

# RMW14

The 14th Workshop on Reactive Metal Processing

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(IIS UTokyo SYMPOSIUM No.98)

March 15 (Fri.) - 16 (Sat.), 2019 @ MIT  
Cambridge, Massachusetts, USA

## Organizers

<b>Antoine Allanore,</b>	<i>Massachusetts Institute of Technology</i>
<b>Shunsuke Yagi,</b>	<i>Institute of Industrial Science (IIS), The University of Tokyo</i>
<b>Toru H. Okabe,</b>	<i>IIS, The University of Tokyo</i>
<b>Donald R. Sadoway,</b>	<i>Massachusetts Institute of Technology</i>

## Program Coordinators

<b>Takanari Ouchi,</b>	<i>IIS, The University of Tokyo</i>
<b>Mary Elizabeth Wagner,</b>	<i>Massachusetts Institute of Technology</i>
<b>Ryohei Yagi,</b>	<i>IIS, The University of Tokyo</i>

## Sponsors

- The Rare Metal Research Workshop, one of the Special Research Group organized by the Foundation for the Promotion of Industrial Science (RC-40: directed by Prof. T. H. Okabe)
- Donation to The University of Tokyo New York Office by Dowa Metals & Mining Co., Ltd., Mitsubishi Materials Corporation, Sumitomo Metal Mining Co., Ltd., and Tanaka Kikinzoku Kogyo K.K..
- Grant-in-Aid for Scientific Research (S) by JSPS (Project No. 26220910)
- Integrated Research Center for Sustainable Energy and Materials (IRCSEM)
- The Strategic Partnerships Project of the Top Global University Project by The University of Tokyo

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

# The 14th Workshop on Reactive Metal Processing (IIS UTokyo SYMPOSIUM No.98)

March 15 (Fri.) – March 16 (Sat.), 2019, MIT, Cambridge, MA

## Time:

- 1st day: on March 15 (9:30 – 16:45 and Banquet at 19:00)
- 2nd day: on March 16 (9:30 – 13:30)

Refreshments will be served around 8:30 AM on both days.

## Venue:

- **Haus Room and Allen Room for Workshop (Building 36)**
- **MIT Museum for Banquet**

(see page 10 or [http:// www.lemeridiencambridge.com/](http://www.lemeridiencambridge.com/))

## Registration Fee:

\$200 / person

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

## Organizers:

<b>Prof. Antoine Allanore,</b>	<i>Massachusetts Institute of Technology</i>
<b>Prof. Shunsuke Yagi,</b>	<i>IIS, The University of Tokyo</i>
<b>Prof. Toru H. Okabe,</b>	<i>IIS, The University of Tokyo</i>
<b>Prof. Donald R. Sadoway,</b>	<i>Massachusetts Institute of Technology</i>

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## Contact:

Mary Elizabeth Wagner, *Massachusetts Institute of Technology*

E-mail: [rmw@iis.u-tokyo.ac.jp](mailto:rmw@iis.u-tokyo.ac.jp)

# Workshop Program

## Day 1

Morning, March 15 (Friday), 2019 @Haus Room and Allen Room at Building 36

8:30 – 9:30      **Coffee & Breakfast Service**

9:30 – 9:40      **Opening Remarks**

*Prof. Donald R. Sadoway*, Massachusetts Institute of Technology

*Prof. Toru H. Okabe*, IIS, The University of Tokyo

Session Chair: Prof. Geir Martin Haarberg

9:40 – 10:10      **“AC-Voltammetry Signals in Molten Salts”**

*Antoine Allanore*<sup>1</sup>

<sup>1</sup>Massachusetts Institute of Technology

10:10 – 10:40      **“Redox Reactions of Sulfides at Low Temperatures for Energy Applications”**

*Shunsuke Yagi*<sup>1</sup>

<sup>1</sup>Institute of Industrial Science, The University of Tokyo

10:40 – 10:55      **Break**

Session Chair: Prof. Toshiyuki Nohira

10:55 – 11:25      **“Electrodeposition of Silicon from Molten Salts Using a Liquid Gallium Cathode”**

