

Ashley E. Morishige

Contact Information Photovoltaic Research Laboratory aemorish@mit.edu
Massachusetts Institute of Technology
77 Massachusetts Ave, 35-211
Cambridge, MA 02139

Education **Massachusetts Institute of Technology** **2013 – 2016**

Ph.D. Candidate in Mechanical Engineering
Thesis: “Metal Impurities in *n*-type Crystalline Silicon for Photovoltaics: Simulation, Synchrotron-Based Characterization, and Mitigation”

Committee:

Prof. Tonio Buonassisi (Mechanical Engineering, advisor)

Prof. Jesús del Alamo (Electrical Engineering)

Prof. Jeffrey Grossman (Materials Science and Engineering)

Relevant Coursework:

Fundamentals of Photovoltaics, Nano-to-Macro Transport Processes, Structural Mechanics, Fluid Mechanics, Kinetic Processes in Materials, Electronic Materials Design, Material Processes for Micro- and Nano- Systems, Sustainable Energy, Power Electronics

Massachusetts Institute of Technology **2013**

M.S. Mechanical Engineering, advised by Prof. Tonio Buonassisi

Thesis: “Co-Optimizing Si Solar Cell Processing for Efficiency and Throughput”

Dartmouth College - Thayer School of Engineering **2011**

Bachelor of Engineering, conc. in Environmental and Energy Engineering

B.A. Engineering Sciences (*cum laude*)

Certifications Engineer in Training, NH, 2011

Analytical Tools Scanning electron microscopy (SEM), Synchrotron-based micro-X-ray fluorescence spectroscopy (μ -XRF), Electron-beam-induced current (EBIC), Electron backscatter diffraction (EBSD), Ellipsometry, Four-point probe, Photoluminescence imaging (PLI), Optical microscopy, Quasi-steady-state photoconductance (QSSPC), Microwave photoconductance decay (μ -PCD)

Fabrication Tools Semiconductor wet chemistry surface cleaning and etching (RCA, CP4, KOH), Atomic layer deposition (ALD), semiconductor surface passivation, phosphorus diffusion gettering, diffusion tube furnace use and maintenance, laser cutter, wafer polishing

Software	MATLAB, Synopsys Sentaurus TCAD, OriginLab
Solar Cell Fabrication	Screen-printed silicon PV cells - Arizona State University, Solar Power Labs Passivated emitter and rear contact (PERC) silicon PV devices - Harvard University, Center for Nanoscale Systems LISE Cleanroom
Honors & Awards	Hands-On PV Experience (HOPE), NREL, Golden, CO, July 2015 Graduate Student Council Travel Grant, MIT, 2015 DeFlores Travel Award in Design and Manufacturing, MIT, 2015 Best Student Seminar, Lab for Manufacturing and Productivity, MIT, 2013 Invited Researcher, Electron Physics Group, Aalto University, Finland, 2013 National Defense Science and Engineering Graduate Fellowship, 2012 Awarded NSF Graduate Research Fellowship, 2012 MIT School of Engineering SMA2 Fellowship, 2011 Sigma Xi, The Scientific Research Society, 2011 Bengt Sonnerup Fellowship for Research in Energy Technologies, 2010–2011 Tau Beta Pi Engineering Honor Society, 2010 Women in Science Project Intern, 2008
Successful Proposals	3/2015 - “Root-cause identification and prevention of potential-induced degradation in photovoltaic modules,” Advanced Photon Source General User Proposal 3/2013 - “Accelerating the learning curve for defect engineering of next-generation silicon solar cell materials,” Advanced Photon Source General User Proposal
Research Experience	<p>MIT Photovoltaic Research Laboratory 2011 – present</p> <ul style="list-style-type: none"> ● Principal Investigator of team that measures trace metal impurities in solar cell materials using world-leading synchrotron X-ray nanoprobe at Argonne National Lab’s Advanced Photon Source ● Lead international collaborations between universities, research institutes, and companies to advance understanding of silicon for photovoltaics ● Work with companies to apply industrially-relevant knowledge of material properties, impurities and defects, and process parameters to improve material quality and device performance, including root-cause analysis ● Characterize, engineer, and simulate trace metal impurities in crystalline silicon to enable cost-effective, yet high-efficiency solar cells

