Michael J. Zachman

R&D Associate
Materials MicroÅnalysis Group
Center for Nanophase Materials Sciences
Oak Ridge National Laboratory
1 Bethel Valley Rd., Oak Ridge, TN 37831
Website, Google Scholar

Education:

2018 Cornell University, Ph.D., Applied Physics
2015 Cornell University, M.S., Applied Physics
2012 Purdue University, B.S., Physics

Research Expertise:

- ~9 years of experience in the field of electron microscopy.
- Expert in development and application of cryogenic focused ion beam (FIB) and aberration-corrected scanning transmission electron microscopy (STEM) techniques, as well as four-dimensional (4D)-STEM techniques.
- Adept at various forms of STEM imaging, electron energy-loss spectroscopy (EELS) – including monochromated EELS, energy-dispersive X-ray spectroscopy (EDS), and four-dimensional (4D)-STEM.
- Research focuses on understanding the structure and properties of energy storage and conversion materials, as well as quantum materials, down to the atomic scale.

Professional Experience:

2019–present	R&D Associate, Center for Nanophase Materials Sciences, ORNL
2018–2019	Postdoctoral Research Associate, Center for Nanophase Materials Sciences, ORNL
2013–2018	Graduate Research Assistant, Cornell University
2012–2013	Teaching Assistant, Cornell University
2011–2012	Undergraduate Research Assistant, Purdue University
2011	Summer Undergraduate Research Fellow, Purdue University
2010	Intern, Thermophysical Properties Research Laboratory, Inc.

Honors and Awards:

William Nichols Findley Award for Outstanding Research Paper, Cornell University School of Applied & Engineering Physics, 2019
Early Career Representative and Scholarship for EMAS 2019, Microanalysis Society, 2019
Best Microscopy and Microanalysis Journal Paper of 2016 Award, Microscopy Society of America, 2017
Materials Handling Prize, Silent Hoist and Crane, 2017
Meeting Scholarship, Enhanced Data Generated by Electrons, 2017
Eric Samuel Scholarship Award, Microscopy Society of America, 2015
Watt W. Webb Graduate Fellowship in Nanoscience, Kavli Institute at Cornell, 2014

Peer Reviewed Publications (h-index: 15 [Google Scholar])

1. Ræder, T.; Qin. S.; Vasudevan, R.K.; Grande, T.; Agar, J.; **Zachman, M.J.**, "High Velocity, Low-Voltage Collective In-Plane Switching in (100) $BaTiO_3$ Thin Films," *Adv. Sci.* (2022).
2. Ul Hassan, N.*; **Zachman, M.J.***; Mandal, M.; Firouzjaie, H.A.; Kohl, P.A.; Cullen, D.A.; Mustain, W.E., "Understanding Recoverable vs. Unrecoverable Voltage Losses and Long-Term Degradation Mechanisms in Anion Exchange Membrane Fuel Cells." *ACS Catal.* **12**, 8116 (2022). ***Contributed equally.**
3. Yu, H.; **Zachman, M.J.**; Reeves, K.S.; Park, J.H.; Kariuki, N.N.; Hu, L.; Mukundan, R.; Neyerlin, K.C.; Myers, D.J.; Cullen, D.A., "Tracking Nanoparticle Degradation Across Fuel Cell Electrodes by Automated Analytical Electron Microscopy." *ACS Nano* (2022).
4. Liu, S.*; Li, C.*; **Zachman, M.J.***; Zeng, Y.; Yu, H.; Li, B.; Wang, M.; Braaten, J.; Liu, J.; Meyer III, H.M.; Lucero, M.; Kropf, A.J.; Alp E.E.; Gong, Q.; Shi, Q.; Feng, Z.; Xu, H.; Wang, G.; Myers, D.J.; Xie, J.; Cullen, D.A.; Litster, S.; Wu, G., "Atomically-dispersed iron sites with a nitrogen-carbon coating as highly active and durable oxygen reduction reaction catalysts for fuel cells." *Nat. Energy* **7**, 652 (2022). ***Contributed equally.**