*Geir Martin Haarberg*<sup>1</sup>

<sup>1</sup>Norwegian University of Science and Technology (NTNU)

11:25 – 11:55      **“Inert Anodes in Low-temperature Aluminium Electrolysis – a Potential Game Changer?”**

*Gudrun Saevardsdottir*<sup>1</sup>

<sup>1</sup>Reykjavik University

11:55 – 13:00      **Lunch**

## Day 1

Afternoon, March 15 (Friday), 2019 @Haus Room and Allen Room at Building 36

Session Chair: Prof. Georges J. Kipouros

13:00 – 13:30      **“What is a Real Bottleneck on LIB recycling”**

*Takashi Nakamura*<sup>1</sup>

<sup>1</sup>IIS, The University of Tokyo

13:30 – 14:00      **“Supply Chains for Tomorrow's Low-Carbon Industries”**

*Adam C. Powell IV*<sup>1</sup>

<sup>1</sup>Worcester Polytechnic Institute

14:00 – 14:30      **“Enabling the Circular Economy through Extraction, Utilization, and Recycling of Strategic Materials”**

*Gisele Azimi*<sup>1</sup>

<sup>1</sup>University of Toronto

14:30 – 14:45      **Photo & Break**

14:45 – 15:45      **3-min Short Presentation by Poster Presenters**

15:45 – 16:45      **Poster Session at the Haus Room and Allen Room at Building 36**

18:00 –              **Reception**              @ MIT Museum

19:00 –              **Banquet**                @ MIT Museum

## Day 2

Morning, March 16 (Saturday), 2019 @Haus Room and Allen Room at Building 36

8:30 – 9:30      **Coffee & Breakfast Service**

9:30 – 9:40      **Opening Remarks**

*Prof. Antoine Allanore*, Massachusetts Institute of Technology

*Prof. Shunsuke Yagi*, IIS, The University of Tokyo

Session Chair: Prof. Antoine Allanore

9:40 – 10:10      **“Electrodeposition of Crystalline Silicon from AF-ACl (A=Li, Na, K, Cs) Molten Salts”**

*Toshiyuki Nohira*<sup>1</sup>, *Kouji Yasuda*<sup>2,3</sup>, *Yutaro Norikawa*<sup>1</sup>, *Tomonori Kato*<sup>1</sup>, and *Airi Kondo*<sup>1</sup>

<sup>1</sup>Institute of Advanced Energy, Kyoto University

<sup>2</sup>Graduate School of Energy Science, Kyoto University

<sup>3</sup>Agency for Health, Safety and Environment, Kyoto University

10:10 – 10:40      **“Recovery of Tungsten, Vanadium, and Titanium from Spent Selective Catalytic Reduction Catalyst”**

*Gyeonghye Moon*<sup>1</sup>, *Jin-Hyung Kim*<sup>1</sup>, *Yeon-Chul Cho*<sup>1,2</sup>, *Jin-Young Lee*<sup>1,3</sup>, and *Jungshin Kang*<sup>1,3</sup>

<sup>1</sup>Korea Institute of Geoscience and Mineral Resources, 124 Gwahak-ro Yuseong-gu, Daejeon 34132, Korea

<sup>2</sup>Daejin University, 1007 Hoguk-ro, Pocheon-si, Gyeonggi-do 11159, Korea

<sup>3</sup>Korea University of Science and Technology, 217 Gajeong-ro Yuseong-gu, Daejeon 34113, Korea

10:40 – 11:00      **Break**

## Day 2

Session Chair: Prof. Shunsuke Yagi

11:00 – 11:30      **“Deoxidation of Titanium Scrap using Mixtures of Magnesium Chloride and Rare-Earth Chlorides”**

*Takanari Ouchi*<sup>1</sup>, Chenyi Zheng<sup>1,2</sup>, Lingxin Kong<sup>1</sup>, and Toru H. Okabe<sup>1</sup>

