Matthew G. Boebinger, Ph.D.

R&D Associate Scientist - User Facility Electron Microscopist
Materials MicroÅnalysis Group
Center for Nanophase Materials Sciences
Oak Ridge National Laboratory
GoogleScholar

EDUCATION

GEORGIA INSTITUTE OF TECHNOLOGY Atlanta, GA
Doctor of Philosophy in Materials Science and Engineering Received May 2020

FLORIDA STATE UNIVERSITY Tallahassee, FL
Bachelor of Science in Mechanical Engineering Received May 2015

RESEARCH EXPERTISE

- Research expertise on the use of advanced *in situ* electron microscopy characterization techniques to investigate nanoscale transformations resulting from a variety of external stimuli
- Conducted numerous experiments using various electrochemical methods on battery materials to examine the chemical and morphological transformations they undergo during cycling
- Research into electron beam matter interactions with 2D materials to use as an automated fabrication method for nanoscale devices
- Data analytics applied to large S/TEM imaging and electrochemical datasets
- Experienced in MATLAB and Python programming languages for image analytics of S/TEM datasets
- Energy Storage Materials, Solid-State Electrolytes, 2D Materials, Catalysts

AWARDS

- Georgia Tech 2021 Sigma Xi Best Ph.D. Thesis Award 2021
- Department of Energy Office of Science Graduate Student Research Award 2019
- Georgia Tech President's Fellowship 2015
- NSF REU-MASS Fellow 2014
- Tau Beta Pi Engineering Honor Society 2013
- Pi Tau Sigma Mechanical Engineering Society 2013
- Phi Eta Sigma Honor Society 2011

RESEARCH EXPERIENCE

User Facility Electron Microscopist - R&D Associate, *ORNL* August 2022 – present
Materials MicroÅnalysis Group, Center for Nanophase Materials Science

- Directly work within the CNMS User program utilizing the various electron microscopes and their associated *in situ* characterization techniques on nanoscale energy and 2D materials.
- Experimentalist for the *in situ* directed nanoscale transformation of multiscale dynamics theme science thrust continuing my research involving the use of automated electron beam manipulations in STEM for direct fabrication defect engineering of 2D materials.

Postdoctoral Research Associate, *Oak Ridge National Laboratory* June 2020 – July 2022
Materials MicroÅnalysis Group, Center for Nanophase Materials Science

- Directed Nanoscale Transformation Theme Science Postdoc in the Materials MicroÅnalysis Group advised by Raymond Unocic, Stephen Jesse and Sergei Kalinin
- Experimentalist for the *in situ* directed nanoscale transformation of nanoscale materials thrust with my current research efforts involving the use of automated electron beam manipulations in STEM for direct fabrication and characterization of 2D materials.
- Directly worked with several User proposals on energy and MXene materials primarily utilizing *in situ* electron microscopy techniques

Graduate Research Assistant, *Georgia Institute of Technology* August 2015 – June 2020

Prof. Matthew McDowell's research group

PhD Thesis: **Investigating the reaction mechanisms involved in the phase transformation of novel battery materials using *in situ* transmission electron microscopy (TEM)**

- Conducted *ex* and *in situ* TEM and XRD experimental techniques to observe the nanoscale reaction mechanisms of electrochemistry related materials
- Focused on nanomaterials for high performance electrodes in Li-ion, Na-ion, and K-ion batteries
- Observed the interfacial phase transformation of solid-state electrolyte systems to better engineer solid electrolytes
- Performed various electrochemical techniques of tested materials to provide links across length-scales between nanoscale phase transformations and tested behavior
- Analyzed *in situ* TEM data and performed stress modeling work on observed transformations
- Conducted six months of research using *in situ* TEM techniques combined with EELS in collaboration as a Fellow of the DOE Office of Science Graduate Student Research Award at Oak Ridge National Laboratory

Undergraduate Research, *Florida State University*

Undergraduate Laboratory Assistant: May 2013 – July 2015

Applied Superconductivity Center of the National High Magnetic Field Laboratory

- Conducted hardness, tensile and fatigue tests to optimize the heat treatment and composition of the alloys used to sheath the superconducting filaments in BSCCO