5. **Zachman, M.J.**, Fung, V.; Polo-Garzon, F.; Cao, S.; Moon, J.; Huang, Z.; Jiang, D.; Wu, Z.; Chi, M., "Measuring and directing charge transfer in heterogeneous catalysts," *Nat. Commun.* **13**, 1 (2022).
6. Li, Y.*; Shan, W.*; **Zachman, M.J.***; Wang, M.; Hwang, S.; Tabassum, H.; Yang, J.; Yang, X.; Karakalos, S.; Feng, Z.; Wang, G.; Wu, G., "Atomically Dispersed Dual-Metal Site Catalysts for Enhanced CO_2 Reduction: Mechanistic Insight into Active Site Structures," *Angew. Chemie.* (2022). ***Contributed equally.**
7. Yu, H.; **Zachman, M.J.**; Li, C.; Hu, L.; Kariuki, N.N.; Mukundan, R.; Xie, J.; Neyerlin, K.C.; Myers, D.J.; Cullen, D.A., "Recreating Fuel Cell Catalyst Degradation in Aqueous Environments for Identical-Location Scanning Transmission Electron Microscopy," *ACS Appl. Mater. and Interfaces* **14**, 20418 (2022).
8. Li, Y.; Mohd Adli, N.; Shan, W.; Wang, M.; **Zachman, M.J.**; Hwang, S.; Tabassum, H.; Karakalos, S.; Feng, Z.; Wang, G.; Li, C.; Wu, G., "Atomically Dispersed Single Ni Site Catalysts for High-Efficiency CO_2 Electroreduction at Industrial-Level Current Densities," *Energy and Environ. Sci.* **15**, 2018 (2022).
9. Snitkoff-Sol, R.Z.; Friedman, A.; Honig, H.C.; Yurko, Y.; Kozhushner, A.; **Zachman, M.J.**; Zelenay, P.; Bond, A.M.; Elbaz, L., "Quantifying the electrochemical active site density of precious metal-free catalysts in situ in fuel cells," *Nat. Catal.* **5**, 162 (2022).
10. **Zachman, M.J.**; Yang, Z.; Du, Y.; Chi, M., "Robust Atomic-Resolution Imaging of Lithium in Battery Materials by Center-of-Mass Scanning Transmission Electron Microscopy," *ACS Nano* **16**, 1358 (2022).
11. **Zachman, M.J.**; Madsen, J.; Zhang, X.; Ajayan, P.M.; Susi, T.; Chi, M., "Interferometric 4D-STEM for Lattice Distortion and Interlayer Spacing Measurements of Bilayer and Trilayer 2D Materials," *Small* **17**, 210088 (2021).
12. El Baggari, I.; Baek, D.J.; **Zachman, M.J.**; Lu, D.; Hikita, Y.; Hwang, H.Y.; Nowadnick, E.A.; Kourkoutis, L.F., "Charge order textures induced by non-linear couplings in a half-doped manganite," *Nat. Commun.* **12**, 1 (2021).
13. Friedman, A.; Mizrahi, M.; Levy, N.; Zion, N.; **Zachman, M.**; Elbaz, L., "Application of Molecular Catalysts for the Oxygen Reduction Reaction in Alkaline Fuel Cells," *ACS Appl. Mater. Interfaces* **13**, 58532 (2021).