<sup>1</sup>Institute of Industrial Science, The University of Tokyo

<sup>2</sup>Department of Materials Engineering, The University of Tokyo

11:30 – 12:00      **“Electrochemical Selectivity for Metals in Molten Sulfides”**

*Mary Elizabeth Wagner*<sup>1</sup> and Antoine Allanore<sup>1</sup>

<sup>1</sup>Massachusetts Institute of Technology

12:00 – 12:10      **Information for the Next RMW & Sadoway70**

*Prof. Toru H. Okabe*, IIS, The University of Tokyo

12:10 – 12:20      **Closing Remarks**

*Prof. Donald R. Sadoway*, Massachusetts Institute of Technology

12:20 – 13:30      **Lunch**

13:30 –              **Laboratory Tour (for applicants)**

## List of Poster Presentations

1. **“Performance enhancement and characterization of liquid displacement battery having faradaic membrane”**  
*Kashif Mushtaq<sup>1,2,3</sup>, Ji Zhao<sup>1</sup>, Norbert Weber<sup>1,4</sup>, and Donald R. Sadoway<sup>1</sup>*  
<sup>1</sup>Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA.  
<sup>2</sup>LEPABE, Department of Chemical Engineering, Faculty of Engineering, University of Porto, Portugal.  
<sup>3</sup>Department of Mechanical Engineering, School of Mechanical and Manufacturing Engineering, National University of Sciences and Technology, Islamabad, Pakistan  
<sup>4</sup>Helmholtz-Zentrum Dresden - Rossendorf, Bautzner Landstr. 400, 01328 Dresden, Germany
2. **“Boron Extraction Reinvented: Electrolytic Production of Elemental Boron from a Molten Oxide”**  
*Lucas Caretta<sup>1</sup>*  
<sup>1</sup>Massachusetts Institute of Technology
3. **“Scale-Up of Molten Sulfide Electrolysis”**  
*Lucas Rush<sup>1</sup>*  
<sup>1</sup>Massachusetts Institute of Technology
4. **“Techno-Economic Analysis of NMC Cathode Recycling”**  
*Caspar Stinn<sup>1</sup>*  
<sup>1</sup>Massachusetts Institute of Technology
5. **“Cryogenic Electron Microscopy Characterizing Reactive Metals”**  
*Xuefeng Wang<sup>1</sup>*  
<sup>1</sup>University of California San Diego
6. **“Application of Liquefied Gas Electrolytes on Reactive Metal Anodes”**  
*Yangyuchen Yang<sup>1</sup>*  
<sup>1</sup>University of California San Diego
7. **“High-purity Pt Recovery from Recycling Process Using ‘Dry Aqua Regia’”**  
*Akihiro Yoshimura<sup>1</sup> and Yasunari Matsuno<sup>1</sup>*  
<sup>1</sup>Graduate School of Engineering, Chiba University
8. **“Dissolution behavior of SiO<sub>2</sub> in molten CaCl<sub>2</sub>-CaO”**  
*Xiao Yang<sup>1</sup>*  
<sup>1</sup>The University of Tokyo
9. **“Electrochemical Deoxidation of Titanium Scrap in a Molten Mixture of Magnesium Chloride and Holmium Chloride”**  
*Lingxin Kong<sup>1</sup>, Takanari Ouchi<sup>1</sup>, and Toru H. Okabe<sup>1</sup>*  
<sup>1</sup>Institute of Industrial Science, The University of Tokyo

