

# RMW17



## The 17th Workshop on Reactive Metal Processing

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**March 8 (Fri.) – 9 (Sat.), 2024 @ Boston/Cambridge**

(After TMS 2024, March 3 (Sun.) – 7 (Thu.), 2024 @ Orlando, Florida)

### **Organizers:**

**Donald R. Sadoway,  
Toru H. Okabe,**

*Massachusetts Institute of Technology  
Institute of Industrial Science (IIS),  
The University of Tokyo*

**Antoine Allanore,  
Shunsuke Yagi,**

*Massachusetts Institute of Technology  
IIS, The University of Tokyo*

### **Program Coordinators:**

**Takanari Ouchi,  
Gen Kamimura,  
Isaac Oda-Bayliss,  
Ethan Benderly-Kremen,  
Kai Shimada,**

*IIS, The University of Tokyo  
Massachusetts Institute of Technology  
IIS, The University of Tokyo  
Massachusetts Institute of Technology  
IIS, The University of Tokyo*

### Sponsors

- The Rare Metal Research Workshop, one of the Special Research Groups organized by the Foundation for the Promotion of Industrial Science (FPIS)
- (RC-40: directed by Prof. T. H. Okabe, RC-104: directed by Prof. S. Yagi)
- Research Center for Sustainable Material Energy Integration (SUSMAT)
- Institute of Industrial Science, The University of Tokyo (IIS UTokyo SYMPOSIUM No.118)

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

# The 17th Workshop on Reactive Metal Processing

## (IIS UTokyo SYMPOSIUM No.118)

March 8 (Fri.) – March 9 (Sat.), 2024, MIT, Cambridge, MA

### Time:

- 1st day: on March 8 (10:00 – 17:00 and Banquet at 18:30)
  - 2nd day: on March 9 (10:00 – 14:00)
- Refreshments will be served around 9:00 AM on both days.

### Venue:

- **Haus Allen Room (MIT)**
- **Le Méridien Cambridge**

### Registration Fee:

\$300 / person

### Organizers:

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

### Program Coordinators:

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| <b>Takanari Ouchi,</b>        | <i>IIS, The University of Tokyo</i>          |
| <b>Gen Kamimura,</b>          | <i>Massachusetts Institute of Technology</i> |
| <b>Isaac Oda-Bayliss,</b>     | <i>IIS, The University of Tokyo</i>          |
| <b>Ethan Benderly-Kremen,</b> | <i>Massachusetts Institute of Technology</i> |
| <b>Kai Shimada,</b>           | <i>IIS, The University of Tokyo</i>          |

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### Contact:

Isaac Oda-Bayliss, *IIS, The University of Tokyo*  
E-mail: [aisaku-oda@g.ecc.u-tokyo.ac.jp](mailto:aisaku-oda@g.ecc.u-tokyo.ac.jp)

# Workshop Program

## Day 1

Morning, March 8 (Friday), 2024 @ Haus Allen Room (MIT)

9:00 – 10:00 **Coffee & Breakfast Service**

10:00 – 10:10 **Opening Remarks**

*Prof. Antoine Allanore*

*Massachusetts Institute of Technology*

Session Chair: *Prof. Antoine Allanore*

10:10 – 10:40 **The Impact of Inert Anode Technology on Primary Aluminum Smelting**

*Donald R. Sadoway*

*Massachusetts Institute of Technology*

10:40 – 11:00 **Break**

Session Chair: *Prof. Jungshin Kang*

11:00 – 11:30 **Origin of Catalytic Activity for Oxygen Evolution Reaction**

*Shunsuke Yagi*

*IIS, The University of Tokyo*

11:30 – 12:00 **Electrolytic Production of Iron in Molten Sulfides**

*Antoine Allanore*

*Massachusetts Institute of Technology*

12:00 – 13:00 **Lunch**

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

13:00 – 13:30 **Iron- and Steel-Making Slag Valorization ~Some Trials toward Sustainable Society in Japan~**

*Kazuki Morita*

*The University of Tokyo*

13:30 – 14:00 **Recycling Li-Ion Batteries - A Crucial Step Towards Sustainability**

*Ragnhild Elizabeth Aune*

*Norwegian University of Science and Technology*

14:00 – 14:20 **Photo & Break**

Session Chair: *Dr. Gen Kamimura*

14:20 – 15:20 **3-min Short Presentation by Poster Presenters**

15:20 – 16:20 **Poster Session at the Haus Room and Allen Room at Building 36**

18:00 – **Reception** @ Le Méridien Cambridge

18:30 – **Banquet** @ Le Méridien Cambridge

## Day 2

Morning, March 9 (Saturday), 2024 @ Haus Allen Room (MIT)