Undergraduate NSF REU-MASS Fellow: June 2014 – August 2014

NSF Research Experience for Undergraduates Multi-physics of Active Systems and Structures (MASS)

- Conducted active research of bio-inspired fluid dynamics at the Aerospace, Mechatronics, and Energy Center at Florida State University

LEADERSHIP EXPERIENCE

Senior Design Project Team Leader, *Florida State University* August 2014 – May 2015

- Selected amongst my peers to be the team leader of the NASA sponsored Magnetically Coupled Mixer/Pump System for Cryogenic Propellant Tank Destratification
- Managed the team's work, assigned tasks and lead all work done for the project

Graduate Student Peer Mentor, *Georgia Institute of Technology* August 2016 – December 2018

- Worked with Graduate Student Advisory Board to help new graduate student transition

Graduate Research Assistant, *Georgia Institute of Technology* August 2015 – Present

- Established a new lab with research advisor
- Mentored and managed new graduate and undergraduate students as the lab grew
- Trained new lab researchers on experimental procedures, techniques and safety protocols

PUBLICATIONS

1. Wu Y, Li Y, Yu X, Ma X, **Boebinger MG**, Weber J, Wu Z (2024). "Insights into size effects of Pt/Al_2O_3 catalysts on hydrogen production from methylcyclohexane dehydrogenation." *Catalysis Science & Technology.*
2. Bracco JN, Camacho Meneses G, Colón O, Yuan K, Stubbs JE, Eng PJ, Wanhala AK, Einkauf JD, **Boebinger MG**, Stack AG, Weber J (2023). "Reaction Layer Formation on MgO in the Presence of Humidity." *ACS Applied Materials & Interfaces.* 16 (1): 712-722
3. **Boebinger MG**, Yilmaz D, Ghosh A, Misra S, Mathis TS, Kalinin SV, Jesse S, Gogotsi Y, van Duin ACT, Unocic RR (2023). "Direct Fabrication of Atomically Defined Pores in MXenes." *arXiv:2311.17864*
4. **Boebinger MG**, Ghosh A, Roccapriore KM, Misra S, Xiao K, Jesse S, Ziatdinov M, Kalinin SV, Unocic RR (2023). "When the atoms dance: exploring mechanisms of electron-beam induced modifications of materials with machine-learning assisted high temporal resolution electron microscopy." *arXiv:2310.08378*
5. Weber J, Starchenko V, Yuan K, Anovitz LM, Ievlev AV, Unocic RR, Borisevich AY, **Boebinger MG**, Stack AG (2023). "Armoring of MgO by a Passivation Layer Impedes Direct Air Capture of CO_2." *American Chemical Society.* 57 (40): 14929-14937
6. Jaiswal S, Fathi-Hafshejani P, Yakupoglu B, **Boebinger MG**, Azam N, Unocic RR, Hamilton MC, Mahjouri-Samani M (2023). "Wafer-Scale Synthesis of 2D Materials by an Amorphous Phase-Mediated Crystallization Approach." *ACS Applied Materials & Interfaces.* 15 (33): 39697-39706