## List of Poster Presentations

10. **“Theoretical Calculation of Thermodynamic Properties of Liquid Transition Metal Alloys Using Distribution Function Theory”**  
*Shun Ueda<sup>1</sup> and Kazuki Morita<sup>1</sup>*  
<sup>1</sup>Department of Materials Engineering, The University of Tokyo
11. **“Thermodynamic Property of Boron in Si-Ni Melts”**  
*Yoshiki Takeuchi<sup>1</sup> and Kazuki Morita<sup>1</sup>*  
<sup>1</sup>Department of Materials Engineering, The University of Tokyo
12. **“Investigation of Redox Reactions of Metal Sulfides toward Novel Rechargeable Batteries”**  
*Ryo Fukunaga<sup>1,2</sup>, Mary Elizabeth Wagner<sup>3</sup>, Antoine Allanore<sup>3</sup>, and Shunsuke Yagi<sup>2</sup>*  
<sup>1</sup>Department of Materials Engineering, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo  
<sup>3</sup>Massachusetts Institute of Technology
13. **“Recovery of Rhenium from Superalloy Scraps by Oxidative Roasting”**  
*Ryohei Yagi<sup>1,2</sup>, Iori Narita<sup>1,2</sup>, and Toru H. Okabe<sup>2</sup>*  
<sup>1</sup>Department of Materials Engineering, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
14. **“Fundamental Research on Lanthanothermic Deoxidation of Titanium and Reduction of Titanium Oxides”**  
*Takara Tanaka<sup>1,2</sup>, Takanari Ouchi<sup>2</sup>, and Toru H. Okabe<sup>2</sup>*  
<sup>1</sup>Department of Materials Engineering, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
15. **“Fundamental Consideration of Electroplating of Precious Metals using Molten Salt Electrolytes”**  
*Shuang Wu<sup>1,2</sup>, Takanari Ouchi<sup>2</sup>, and Toru H. Okabe<sup>2</sup>*  
<sup>1</sup>Department of Multidisciplinary Sciences, Graduate School of Arts and Sciences, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
16. **“Thermodynamic Consideration of New Recycling Process of Gold from Electronic Waste by Utilizing FeCl<sub>2</sub> Vapor Treatment”**  
*Er Li<sup>1,2</sup>, Takanari Ouchi<sup>2</sup>, and Toru H. Okabe<sup>2</sup>*  
<sup>1</sup>Department of Multidisciplinary Sciences, Graduate School of Arts and Sciences, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
17. **“Dynamic Current Distribution in Submerged Arc Furnace”**  
*Yonatan Afework Tesfahunegn<sup>1</sup>*  
<sup>1</sup>Reykjavik University
18. **“Workshop on Reactive Metal Processing (Introduction of RMWs)”**



## 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
- 2014 **The 9th Workshop on Reactive Metal Processing (RMW9)**  
February 21 (Fri.) - February 22 (Sat.), Pasadena, Caltech
- 2015 **The 10th Workshop on Reactive Metal Processing (RMW10)**  
March 20 (Fri.) - March 21 (Sat.), Cambridge, MIT
- 2016 **The 11th Workshop on Reactive Metal Processing (RMW11)**  
February 19 (Fri.) - February 20 (Sat.), Cambridge, MIT
- 2017 **The 12th Workshop on Reactive Metal Processing (RMW12)**  
March 3 (Fri.) - March 4 (Sat.), Cambridge, MIT
- 2018 **The 13th Workshop on Reactive Metal Processing (RMW13)**  
March 16 (Fri.) - March 17 (Sat.), Cambridge, MIT