14. Yang, X.; Wang, M.; **Zachman, M.J.**; Zhou, H.; He, Y.; Liu, S.; Zang, H.-Y.; Feng, Z.; Wu, G., "Binary Atomically Dispersed Metal-Site Catalysts with Core-Shell Nanostructures for O_2 and CO_2 Reduction Reactions," *Small Sci.* **1** (10), 2100046 (2021).
15. O'Brien, T.; Herrera, S.; Langlois, D.; Kariuki, N.; Yu, H.; **Zachman, M. J.**; Myers, D.J.; Cullen, D.A.; Borup, R.; Mukundan, R., "Impact of Carbon Support Structure on the Durability of PtCo Electrocatalysts," *J. Electrochem. Soc.* **168**, 054517 (2021).
16. Houseman, L.; Mukherjee, S.; Andris, R.; **Zachman, M.J.**; Pomerantseva, E., "Free-standing bilayered vanadium oxide films synthesized by liquid exfoliation of chemically preintercalated δ-$Li_xV_2O_5{\cdot}nH_2O$," *Mater. Adv.* **2***,* 2711 (2021).
17. Possinger, A.R.; **Zachman, M.J.**; Dynes, J.J.; Regier, T.Z.; Kourkoutis, L.F.; Lehmann, J., "Co-precipitation induces changes to iron and carbon chemistry and spatial distribution at the nanometer scale," *Geochim. Cosmochim. Acta* **314**, 1 (2021).
18. Blum, T.; Graves, J.; **Zachman, M.J.**; Polo-Garzon, F.; Wu, Z.; Kannan, R.; Pan, X.; Chi, M., "Machine Learning Method Reveals Strong Metal-Support Interaction in Microscopy Datasets," *Small Methods*, 2100035 (2021).
19. Possinger, A. R.; **Zachman, M. J.**; Enders, A.; Levin, B. D. A.; Muller, D. A.; Kourkoutis, L. F.; Lehmann, J., "Organo-organic and organo-mineral interfaces in soil at the nanometer scale," *Nat. Commun.* **11**, 6103 (2020).
20. DeRocher, K. A.; Smeets, P. J. M.; Goodge, B. H.; **Zachman, M. J.**; Balachandran, P.V.; Stegbauer, L.; Cohen, M. J.; Gordon, L. M.; Rondinelli, J. M.; Kourkoutis, L. F.; Joester, D., "Chemical gradients in human enable crystallites," *Nature* **583**, 66 (2020).
21. **Zachman, M. J.**; Tu, Z.; Archer, L. A.; Kourkoutis, L. F., "Nanoscale Elemental Mapping of Intact Solid-Liquid Interfaces and Reactive Materials in Energy Devices Enabled by Cryo-FIB/SEM," *ACS Energy Lett.* **5** (4), 1224 (2020).
22. **Zachman, M. J.**; De Jonge, N.; Fischer, R.; Jungjohann, K. L.; Perea, D. E., "Cryogenic specimens for nanoscale characterization of solid-liquid interfaces," *MRS Bull.* **44** (12), 949 (2019).
23. Yu, S.-H.*; **Zachman, M. J.***; Kang, K.; Gao, H.; Huang, X.; DiSalvo, F. J.; Park, J.; Kourkoutis, L. F.; Abruña, H. D., "Atomic-Scale Visualization of Electrochemical Lithiation Processes in Monolayer MoS_2 by Cryogenic Electron Microscopy," *Adv. Energy Mater.* **9**, 1902773 (2019). ***Contributed equally.**