- Develop processing that mitigates impurity- and defect-related solar cell device degradation in conventional and new materials
- Develop impurity kinetics simulation for phosphorus diffusion gettering of iron in silicon using state-of-the-art Sentaurus TCAD software; published online at <http://pv.mit.edu/impurity-to-efficiency-i2e-simulator-for-sentaurus-tcad/>
- Mentor fellow graduate students in simulation tools, experimental methods, and operation of synchrotron beamline

Lynd Research Laboratory, Dartmouth College

2009 - 2011

Institute on the Environment, University of Minnesota

- Modeled globally-distributed pastureland productivity in MATLAB with the goal of identifying opportunities to sustainably meet increasing global demands for fiber, fuel, feed, and food

U.S. Army Cold Regions Research and Engineering Lab **2008 - 2011**

- Improved mechanical and electrical performance of ground-penetrating radar, a cost-effective, non-destructive remote-sensing device, on rough terrain (2010-11)
- Investigated the effect of soil biochemistry on dissolved explosives left in the soil of live-fire ranges after incomplete explosions with the objective of informing bioremediation protocols (2008)

**Peer-
Reviewed
Publications**

1. K. Nakayashiki, J. Hofstetter, **A. E. Morishige**, T. A. Li, D. Berney Needleman, M. A. Jensen, T. Buonassisi, “Engineering Solutions and Root-Cause Analysis for Light-Induced Degradation in *p*-Type Multicrystalline Silicon PERC Modules,” *IEEE Journal of Photovoltaics* (2016).
2. **A. E. Morishige**, M. A. Jensen, J. Hofstetter, P. X. T. Yen, C. Wang, B. Lai, D. P. Fenning, T. Buonassisi, “Synchrotron-based investigation of transition-metal getterability in *n*-type multicrystalline silicon,” *Applied Physics Letters* **108**, 202104 (2016).
3. S. Castellanos, K. E. Ekstrøm, A. Autruffe, M. A. Jensen, **A. E. Morishige**, J. Hofstetter, P. Yen, B. Lai, G. Stockman, C. del Cañizo, T. Buonassisi, “High-Performance and Traditional Multicrystalline Silicon: Comparing Gettering Responses and Lifetime-Limiting Defects,” *Journal of Applied Physics* **6**(3), 632–640 (2016).
4. D. M. Powell, V. P. Markevich, J. Hofstetter, M. A. Jensen, **A. E. Morishige**, S. Castellanos, B. Lai, A. R. Peaker, T. Buonassisi, “Exceptional gettering response of epitaxially grown kerfless silicon,” *Journal of Applied Physics* **119**, 065101 (2016).

5. **A. E. Morishige**, H. Wagner, J. Hofstetter, I. Avci, C. del Cañizo, T. Buonassisi, “Combined impact of heterogeneous lifetime and gettering on solar cell performance,” *Energy Procedia* **77**, 119-128 (2015).
6. **A. E. Morishige**, H. S. Laine, J. Schön, A. Haarahiltunen, J. Hofstetter, C. del Cañizo, M. C. Schubert, H. Savin, T. Buonassisi, “Building Intuition of Iron Evolution during Solar Cell Processing through Analysis of Different Process Models,” *Applied Physics A* **120**, 1357 (2015).
7. M. A. Jensen, J. Hofstetter, **A. E. Morishige**, G. Coletti, B. Lai, D. P. Fenning, T. Buonassisi, “Synchrotron-based analysis of chromium distributions in multi crystalline silicon for solar cells,” *Applied Physics Letters* **106** 202104 (2015).
8. D. P. Fenning, J. Hofstetter, **A. E. Morishige**, D. M. Powell, A. Zuschlag, G. Hahn, and T. Buonassisi. “Darwin at High Temperature: Advancing Solar Cell Material Design Using Defect Kinetics Simulations and Evolutionary Optimization,” *Advanced Energy Materials* **4** (13), (2014).
9. J. Hofstetter, D. P. Fenning, D. M. Powell, **A. E. Morishige**, H. Wagner, and T. Buonassisi. “Sorting metrics for customized phosphorus diffusion gettering,” *IEEE Journal of Photovoltaics* **4** (6), pp. 1421-1428 (2014).
10. M. Kivambe, D. M. Powell, S. Castellanos, M. A. Jensen, **A. E. Morishige**, K. Nakajima, K. Morishita, R. Murai, T. Buonassisi, “Minority-carrier lifetime and defect content of n-type silicon grown by the noncontact crucible method,” *Journal of Crystal Growth* **407**, pp. 31-36 (2014).