7. Unocic RR, Wang J, Tsai W-Y, Gogotsi Y, **Boebinger MG**, Yu H, Cullen DA, Veith GM, Williams AN, Zachman MJ (2023). "Understanding Interfacial Electrochemical Reactions through *in situ* ec-STEM and IL-Cryo-STEM." *Microscopy and Microanalysis.* 29 (S1): 671-671
8. **Boebinger MG**, Roccapriore KM, Ghosh A, Xiao K, Lupini AR, Ziatdinov M, Kalinin SV, Unocic RR (2023). "Fabrication of Atomic-scale Defect Structures within 2D Materials through Automated Electron Beam Control." *Microscopy and Microanalysis.* 29 (S1): 1380-1381
9. Roccapriore KM, **Boebinger MG,** Klein J, Weile M, Ross F, Ziatdinov M, Unocic RR, Kalinin SV (2023). "AI-enabled Automation of Atomic Manipulation and Characterization in the STEM." *Microscopy and Microanalysis.* 29 (S1): 1366-1367
10. Thisera A, Riddle A, **Boebinger MG,** Guiton SV (2023). "Investigation of Metal-Metal Oxide Interfaces via Real-Time in situ TEM Heating." *Microscopy and Microanalysis.* 29 (S1): 1616-1617
11. Zand F, Hangx SJT, Spiers CJ, van den Brink PJ, Burns J, **Boebinger MG**, Poplawsky JD, Monai M, Weckhuysen BM (2023). "Elucidating the Structure and Composition of Individual Bimetallic Nanoparticles in Supported Catalysts by Atom Probe Tomography." *Journal of the American Chemical Society.* 145 (31): 17299-17308
12. **Boebinger MG**, Brea C, Ding L-P, Misra S, Olunloyo O, Yu Y, Xiao K, Lupini AR, Ding F, Hu G, Ganesh P, Jesse S, Unocic RR (2023). "The atomic drill bit: Precision controlled atomic fabrication of 2D materials." *Advanced Materials.* 35 (14): 2210116
13. Roccapriore KM, **Boebinger MG**, Dyck O, Ghosh A, Unocic RR, Kalinin SV, Ziatdinov M (2022). "Probing electron beam induced transformations on a single defect level via automated scanning transmission electron microscopy." *ACS Nano.* 16 (10): 17116-17127
14. Roccapriore KM, Ghosh A, Vasudevan R, Unocic RR, **Boebinger MG,** Ziatdinov M, Kalinin SV (2022). "Building Atomic and Plasmonic Devices via Electron Beams: from Desired Structures to Desired Properties." *Microscopy and Microanalysis.* 28 (S1): 1726-1727
15. **Boebinger MG**, Ghosh A, Misra S, Roccapriore KM, Xiao K, Lupini AR, Ganesh P, Ziatdinov M, Kalinin SV, Jesse S, Unocic RR (2022). "Atomic-scale Fabrication of 1D-2D Nano Hetero-structures within 2D Materials through Automated Tracking and Electron Beam Control." *Microscopy and Microanalysis.* 28 (S1): 2178-2180
16. Misra S, Hachtel JA, **Boebinger MG**, Muraleedharan MG, Konečná A, Mathis TS, Kent PRC, Naguib M, Gogotsi Y, Unocic RR (2022). "Understanding the Surface Chemistry Dependent Plasmon Response in $Ti_3C_2T_x$ MXenes using Monochromated STEM-EELS." *Microscopy and Microanalysis.* 28 (S1): 2460-2461