24. **Zachman, M. J.**; Hachtel, J. A.; Idrobo, J. C.; Chi, M., "Emerging Electron Microscopy Techniques for Probing Functional Interfaces in Energy Materials," *Angew. Chemie* **131**, 2 (2019).
25. Wang, Z.; Goodge, B. H.; Baek, D. J.; **Zachman, M. J.**; Huang, X.; Bai, X.; Brooks, C. M.; Paik, H.; Mei, A. B.; Brock, J. D.; Maria, J. P.; Kourkoutis, L. F.; Schlom, D. G., "Epitaxial $SrTiO_3$ film on silicon with narrow rocking curve despite huge defect density," *Phys. Rev. Mater.* **3** (7), 073403 (2019).
26. Choudhury, S.; Tu, Z.; Nijamudheen, A.; **Zachman, M. J.**; Stalin, S.; Deng, Y.; Zhao, Q.; Vu, D.; Kourkoutis, L. F.; Mendoza-Cortes, J. L.; Archer, L. A., "Stabilizing Polymer Electrolytes in High-Voltage Lithium Batteries," *Nat. Commun.* **10**, 3091 (2019).
27. Zhao, Q.; **Zachman, M. J.**; Al Sadat, W. I.; Zheng, J.; Kourkoutis, L. F.; Archer, L. A., "Solid Electrolyte Interphases for High-Energy Aqueous Aluminum Electrochemical Cells," *Sci. Adv.* **4**, eaau8131 (2018).
28. **Zachman, M. J.**; Tu, Z.; Choudhury, S.; Archer, L. A.; Kourkoutis, L. F., "Cryo-STEM Mapping of Solid-Liquid Interfaces and Dendrites in Li-Metal Batteries," *Nature* **560**, 345 (2018).
29. Tu, Z.*; **Zachman, M. J.***; Choudhury, S.; Khan, K. A.; Zhao, Q.; Kourkoutis, L. F.; Archer, L. A., "Stabilizing Protic and Aprotic Liquid Electrolytes at High-Bandgap Oxide Interphases," *Chem. Mater.* **30**, 5655 (2018). ***Contributed equally.**
30. Prasad, B.; Pfanzelt, G.; Fillis-Tsirakis, E.; **Zachman, M. J.**; Kourkoutis, L. F.; Mannhart, J., "Integrated Circuits Comprising Patterned Functional Liquids," *Adv. Mater.* **30**, 1802598 (2018).
31. Tu, Z.; Choudhury, S.; **Zachman, M. J.**; Wei, S.; Zhang, K., Kourkoutis, L. F.; Archer, L. A., "Fast Ion Transport at Solid-Solid Interphases in Hybrid Battery Anodes," *Nat. Energy* **3**, 310 (2017).
32. Tu, Z.; Choudhury, S.; **Zachman, M. J.**; Wei, S.; Zhang, K., Kourkoutis, L. F.; Archer, L. A., "Designing Artificial Solid-Electrolyte Interphases for Single-Ion and High-Efficiency Transport in Batteries," *Joule* **1**, 394 (2017).
33. Choudhury, S.; Wei, S.; Ozhabes, Y.; Gunceler, D.; **Zachman, M. J.**; Tu, Z.; Shin, J.-H.; Nath, P.; Agrawal, A.; Kourkoutis, L. F.; Archer, L. A., "Designing Solid-Liquid Interphases for Sodium Batteries," *Nat. Commun.* **8**, 898 (2017).
34. Choudhury, S.; Wan, C. T.-C.; Al Sadat, W. I.; Tu, Z.; Lau, S.; **Zachman, M. J.**; Kourkoutis, L. F.; Archer, L. A., "Designer Interphases for the Lithium-Oxygen Electrochemical Cell," *Sci. Adv.***3** (4), e1602809 (2017).
35. Levin, B. D. A.; **Zachman, M. J.**; Werner, J.; Sahore, R.; Nguyen, K. X.; Han, Y.; Xie, B.; Ma, L.; Archer, L. A.; Giannelis, E. P.; Wiesner, U.; Kourkoutis, L. F.; Muller, D. A., "Characterization of Sulfur and Nanostructured Sulfur Battery Cathodes in Electron Microscopy without Sublimation Artifacts," *Microsc. Microanal.* **23**, 155 (2017).
36. Tu, Z.; **Zachman, M. J.**; Choudhury, S.; Wei, S.; Ma, L.; Yang, Y.; Kourkoutis, L. F.; Archer, L. A., "Nanoporous Hybrid Electrolytes for High-Energy Batteries Based on Reactive Metal Anodes," *Adv. Energy Mater.* **7**, 1602367 (2017).
37. **Zachman, M. J.**; Asenath-Smith, E.; Estroff, L. A.; Kourkoutis, L. F., "Site-Specific Preparation of Intact Solid-Liquid Interfaces by Label-Free *In-Situ* Localization and Cryo-Focused Ion Beam Lift-Out," *Microsc. Microanal.* **22**, 1338 (2016).