Conference Proceedings

1. **A. E. Morishige**, M. A. Jensen, D. Berney Needleman, K. Nakayashiki, J. Hofstetter, T. A. Li, T. Buonassisi, “Lifetime Spectroscopy Investigation of Light-Induced Degradation in *p*-Type Multicrystalline Silicon PERC,” 43rd IEEE PVSC, Portland, OR, June 2016.
2. **A. E. Morishige**, H. S. Laine, M. A. Jensen, P. X. T. Yen, E. E. Looney, S. Vogt, B. Lai, H. Savin, T. Buonassisi, “Accelerating Synchrotron-Based Characterization of Solar Materials: Development of Flyscan Capability,” 43rd IEEE PVSC, Portland, OR, June 2016.
3. **A. E. Morishige**, D. Berney Needleman, M. A. Jensen, H. Wagner, J. Hofstetter, D. P. Fenning, C. del Cañizo, T. Buonassisi. “Vertically-Integrated Defect Engineering for Photovoltaics,” 25th Workshop on Crystalline Silicon Solar Cells & Modules: Materials and Processes, Breckenridge, CO, July 2015.
4. **A. E. Morishige**, D. P. Fenning, J. Hofstetter, M. A. Jensen, S. Ramanathan, C. Wang, B. Lai, T. Buonassisi. “Elucidating and Engineering Recombination-Active Metal-Rich Precipitates in *n*-type Multicrystalline Silicon,” 40th IEEE-PVSC, Denver, CO, June 2014.

5. **A. E. Morishige**, H. S. Laine, J. Schön, J. Hofstetter, A. Haarahiltunen, M. Schubert, H. Savin, and T. Buonassisi, “Analysis of Different Models of Iron Precipitation in Multicrystalline Silicon,” 40th IEEE-PVSC, Denver, CO, June 2014.
6. H. Wagner, J. Hofstetter, B. Mitchell, **A. E. Morishige**, T. Buonassisi, P. P. Altermatt. “Pathway to predict solar cell efficiencies from as-grown multicrystalline silicon bricks,” 40th IEEE-PVSC, Denver, CO, June 2014.
7. D. P. Fenning, V. Vähänissi, J. Hofstetter, **A. E. Morishige**, H. Laine, A. Haarahiltunen, S. C. Castellanos, M. A. Jensen, B. Lai, H. Savin. “Iron Precipitation upon Gettering in Phosphorus-Implanted Czochralski Silicon and its Impact on Solar Cell Performance.” 40th IEEE-PVSC, Denver, CO, June 2014.
8. M. Kivambe, D. M. Powell, M. A. Jensen, **A. E. Morishige**, K. Nakajima, R. Murai, K. Morishita, T. Buonassisi, “>1.8 millisecond effective lifetime in *n*-type silicon grown by the non contact crucible method,” 40th IEEE-PVSC, Denver, CO, June 2014.
9. M. A. Jensen, J. Hofstetter, D.P. Fenning, **A.E. Morishige**, G. Coletti, B. Lai, T. Buonassisi. “Engineering the Distribution of Chromium in Multicrystalline Silicon,” 40th IEEE-PVSC, Denver, CO, June 2014.
10. S. M. Scott, J. Hofstetter, **A. E. Morishige**, T. Buonassisi, “Sacrificial High-Temperature Phosphorus Diffusion Gettering Process for Lifetime Improvement of Multi-Crystalline Silicon Wafers,” 40th IEEE-PVSC, Denver, CO, June 2014.
11. J. Hofstetter, D.P. Fenning, D.M. Powell, **A. E. Morishige**, T. Buonassisi. “Iron management in multicrystalline silicon through predictive simulation: point defects, precipitates, and structural defect interactions,” Solid State Phenomena, 205-6, pp. 15-25 (2014).
12. **A. E. Morishige**, D. P. Fenning, J. Hofstetter, D. M. Powell, T. Buonassisi, “Simulated co-optimization of crystalline silicon solar cell throughput and efficiency using continuously ramping phosphorus diffusion profiles,” 38th IEEE Photovoltaics Specialist Conference, Austin, TX, June 2012.

