashi, Yoshinobu Adachi, Naoyuki Hatada, Tetsuya Uda,
 Department of Materials Science and Engineering, Kyoto University
24. **“Improving Thermoelectric Performance of Single-doped Skutterudites (Ga, In or Yb-CoSb₃) by Phase Diagram Study”**
*Yinglu Tang*¹, Yuting Qiu^{2,3}, Lili Xi², Pengfei Qiu², Xun Shi², Wenqing Zhang²,
 Lidong Chen², Yuan-chun Chien⁴, Ssu-Ming Tseng⁴, Sinn-wen Chen⁴,
 James R. Salvador⁵, Jung Y. Cho⁵, Jihui Yang⁵, G. Jeffrey Snyder¹,
 1: Department of Materials Science, California Institute of Technology
 2: State Key Laboratory of High Performance Ceramics and Superfine Microstructure,
 Shanghai Institute of Ceramics, Chinese Academy of Sciences
 3: Graduate University of Chinese Academy of Sciences
 4: Department of Chemical Engineering, National Tsing Hua University
 5: Materials Science & Engineering Department, University of Washington
25. **“Proton Trapping in Yttrium-doped Barium Zirconate”**
Yoshihiro Yamazaki^{1,2}, Frédéric Blanc³, Yuji Okuyama², Lucienne Buannic⁴,
 Juan C. Lucio-Vega², C.P. Grey^{3,4}, Sossina M. Haile²,
 1: Japan Science and Technology Agency
 2: California Institute of Technology
 3: University of Cambridge
 4: Stony Brook University
26. **“Reaction Behavior and Kinetics of Electrochemical Reduction of SiO₂ Granules in Molten CaCl₂”**
*Xiao Yang*¹, Kouji Yasuda^{1,2}, Toshiyuki Nohira¹, Rika Hagiwara¹, Koki Ichitsubo³,
 Kenta Masuda³, Takayuki Homma⁴,
 1: Graduate School of Energy Science, Kyoto University
 2: Environment, Safety, and Health Organization, Kyoto University
 3: R&D Center, Taiheiyo Cement Corporation
 4: Graduate School of Advanced Science and Engineering, Waseda University

27. **“Complex Zintl Phases as Thermoelectric Materials”**
*Saneyuki Ohno*¹, Alex Zevalkink², Sabah Bux², Eric Toberer¹, Jeff Snyder¹,
1: Department of Materials Science, California Institute of Technology
2: Jet Propulsion Laboratory
28. **“Interaction of Sodium and Graphite Materials Studied by Thermo-gravimetric Analysis - Assisted by FEM Simulations and DEF Calculations”**
*Zhaohui Wang*¹, Sverre M. Selbach¹, Arne P. Ratvik², Egil Skybakmoen², Tor Grande¹,
1: Norwegian University of Science and Technology
2: SINTEF Materials and Chemistry
29. **“A Tilt-casting Arc-melter with Ultra-high-purity Inert Atmosphere”**
Erno Soinila, Petri Mikkonen, Hannu Hänninen, *Sven Bossuyt*,
Department of Engineering Design and Production, Aalto University

List of Participants

2014/2/13

Allanore, Antoine	Assistant Professor	MIT
Aydemir, Umut	Postdoctoral Scholar	CALTECH
Åsheim, Henrik	Ph.D. Candidate	NTNU
Bajaj, Saurabh	Graduate Student	CALTECH
Barriga, Salvador	Research engineer & technical leader	INFINIUM, Inc.
Bossuyt, Sven	Professor	Aalto University
Chisholm, Calum R. I.	CEO & President	SAFCell, Inc.
Conner, R. Dale	Professor	California State University
Cui, Peng	Ph.D. Candidate	NTNU
Das, Subodh K.	CEO & Founder	Phinix, LLC.
Dasari, Hari	Postdoctoral Associate	CALTECH
Davenport, Timothy C.	Postdoctoral Associate	CALTECH
Dorn, Christopher	Vice-President	Materion Brush Beryllium & Composites
Earlam, Matthew	Director	INFINIUM, Inc.
Gaertner, Heiko	Ph.D. Candidate	NTNU
Granata, Guiseppe	Postdoctoral Associate	Waseda University
Haarberg, Geir M.	Professor	NTNU
Haile, Sossina M.	Professor	CALTECH
Hamanaka, Yuki	Graduate Student	IIS, the University of Tokyo
Hatada, Naoyuki	Assistant Professor	Kyoto University
Hatakeyama, Kazunori	Administrative staff	IMRAM, Tohoku University
Hoff, Andrew	Graduate Student	CALTECH
Ignatowich, Mike	Graduate Student	CALTECH
Ikeda, Teruyuki	Professor	Ibaraki University
Ishii, Makoto	Graduate Student	IIS, the University of Tokyo
Iyozumi, Fumiaki	Administrative Staff	IIS, the University of Tokyo
Johnson, William L.	Professor	CALTECH
Kang, Jungshin	Ph.D. Candidate	IIS, the University of Tokyo
Khan, Anupama	Graduate Student	CALTECH
Kim, Hojong	Assistant Professor	Penn State University
Kipouros, Georges J.	Professor	University of Saskatchewan
Kjos, Ole S.	Research Scientist	SINTEF Materials and Chemistry
Kobashi, Yoshifumi	Graduate Student	IIS, the University of Tokyo
Konno Yoshinori	Administrative staff	IMRAM, Tohoku University
Kremmervik, Kjersti		Dr. Skybakmoen's spouse
Kremmervik, Vegard		Dr. Skybakmoen's son
Kucharczyk, Chris	Graduate Student	CALTECH
Lambotte, Guillaume	Postdoctoral Associate	MIT
Mahadevan, Nalini	General Counsel	Phinix, LLC.
Meirbekova, Rauan	Ph.D. Candidate	Reykjavik University & NTNU
Mokkelbost, Tommy	Senior Research Scientist	SINTEF Materials and Chemistry
Morita, Kazuki	Professor	the University of Tokyo
Nagai, Takashi	Associate Professor	Chiba Institute of Technology
Nakagawara, Takashi	Financial Section Chief	IMRAM, Tohoku University
Nakamura, Takashi	Professor	IMRAM, Tohoku University