Presentations:

1. "Robust Atomic-Resolution Imaging of Lithium by CoM-STEM," *BES User Facility Science Slam!*, Virtual (2022).
2. ***(Invited)*** "Probing Intact Solid-Liquid Interfaces and Reactive Materials by Cryo-FIB and Cryo-STEM," *International Cryo-EM (ICE) Workshop for Advanced Materials*, Albuquerque, NM (2022).
3. ***(Invited)*** "Method for cryo-(S)TEM characterization of reactive/sensitive materials and samples containing liquids," in "Cryo-STEM and EELS for Material Sciences" Sunday Short Course at *Microscopy and Microanalysis*, Portland, OR (2022).
4. "Imaging Sensitive Catalyst Active Site Structure by 30 keV Electron Ptychography," *Microscopy and Microanalysis*, Portland, OR (2022).
5. Mapping pm-scale Lattice Distortions and Measuring Interlayer Separations in Stacked 2D Materials by Interferometric 4D-STEM," *Microscopy and Microanalysis*, Portland, OR (2022).
6. "Simultaneous Atomic-Resolution Imaging of Light and Heavy Elements in Functional Materials by CoM-STEM," *Materials Research Society Spring Meeting*, Virtual (2022).
7. "Measuring Local Structural Distortions and Interlayer Spacings of 2D Moiré Materials by Interferometric 4D-STEM," *Materials Research Society Spring Meeting*, Virtual (2022).

8. ***(Invited)*** "Investigating Intact Solid-Liquid Interfaces at the Nanoscale by Cryo-FIB and Cryo-STEM," *Energy and Soft Matter Seminar Series*, Oak Ridge National Laboratory, Oak Ridge, TN (2021).
9. "Atomic-scale Imaging of PGM-free Catalyst Active Sites by 30 keV 4D-STEM," *Microscopy and Microanalysis*, Virtual (2021).
10. "Mapping the Evolution of Surface Strain in PtCo Core-Shell Catalysts by 4D-STEM," *240th Electrochemical Society Meeting*, Virtual (2021).
11. ***(Invited)*** "Cryogenic Specimens for Nanoscale Characterization of Solid-Liquid Interfaces," *MRS On Demand Webinar Series* (2020).
12. ***(Invited)*** "Cryo-FIB and Cryo-STEM for Battery Materials Research," *Oxford University Electron Microscopy Group*, Virtual (2020).
13. "Atomic-Scale Structural Mapping of Active Sites in Monolayer PGM-free Catalysts by Low-Voltage 4D-STEM," *Microscopy and Microanalysis*, Virtual (2020).
14. "Enhancing Atomic-Scale Imaging of PGM-free Catalysts by Low-Voltage Scanning Transmission Electron Microscopy," *The Electrochemical Society, Pacific Rim Meeting on Electrochemical and Solid State Science (PRiME)*, Virtual (2020).
15. ***(Invited)*** "Mapping Local Structural and Electronic Properties of 2D Materials by Multi-Dimensional STEM," *Microscopy and Microanalysis*, Portland, OR (2019).
16. ***(Invited)*** "Probing the Native Structure and Chemistry of Li-Metal Batteries by Cryo-Electron Microscopy," *EMAS 2019 – 16th Workshop on Modern Developments and Applications in Microbeam Analysis*, Trondheim, NO (2019).
17. ***(Invited)*** "Recent Progress and Future Opportunities for Cryo-STEM in Materials Science," *Center for Nanophase Materials Sciences Seminar Series*, Oak Ridge National Laboratory, Oak Ridge, TN (2019).
18. "Mapping Local Structure and Electronic Properties of 2D Materials by Multidimensional STEM," *Microscopy and Microanalysis*, Portland, OR (2019).
19. "Mapping Local Properties in Twisted Bilayer Materials by 4D-STEM," *17th Frontiers of Electron Microscopy in Materials Science*, Asheville, NC (poster) (2019).
20. ***(Invited)*** "Ion Conductivity and Stability of Interfaces Involving Solid Electrolytes," *14th Annual Lithium Battery Materials and Chemistries Conference*, Arlington, VA (2018).
21. "Probing the Native Structure and Chemistry of Dendrites and SEI Layers in Li-Metal Batteries by Cryo-FIB Lift-Out and Cryo-STEM," *Microscopy and Microanalysis*, Baltimore, MD (2018).
22. "Revealing the Nanoscale Structure and Chemistry of Intact Solid-Liquid Interfaces in Electrochemical Energy Storage Devices by Cryo-FIB and Cryo-STEM," *Microscopy and Microanalysis,* St. Louis, MO (2017).
23. "Mapping of Local Bonding States at Intact Solid-Liquid Interfaces by Cryo-FIB Lift-Out and Cryo-STEM EELS," *Enhanced Data Generated by Electrons Meeting*," Okinawa, Japan (poster) (2017).
24. "Nanoscale Structure and Bonding at Intact Solid-Liquid Interfaces Revealed by Cryo FIB Lift-Out and Analytical Cryo-STEM," *FIB User Meeting*, National Institute of Standards and Technology, Gaithersburg, MD (poster) (2017).
25. ***(Invited)*** "New Applications in Materials Science Enabled by Cryo-FIB Lift-Out and Cryo-STEM," Oxford Instruments NanoAnalysis, High Wycombe, UK (2016).
26. ***(Invited)*** "New Applications in Materials Science Enabled by Cryo-FIB Lift-Out and Cryo-STEM," *Cryo Microscopy Group Meeting*, University of Nottingham, Nottingham, UK (2016).
27. "Advances in Cryo-FIB Lift-Out Preparation of Intact Solid-Liquid Interfaces and Hard Soft Composite Materials for Cryo-TEM," *FIB User Meeting*, Johns Hopkins Applied Physics Laboratory, Laurel, MD (2016).
28. "Localization of Subsurface Structure for Site-Specific Cryo-FIB Lift-Out Preparation of Solid-Liquid Interfaces," *Microscopy and Microanalysis* (2016).
29. "Revealing the Internal Structure and Local Chemistry of Nanocrystals Grown in Hydrogel with Cryo-FIB Lift-Out and Cryo-STEM," *Microscopy and Microanalysis* (2015).
30. "Cryo-STEM for Energy Materials Research," *Microscopy and Microanalysis* (poster) (2014).