**RMW1 in 2006 at MIT**



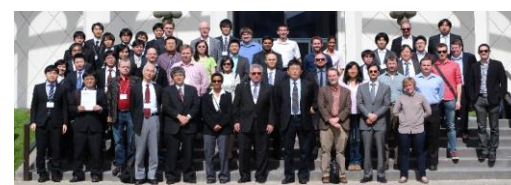
**RMW2 in 2006 at IIS**



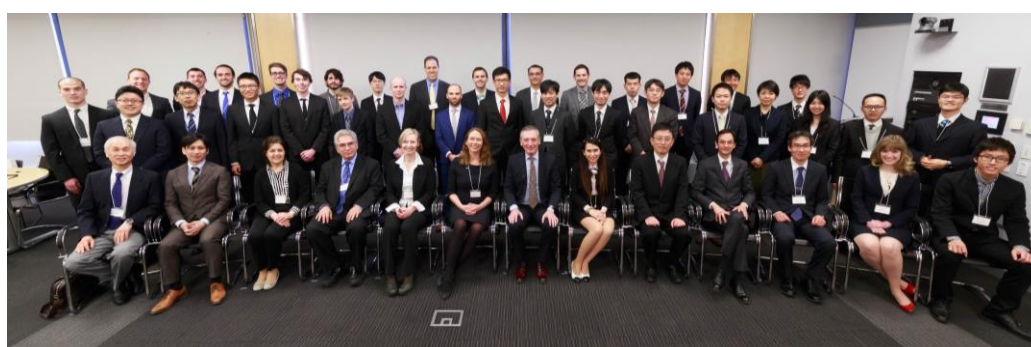
**RMW5 in 2010 at Seattle**



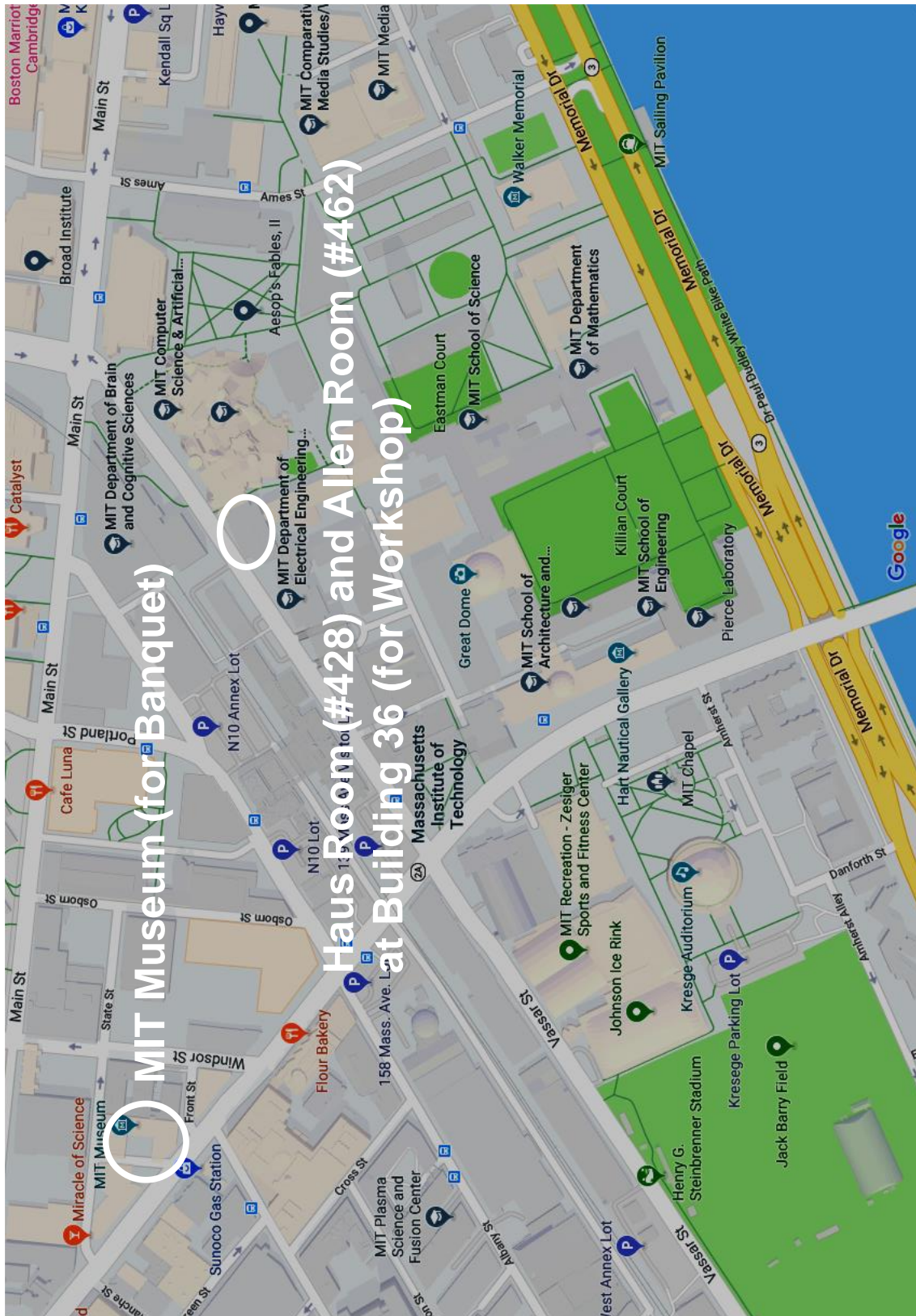
**RMW9 in 2014 at CALTECH**



**RMW13 in 2018 at MIT**



## MAP



## List of Participants

Adam C. Powell, IV	Associate Professor	Worcester Polytechnic Institute
Akihiro Yoshimura	Assistant Professor	Chiba University
Andrew Caldwell	Graduate Student	MIT
Antoine Allanore	Associate Professor	MIT
Asami Sato	Administration Staff	IIS, The University of Tokyo
Casper Stinn	Graduate Student	MIT
Charles Boury	Visiting Student	MIT
Donald Sadoway	Professor	MIT
Geir Martin Haarberg	Professor	NTNU
Georges J. Kipouros	Adjunct Professor	University of Waterloo
Gisele Azimi	Assistant Professor	Univesity of Toronto
Gudrun Saevarsdottir	Associate Professor	Reykjavik University
Guillaume Lambotte	Senior R&D Scientist	Boston Metal
Hilary Sheldon		MIT
Hojong Kim	Assistant Professor	The Pennsylvania State University
Jiashen Meng	Visiting Student	MIT
Jungshin Kang	Senior Researcher	KIGAM
Kashif Mushtaq	Visiting Student	MIT
Katie Daehn	Postdoc	MIT
Kazuki Morita	Professor	The University of Tokyo
Kong Lingxin	Visiting Associate Research Fellow	IIS, The University of Tokyo
Li Er	Graduate Student	IIS, The University of Tokyo
Lucas Caretta	PhD Candidate	MIT
Lucas Rush	PhD Candidate	MIT
Mary Elizabeth Wagner	PhD Candidate	MIT