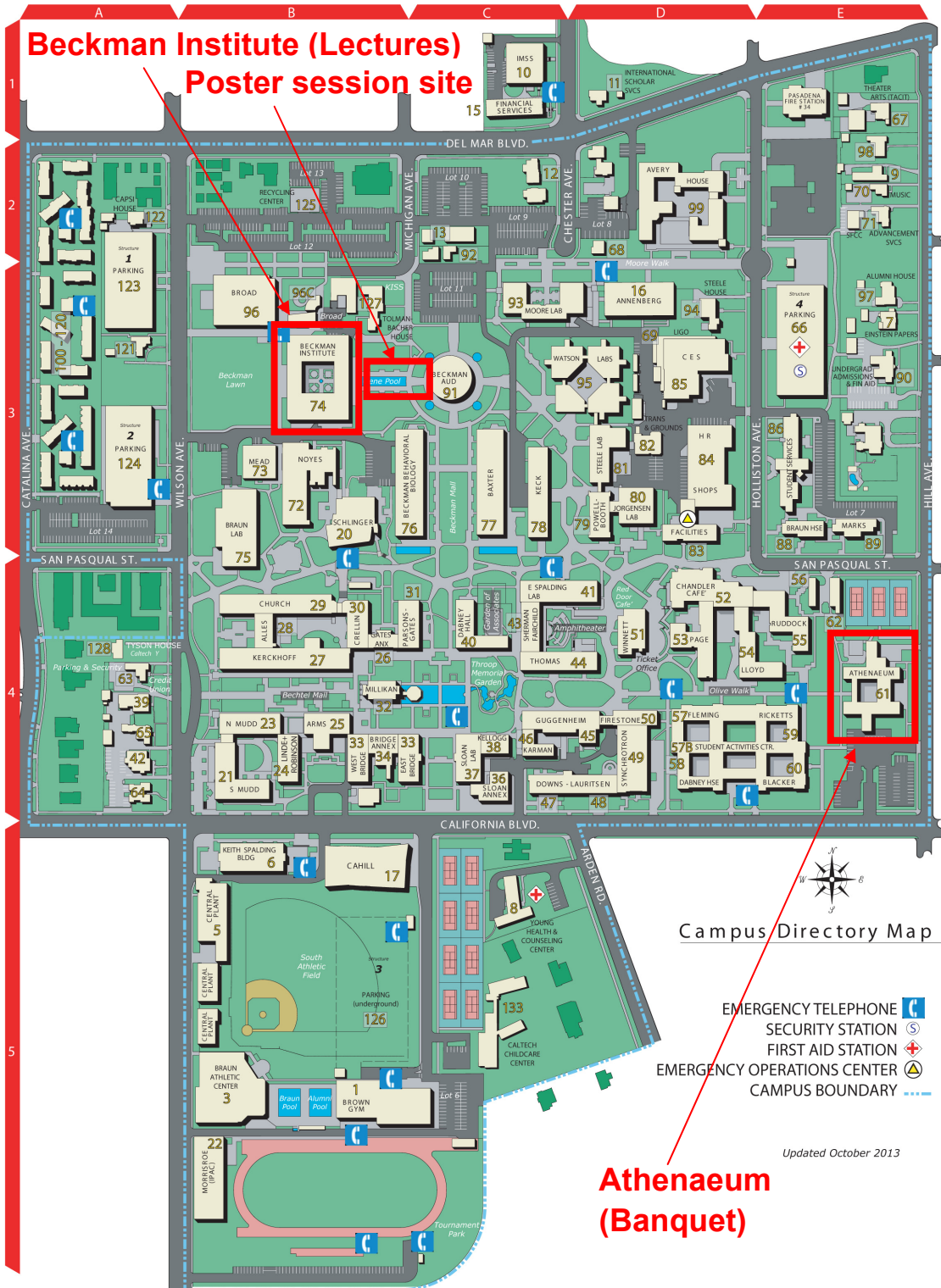
List of Participants

2014/2/13

Nishiyama, Yuichi	Manager	IHI Inc.
Nose, Katsuhiko	Project Research Associate	IIS, the University of Tokyo
Ohno, Saneyuki	Graduate Student	CALTECH
Oka, Hiromi	Administrative staff	IIS, the University of Tokyo
Okabe, Toru H.	Professor	IIS, the University of Tokyo
Okabe, Yu	Undergraduate Student	Saitama University
Onishi, Takayuki	Ph.D. Candidate	Kyoto University
Ouchi, Takanari	Postdoctoral Associate	MIT
Powell IV, Adam C.	CTO	INFINIUM, Inc.
Sasaki, Hideaki	Research Associate	IIS, the University of Tokyo
Sasaki, Sakae	Administrative staff	IMRAM, Tohoku University
Sato, Akihiro	Senior Researcher	IHI Corporation
Sato, Nobuaki	Professor	IMRAM, Tohoku University
Sekimoto, Hidehiro	Assistant Professor	Iwate University
Shionoya, Katsuhiko	Administrative staff	Tohoku University
Shirayama, Sakae	Ph.D. Candidate	Kyoto University
Skybakmoen, Egil	Research Director	SINTEF
Snyder, G. Jeffery	Faculty Associate	CALTECH
Sommerseth, Camilla	Ph.D. Candidate	NTNU
Sumiuchi, Ryota	Undergraduate Student	Waseda University
Takagiwa, Yoshiki	Assistant Professor	the University of Tokyo
Takahashi, Kota	Graduate Student	Kyoto University
Takeda, Osamu	Research Associate	Tohoku University
Tang, Yinglu	Graduate Student	CALTECH
Taninouchi, Yu-ki	Research Associate	IIS, the University of Tokyo
Uda, Tetsuya	Associate Professor	Kyoto University
Ueno, Masatoshi	Senior Manager	AGC America Inc.
Wang, Heng	Ph.D. Candidate	CALTECH
Wang, Zhaohui	Postdoctoral Associate	NTNU
Xu, Qian	Professor	Northeastern University
Yamazaki, Yoshihiro	Visiting Associate	CALTECH
Yang, Xiao	Project Research Associate	Kyoto University
Yasuda, Kouji	Assistant Professor	Kyoto University
Yurko, James A.	Director	Materion Brush Beryllium & Composites