Talks

1. **A. E. Morishige**, M. A. Jensen, D. Berney Needleman, K. Nakayashiki, J. Hofstetter, T. A. Li, T. Buonassisi, “Lifetime Spectroscopy Investigation of Light-Induced Degradation in p-Type Multicrystalline Silicon PERC,” 43rd IEEE PVSC, Portland, OR, June 2016.
2. **A. E. Morishige**, H. S. Laine, M. A. Jensen, P. X. T. Yen, E. E. Looney, S. Vogt, B. Lai, H. Savin, T. Buonassisi, “Accelerating Synchrotron-Based Characterization of Solar Materials: Development of Flyscan Capability,” 43rd IEEE PVSC, Portland, OR, June 2016.

3. **A. E. Morishige** (invited), D. Berney Needleman, M. A. Jensen, H. Wagner, J. Hofstetter, D. P. Fenning, C. del Cañizo, T. Buonassisi. “Vertically-Integrated Defect Engineering for Photovoltaics,” 25th Workshop on Crystalline Silicon Solar Cells & Modules: Materials and Processes, Breckenridge, CO, July 2015.
4. R. Jaramillo (invited), S. C. Siah, R. Chakraborty, **A. E. Morishige**, D. M. Powell, M. A. Jensen, S. Castellanos, J. Maser, B. Lai, M. Marcus, D. P. Fenning, J. Hofstetter, T. Buonassisi, “Synchrotron-based analytical techniques elucidate defect structure-property relations in Silicon and Thin-Film Solar Cell Material,” 2015 Materials Research Society Spring Meeting, San Francisco, CA, April 2015.
5. **A. E. Morishige** (invited), D. P. Fenning, J. Hofstetter, S. Castellanos, M. A. Jensen, P. Yen, B. Lai, and T. Buonassisi, “Microprobe X-Ray Fluorescence Characterization of Defects in Crystalline Silicon Solar Cells,” APS User Science Seminar, Advanced Photon Source, Argonne National Laboratory, IL, March 20, 2015.
6. J. Hofstetter, **A.E. Morishige**, M.A. Jensen, D.M. Powell, M.M. Kivambe, S. Castellanos, D. B. Needleman, S.M. Scott, J. Mailoa, J.Z. Lee, M.A. Mahaffey, H. Wagner, D.P. Fenning, T. Buonassisi. “Alternative Approaches for High-Efficiency Silicon Wafers,” 24th Workshop on Crystalline Silicon Solar Cells & Modules: Materials and Processes, Breckenridge, CO, July 2014.
7. D. P. Fenning, V. Vähänissi, J. Hofstetter, **A. E. Morishige**, H. Laine, A. Haarahiltunen, S. C. Castellanos, M. A. Jensen, B. Lai, H. Savin. “Iron Precipitation upon Gettering in Phosphorus-Implanted Czochralski Silicon and its Impact on Solar Cell Performance.” 40th IEEE-PVSC, Denver, CO, June 2014.
8. J. Hofstetter, S. Castellanos, D. P. Fenning, **A. E. Morishige**, M. Kivambe, B. Lai, T. Ervik, M. Rinio, T. Buonassisi. “Studying metal decoration at dislocations in multicrystalline silicon using X-ray nano probes,” Materials Research Society Fall Meeting & Exhibition, Boston, MA, December 3, 2013.
9. J. Hofstetter, D. P. Fenning, D. M. Powell, **A. E. Morishige**, T. Buonassisi. “Iron management in multicrystalline silicon through predictive simulation: point defects, precipitates, and structural defect interactions,” Gettering and Defect Engineering in Semiconductor Technology, Oxford, UK, September 22-27, 2013.
10. **A. E. Morishige** (invited), D. P. Fenning, J. Hofstetter, D. M. Powell, T. Buonassisi, “Moving Beyond Traditional Silicon Solar Cell Manufacturing: Optimizing for Performance and Throughput,” Lab for Manufacturing and Productivity Seminar Series, MIT, May 2013.
11. D. P. Fenning, J. Hofstetter, **A. E. Morishige**, D. M. Powell, T. Buonassisi. “Engineering Metal Impurities to Enable Low-Cost Silicon Solar Cells,” Micro-Nano Seminar Series, MIT, April 2013.