Professional Memberships:
Microscopy Society of America (MSA)
Microanalysis Society (MAS)
Materials Research Society (MRS)

Professional Activities:
Ran cryo-FIB lift-out demonstrations at *'International Cryo-EM (ICE) Workshop for Advanced Materials,'* Albuquerque, NM, 8/22/22 – 8/25/22.
Co-organizer of "Cryo-STEM and EELS for Materials Sciences" Sunday Short Course at *'Microscopy and Microanalysis,'* Portland, OR, 7/31/22.
Guest Editor of "State-of-the-Art Electron Microscopy for Physical Sciences Research" Methods Collection in the "*Journal of Visualized Experiments*," 2021-2022.
Co-organizer of "Microscopy & Spectroscopy of Energy Storage and Conversion Materials" session at *'Microscopy and Microanalysis,'* Pittsburgh, PA, 8/1/21 – 8/5/21.
Session Chair at *'17th Frontiers of Electron Microscopy in Materials Science,'* Asheville, NC, 9/6/19.
Session Chair at *'Microscopy and Microanalysis,'* Portland, OR, 8/7/19.
Session Chair at *'14th Annual Lithium Battery Materials and Chemistries Conference,'* Arlington, VA, 11/2/2018.

Graduate and Postdoctoral Research Advisors:
Prof. Lena F. Kourkoutis, Applied and Engineering Physics, Cornell University (PhD)
Dr. Miaofang Chi, Center for Nanophase Materials Sciences, Oak Ridge National Laboratory (Postdoc)

Outreach and Mentoring Activities:
Volunteer and tabletop scanning electron microscope operator for ORNL CNMS Science Trailer events, 2019–present
Volunteer and microscopy activity designer/presenter, Cornell CCMR Outreach Program, 2013–2018
Undergraduate mentor, REU Program, Cornell University, 2014
Volunteer and designer/presenter of an interactive microscopy program, Sciencenter, Ithaca, NY, 2013–2014