17. Azam N, **Boebinger MG**, Jaiswal S, Unocic RR, Fathi-Hafshejani P, Mahjouri-Samani M (2022). "Laser-Assisted Synthesis of Monolayer 2D $MoSe_2$ Crystals with Tunable Vacancy Concentrations: Implications for Gas and Biosensing." *ACS Applied Nano Materials.* 5 (7): 9129-9139
18. Sun S, **Boebinger MG**, Liu M, Lu P, Fu W, Wang B, Magasinski A, Zhang Y, Huang Y, Song AY, McDowell MT, Yushin G (2021). "The roles of atomic layer deposition (ALD) coatings on the stability of FeF_3 Na-ion cathodes." *Journal of Power Sources.* 507: 230281
19. **Boebinger MG**, Misra S, Yu Y, Xiao K, Mathis T, Gogotsi Y, Lupini AR, Kalinin S, Jesse S, Unocic RR (2021). "Atomic-scale Feedback-controlled Electron Beam Fabrication of 2D Materials." *Microscopy and Microanalysis.* 27 (S1): 3072-3073
20. Misra S, **Boebinger MG**, Mathis T, Naguib M, Gogotsi Y, Unocic RR (2021). "In Situ TEM Investigation of Lithium Intercalation in $Ti_3C_2T_x$ MXenes for Energy Storage Applications." *Microscopy and Microanalysis.* 27 (S1): 2736-2737
21. **Boebinger MG**, Yarema O, Yarema M, Unocic KA, Unocic RR, Wood V, McDowell MT (2021). "In Situ TEM Investigation of the Spontaneous Hollowing of Alloy Anode Nanocrystals." *Microscopy and Microanalysis.* 27 (S1): 1972-1973
22. Unocic RR, Sang X, Hu G, Fung V, **Boebinger MG**, Xiao K, Ganesh P (2021). "Designing Atomic Edge Structures in 2D Transition Metal Dichalcogenides for Improved Catalytic Activity." *Microscopy and Microanalysis.* 27 (S1): 964-965
23. Shetty PP, Kondekar N, Thenuwara AC, **Boebinger MG**, Wright SC, Tian M, McDowell MT (2020). "In Situ Dynamics during Heating of Copper-Intercalated Bismuth Telluride." *Matter.* 3 (4): 1246-1262
24. **Boebinger MG**, Yarema O, Yarema M, Unocic KA, Unocic RR, Wood V, McDowell MT (2020). "Spontaneous and Reversible Hollowing of Alloy Anode Nanocrystals for Stable Battery Cycling." *Nature Nanotech.* 15: 475-481.
25. **Boebinger MG**, Lewis J, Sandoval SE, McDowell MT (2020). "Understanding Transformations in Battery Materials using In Situ and Operando Experiments: Progress and Outlook." *ACS Energy Lett,* 5: 335-345
26. Nava G, Schwan J, **Boebinger MG**, McDowell MT, Mangolini L (2019). "Silicon-Core Carbon-Shell Nanoparticles for Lithium-ion Batteries: Rational Comparison Between Amorphous and Graphitic Carbon Coatings." *Nano Lett.* Article ASAP.
27. Kondekar NP, **Boebinger MG**, Tian M, Kirmani MH, McDowell MT (2019). "The Effect of Nickel on MoS_2 Growth Revealed with in Situ Transmission Electron Microscopy." *ACS Nano*, 13: 7117-7126.
28. Lewis JA, Cortes FJQ, **Boebinger MG**, Tippens J, Marchese TS, Kondekar NP, Liu X, Chi M, McDowell MT (2019). "Interphase morphology between a solid-state electrolyte and lithium controls cell failure." *ACS Energy Lett.*, 4 (2): 591-599.
29. **Boebinger MG**, Yeh D, Xu M, Miles BC, Wang B, Papakyriakou M, Lewis JA, Kondekar NP, Cortes FJQ, Hwang S, Sang X, Su D, Unocic RR, Xia S, Zhu T, McDowell MT (2018). "Avoiding Fracture in a Conversion Battery Material through Reaction with Larger Ions." *Joule,* 2 (9): 1783-1799.
30. Han SY, **Boebinger MG**, Kondekar NP, Worthy TJ, McDowell MT (2018). "Seeded Nanowire and Microwire Growth from Lithium Alloys." *Nano Lett.*, 18 (7): 4331-4337.
31. Kondekar NP, **Boebinger MG**, Cortes FJQ, McDowell MT (2018). "In Situ Investigation of Dynamic Processes in Materials for Energy Storage." *SPIE Commercial Scientific Sensing and Imaging 2018*.
32. Kirshenbaum MJ, **Boebinger MG**, Katz MJ, McDowell MT, Dasog M (2018). "Solid-State Route for Synthesis of Scalable, Luminescent Si and Ge Nanocrystals." *Chem. Nano. Mat.,* 4 (4): 423-429.
33. Cortes FJQ, **Boebinger MG**, Xu M, Ulvestad A, McDowell MT (2018). "Operando Synchrotron Measurement of Strain Evolution in Individual Alloying Anode Particles within Lithium Batteries." *ACS Energy Lett.*, 3 (2): 349-355.
34. Kondekar NP, **Boebinger MG**, Woods EV, McDowell MT (2017). "In Situ XPS Investigation of Transformations at Crystallographically Oriented MoS2 Interfaces." *ACS Appl. Mater. Interfaces*, 9 (37): 32394–32404.