9:00 – 10:00 **Coffee & Breakfast Service**

10:00 – 10:10 **Opening Remarks**

*Prof. Shunsuke Yagi*

*IIS, The University of Tokyo*

Session Chair: *Prof. Shunsuke Yagi*

10:10 – 10:40 **SOLSTICE – European molten salt battery research**

*Ole Kjos*

*SINTEF Industry*

10:40 – 11:00 **Break**

Session Chair: *Dr. Takanari Ouchi*

11:00 – 11:30 **Investigation of deoxidation method for off-grade titanium sponge using Mg metal under high hydrogen chemical potential**

*Jungshin Kang*

*Seoul National University*

11:30 – 12:00 **Metal Production in the Age of Renewables**

*Adam C. Powell IV*

*Worcester Polytechnic Institute*

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

*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**

## List of Poster Presenters

- 1. Effect of Vanadium Doping on  $\alpha$ - $K_x$ MnO<sub>2</sub> Positive Electrode Active Materials for Rechargeable Magnesium Batteries**  
*Isaac Oda-Bayliss*<sup>1,2</sup>,  
<sup>1</sup>Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
- 2. Sulfidation treatment of apatite for alternative phosphorus fertilizers**  
*Ava Waitz*<sup>1</sup>,  
<sup>1</sup>Massachusetts Institute of Technology
- 3. Electrochemical Behavior of Alkaline Hematite Reduction**  
*Gavin Winter*<sup>1</sup>,  
<sup>1</sup>Massachusetts Institute of Technology
- 4. Iron production through Molten Sulfide electrolysis**  
*Kimaya Suryarao*<sup>1</sup>,  
<sup>1</sup>Massachusetts Institute of Technology
- 5. Dissolved Gas Studies in Molten Chloride Salts**  
*Nathan Bradshaw*<sup>1</sup>,  
<sup>1</sup>Massachusetts Institute of Technology
- 6. Recovery of REE from magnets via non-oxidative pathway**  
*Zachary Adams*<sup>1</sup>,  
<sup>1</sup>Massachusetts Institute of Technology
- 7. Concentration of precious metals from ores or scraps using electrochemical anodic deposition in molten salt electrolyte**  
*Yuka Kujiraoka*<sup>1,2</sup>,  
<sup>1</sup>Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
- 8. Zero Emission Silicon and Manganese Production through Electrowinning**  
*Gøril Jahrsengene*<sup>1</sup>,  
<sup>1</sup>SINTEF

## List of Poster Presenters

9. **Molten salt electrolysis of MgO using high-density metal cathode and vacuum distillation for the production of high-purity Mg metal**  
*Hyeong-Jun Jeoung*<sup>1</sup>,  
<sup>1</sup>Seoul National University
10. **Differential Thermal Analysis of Nickel Sulfide for Molten Sulfide Electrolysis**  
*Lucas Marden*<sup>1</sup>,  
<sup>1</sup>Massachusetts Institute of Technology
11. **The intrinsic chemical reaction rate for the sulfidation of artificial ferric oxide**  
*Matthew Michalek*<sup>1</sup>,  
<sup>1</sup>Massachusetts Institute of Technology
12. **Recycling of Magnesium alloy using G-METS distillation**  
*Daniel Mc Arthur Sehar*<sup>1</sup>,  
<sup>1</sup>Worcester Polytechnic Institute
13. **Development of a new deoxidation method for titanium using the vapors of rare earth metals and yttrium chloride**  
*Tomoki Yamazaki*<sup>1,2</sup>,  
<sup>1</sup>Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
14. **The Catalytic Activity of Transition Metal Doped  $\alpha$ -MnO<sub>2</sub> for Oxygen Evolution Reaction**  
*Kai Shimada*<sup>1,2</sup>,  
<sup>1</sup>Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo  
<sup>2</sup>Institute of Industrial Science, The University of Tokyo
15. **Metal Leaching And Multiple Effect Distillation for Rare Earth Magnet Recycling**  
*Emmanuel Offei Opoku*<sup>1</sup>,  
<sup>1</sup>Worcester Polytechnic Institute
16. **Monte Carlo Cost Modeling of Magnesium Primary Production**  
*Isaak Donley Olson*<sup>1</sup>,  
<sup>1</sup>Worcester Polytechnic Institute
17. **Reduced Order Model of Magnesium Distillation Apparatus**  
*Artem Iurkovskiy*<sup>1</sup>, *Armaghan Telgerafchi*<sup>1</sup>,  
<sup>1</sup>Worcester Polytechnic Institute