Map

CALIFORNIA INSTITUTE OF TECHNOLOGY



History of RMW

- 2006 **The 1st Workshop on Reactive Metal Processing (RMW1)**
March 17 (Fri.)- March 19 (Sat.), Cambridge, MIT
- 2006 **The 2nd Workshop on Reactive Metal Processing (RMW2)**
November 16 (Thurs.)- November 17 (Fri.), Tokyo, The University of Tokyo
- 2007 **The 3rd Workshop on Reactive Metal Processing (RMW3)**
March 2 (Fri.)- March 3 (Sat.), Cambridge, MIT
- 2008 **The 4th Workshop on Reactive Metal Processing (RMW4)**
March 14 (Fri.)- March 15 (Sat.), Cambridge, MIT
- 2010 **The 5th Workshop on Reactive Metal Processing (RMW5)**
February 18 (Thurs.)- February 19 (Fri.), Seattle, Red Lion Hotel on 5th Avenue
- 2011 **The 6th Workshop on Reactive Metal Processing (RMW6)**
March 4 (Fri.)- March 5 (Sat.), Pasadena, Caltech
- 2012 **The 7th Workshop on Reactive Metal Processing (RMW7)**
March 16 (Fri.)- March 17 (Sat.), Cambridge, MIT
- 2013 **The 8th Workshop on Reactive Metal Processing (RMW8)**
March 8 (Fri.)- March 9 (Sat.), Cambridge, MIT

RMW1 in 2006 at MIT



RMW2 in 2006 at IIS



RMW5 in 2010 at MIT



RMW6 in 2011 at CALTECH



RMW7 in 2012 at MIT



RMW8 in 2013 at MIT



Announcement for the Next Workshop

RMW10

[The 10th Workshop on
Reactive Metal Processing](#)



[March 20 \(Fri.\) – 21 \(Sat.\), 2015 @ MIT, Cambridge](#)
(After TMS 2015, March 15 – 19, 2015 @ Orland, Florida)

Organizers:

Toru H. Okabe, *IIS, the University of Tokyo*

Antoine Allanore, *Massachusetts Institute of Technology*

Donald R. Sadoway, *Massachusetts Institute of Technology*

Program Coordinators:

Jungshin Kang, *IIS, the University of Tokyo*

Katsuhiko Nose, *Massachusetts Institute of Technology*

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