Michael Martin	Graduate Student	University of Connecticut
Mindy Wu	Undergraduate Student	MIT
Minoru Kawasaki	President	Nippon PGM America, Inc.
Nick Myers	Alumni	Northeastern University
Parker Buntin	Graduate Student	MIT
Quanuqan Pang	PDA	MIT



## List of Participants

Ragnhild Aune	Professor	NTNU
Rebecca Miller		
Rich Bradshaw	Director of Operation	Boston Metal
Ryo Fukunaga	Graduate Student	IIS, The University of Tokyo
Ryohei Yagi	Graduate Student	IIS, The University of Tokyo
Shuang Wu	Graduate Student	IIS, The University of Tokyo
Shun Ueda	Graduate Student	The University of Tokyo
Shunsuke Yagi	Associate Professor	IIS, The University of Tokyo
Takanari Ouchi	Research Associate	IIS, The University of Tokyo
Takara Tanaka	Graduate Student	IIS, The University of Tokyo
Takashi Nakamura	Project Professor	IIS, The University of Tokyo
Thomas Villalon, Jr.	Alumni	Boston University
Toru H. Okabe	Professor	IIS, The University of Tokyo
Toshiyuki Nohira	Professor	Kyoto University
Xiao Yang	Assistant Professor	The University of Tokyo
Xuefeng Wang	Postdoc	University of California San Diego
Yangyuchen Yang	PhD Candidate	University of California San Diego
Yonatan Afework	Assistant Professor	Reykjavik University
Tesfahunegn		
Yoshiki Takeuchi	Undergraduate Student	The University of Tokyo
Yu Maeda	Private Sector	Nichicon Corporation
	Collaborative Researcher	
Yuya Saeki	Administration Staff	IIS, The University of Tokyo