## 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
- 2019 **The 14th Workshop on Reactive Metal Processing (RMW14)**  
March 15 (Fri.) - March 16 (Sat.), Cambridge, MIT
- 2020 **The 15th Workshop on Reactive Metal Processing (RMW15)**  
February 28 (Fri.) - February 29 (Sat.), San Diego, UC San Diego
- 2023 **The 16th Workshop on Reactive Metal Processing (RMW16)**  
March 24 (Fri.) - March 25 (Sat.), Cambridge, MIT

**RMW1 in 2006 at MIT**



**RMW2 in 2006 at IIS**



**RMW5 in 2010 at Seattle**



**RMW16 in 2023 at MIT**



## List of Participants

Adam Powell	Associate Professor	Worcester Polytechnic Institute
Antoine Allanore	Professor	MIT
Armaghan Telgerafchi	PhD graduate student	Worcester Polytechnic Institute
Artem Iurkovskiy	Undergraduate Researcher	Worcester Polytechnic Institute
Ava Waitz	Graduate Student	MIT
Benjamin Sabatini	Postdoctoral Associate	MIT
Bohdanna Naidych	Postdoctoral Associate	Sadoway Labs Foundation
Caspar Stinn	Principal Scientist	Outokumpu
Charles Boury	Graduate Student	MIT
Daniel Mc Arthur Sehar	PhD graduate student	Worcester Polytechnic Institute
Donald Sadoway	Professor Emeritus	MIT
Egil Skybakmoen	Research Manager	SINTEF
Emmanuel Opoku	Research Assistant	Worcester Polytechnic Institute
Ethan Benderly-Kremen	Graduate Student	MIT
Eve Meltzer	Graduate Student	MIT
Gavin Winter	Graduate Student	MIT
Gen Kamimura	Postdoctoral Associate	MIT
Gøril Jahrsengene	Research Scientist	SINTEF
Hiroyuki Iwasaki	Technical advisor	KINA Corporation
Hyeong-Jun Jeoung	Graduate Student	Seoul National University
Isaac Oda-Bayliss	Graduate Student	IIS, The University of Tokyo
Isaak Olson	Undergraduate Research Assistant	Worcester Polytechnic Institute
Jacob Brown	CTO	Magrathea
Johanna Castillo	Assistant	Worcester Polytechnic Institute
John van Eeghen	Director	US Green Magnesium LLC
Jonathan Paras	Harry S. Truman Fellow	Sandia National Laboratories
Joseph Lessard	Materials Engineer	Apple Inc.
Jungshin Kang	Assistant Professor	Seoul National University
Kai Shimada	Graduate Student	IIS, The University of Tokyo
Kali Simonds	Engineer	Sadoway Labs Foundation
Katie Daehn	Research Scientist	MIT
Kazuki Morita	Professor	The University of Tokyo
Kim Peace	International Consultant	Phoenix Tailings
Kimaya Suryarao	Graduate Student	MIT
Lucas Marden	Undergraduate Student	MIT



## List of Participants

Masatoshi Ueno	Managing Director	Komatsu
Matthew Humbert	Staff Scientist	Sadoway Labs Foundation
Matthew Michalek	Graduate Student	MIT
Midori Yoneyama	Administrative Staff	IIS, The University of Tokyo
Natalie Chapman	Graduate Student	MIT
Nathan Bradshaw	Graduate Student	MIT
Nathan Hastings	Student	Worcester Polytechnic Institute
Ole Kjos	Senior Research Scientist	SINTEF Industry
Ragnhild Aune	Professor	NTNU
Richard Bradshaw	COO	Sadoway Labs Foundation
Richard Salvucci	Principal Development Engineer	Phoenix Tailings
Rin Hirotsu	Administrative Staff	IIS, The University of Tokyo
Shingo Katayama	Advisor	NIPPON DENKO Co., Ltd.
Shunsuke Yagi	Associate Professor	IIS, The University of Tokyo
Sung-Hun Park	Postdoctoral Associate	Seoul National University
Tae-Hyuk Lee	Senior Researcher	KIGAM
Takanari Ouchi	Assistant Professor	IIS, The University of Tokyo
Tatsuya Nakazawa	Section Manager	TANAKA Precious Metals
Tomás Villalon	CTO	Phoenix Tailings
Tomoki Yamazaki	Graduate Student	IIS, The University of Tokyo
Toru Okabe	Professor	IIS, The University of Tokyo
Xueqi Pang	Postdoctoral Associate	Sadoway Labs Foundation
Yuka Kujiraoka	Graduate Student	IIS, The University of Tokyo
Zachary Adams	Graduate Student	MIT

## Venue Details

### Workshop:

Haus Allen Room

Building 36, Room 462 (4th floor)

50 Vassar St, Cambridge, MA 02139

Interactive Campus Map available at: <http://whereis.mit.edu/>

### Banquet:

Le Méridien Boston Cambridge

20 Sidney St, Cambridge, MA 02139