35. Hu W, Guo S, Gaul JP, **Boebinger MG**, McDowell MT, Filler MA (2017). "Reversible Tuning of the Surface Plasmon Resonance of Indium Tin Oxide Nanocrystals by Gas-Phase Oxidation and Reduction." *J. Phys. Chem. C*, 121 (29): 15970–15976.
36. **Boebinger MG**, Xu M, Ma X, Chen H, Unocic RR, McDowell MT (2017). **"**Distinct Nanoscale Reaction Pathways in a Sulfide Material for Sodium and Lithium Batteries." *J. Mater. Chem. A,* 5: 11701-11709.

PRESENTATIONS

1. "Automated Fabrication and Characterization of Nanoscale Defect Structures for Enhanced Properties via Aberration-Corrected STEM." *CNMS User Meeting: Machine Learning in Autonomous Science: Synthesis, Characterization, and Theory Workshop*, August 7, 2023. **Invited** Workshop.
2. "Atomic-scale Fabrication of 1D-2D Nano Hetero-structures within 2D Materials through Automated Tracking and Electron Beam Control." *2023 Microscopy & Microanalysis Annual Meeting*, July 22–27, 2023, Minneapolis, MN. Conference Poster.
3. "Automated Fabrication and Characterization of Nanoscale Defect Structures for Enhanced Properties via Aberration-Corrected STEM." *Deep Learning for Microscopy Image Analysis in Nuclear Material Workshop*, June 5-6, 2023. **Invited** Workshop.
4. "Autonomous Beam Fabrication of 1D-2D Nano Hetero-structures within 2D Materials." *2023 Materials Research Society Spring Meeting,* May 23-25, 2023, San Francisco, CA. Conference Presentation.
5. "Atomic-scale Fabrication of 1D-2D Nano Hetero-structures within 2D Materials through Automated Tracking and Electron Beam Control." *2022 Microscopy & Microanalysis Annual Meeting*, July 31 – August 6, 2022, Portland, OR. Conference Poster.
6. "In Situ Atomic-Scale Electron Beam Fabrication of 2D Materials with Automated Feedback-Control." *2022 Materials Research Society Spring Meeting,* May 23-25, 2022, Virtual. Conference Presentation.
7. "Delving into Nanoscale Reaction Mechanisms and Kinetics using *In Situ* Electron Microscopy." *2021 FSU Material Science Seminar Series*, November 17, 2021, Virtual. **Invited** Seminar.
8. "Atomic-scale Feedback-controlled Electron Beam Fabrication of 2D Materials." *2021 Microscopy & Microanalysis Virtual Meeting*, August 1-5, 2021, Virtual. **Invited** Conference Presentation.
9. "*In Situ* TEM Investigation of the Spontaneous Hollowing of Alloy Anode Nanocrystals." *2021 Microscopy & Microanalysis Virtual Meeting*, August 1-5, 2021, Virtual. Conference Presentation.
10. "Stable Cycling of Alloy Anode Nanocrystals through Spontaneous Hollowing Behavior." *Batteries Gordon Research Seminar*, February 15-16, 2020, Ventura, CA. Conference Presentation.
11. "Understanding Chemo-Mechanical Degradation in High-Capacity Electrode Materials for Beyond-Lithium-Ion Batteries." *236th Electrochemical Society Meeting*, October 13-17, 2019, Atlanta, GA. Conference Presentation.
12. "In Situ TEM for Understanding Chemo-Mechanical Degradation in Battery Materials." 2019 Center for Nanophase Materials Science User Meeting, August 12-14, 2019, Oak Ridge, TN. Conference Presentation.
13. "Reaction with Larger Ions Avoids Fracture in a Conversion Battery Material—In Situ TEM Investigation." *2018 Materials Research Society Fall Meeting,* November 25-30, 2018, Boston, MA. Conference Presentation.
14. "In Situ TEM Investigation of the Electrochemical Reaction Pathways of Sulfide Materials with Different Alkali Ions." *255th ACS National Meeting*, March 18-22, 2018, New Orleans, LA. Conference Presentation.
15. **"**Distinct Nanoscale Reaction Pathways in a Sulfide Material for Sodium and Lithium Batteries." *2017 Joint Nanoscience and Neutron Scattering User Meeting,* July 31-August 4, 2017, Oak Ridge National Laboratory, Oak Ridge, TN. Conference Presentation.
16. "In Situ Multiscale Investigation of Reaction Pathways in a Sulfide Material for Sodium and Lithium Batteries." *Electrochemical Society Meeting*, May 28-June 1, 2017, New Orleans, LA. Conference Poster.

PROFESSIONAL SOCIETY MEMBERSHIP

Materials Research Society (MRS)
Microscopy Society of America (MSA)