12. D. P. Fenning, J. Hofstetter, **A. E. Morishige**, A. Zuschlag, G. Hahn, T. Buonassisi, "Iron Kinetics Simulation and Experimentation Demonstrating Potential for Novel Industrial Processing of Silicon Solar Cells," Materials Research Society Fall Meeting & Exhibition, Boston, MA, November 25-30, 2012.
13. D. P. Fenning (invited), J. Hofstetter, D. M. Powell, **A. E. Morishige**, A. Zuschlag, G. Hahn, T. Buonassisi. "Design Guidelines for Tailored Phosphorus Diffusion Gettering," 22nd NREL Workshop on Crystalline Silicon Solar Cells & Modules, Vail, CO, July 2012.

Poster

Presentations

1. **A. E. Morishige**, J. Hofstetter, H. Wagner, M. A. Jensen, I. Avci, B. Lai, D. P. Fenning, C. del Cañizo, T. Buonassisi, "Engineering Metal Impurities in Crystalline Si for Cost-Effective, High-Performance Solar Cells," MIT Mechanical Engineering Research Exhibition, September 18, 2015.
2. H. Laine, V. Vähänissi, J. Hofstetter, **A. E. Morishige**, A. Haarahiltunen, D. P. Fenning, and H. Savin, "Modeling the size distribution of iron precipitates in phosphorus-implanted emitters," European Photovoltaics Specialists Exhibition and Conference, September 2014.
3. **A. E. Morishige**, D. P. Fenning, J. Hofstetter, M. A. Jensen, S. Ramanathan, C. Wang, B. Lai, T. Buonassisi. "Elucidating and Engineering Recombination-Active Metal-Rich Precipitates in n-type Multicrystalline Silicon," 40th IEEE-PVSC, Denver, CO, June 2014.
4. **A. E. Morishige**, H. S. Laine, J. Schon, J. Hofstetter, A. Haarahiltunen, M. Schubert, H. Savin, and T. Buonassisi, "Analysis of Different Models of Iron Precipitation in Multicrystalline Silicon," 40th IEEE-PVSC, Denver, CO, June 2014.
5. M. Kivambe, D. M. Powell, M. A. Jensen, **A. E. Morishige**, K. Nakajima, R. Murai, K. Morishita, T. Buonassisi, ">1.8 millisecond effective lifetime in n-type silicon grown by the non contact crucible method," 40th IEEE-PVSC, Denver, CO, June 2014.
6. M. A. Jensen, J. Hofstetter, D. P. Fenning, **A. E. Morishige**, G. Coletti, B. Lai, T. Buonassisi. "Engineering the Distribution of Chromium in Multicrystalline Silicon," 40th IEEE-PVSC, Denver, CO, June 2014.
7. S. M. Scott, J. Hofstetter, **A. E. Morishige**, T. Buonassisi, "Sacrificial High-Temperature Phosphorus Diffusion Gettering Process for Lifetime Improvement of Multi-Crystalline Silicon Wafers," 40th IEEE-PVSC, Denver, CO, June 2014.
8. **A. E. Morishige**, D. P. Fenning, J. Hofstetter, D. M. Powell, and T. Buonassisi. "Simulated Co-Optimization of Crystalline Silicon Solar Cell Efficiency and Throughput Using Continuously Ramping Phosphorus Diffusion Profiles," American Society for Precision Engineering Spring Topical Meeting and MIT

Laboratory for Manufacturing and Productivity Annual Summit, Cambridge, MA, April 21-23, 2013.

9. **A. E. Morishige**, D. P. Fenning, J. Hofstetter, D. M. Powell, T. Buonassisi, “Simulated co-optimization of crystalline silicon solar cell throughput and efficiency using continuously ramping phosphorus diffusion profiles,” 38th IEEE Photovoltaics Specialist Conference, Austin, TX, June 2012.
10. **A. E. Morishige**, D. P. Fenning, J. Hofstetter, T. Buonassisi. “Co-optimizing the phosphorus diffusion time-temperature profile for gettering and throughput,” 5th International Workshop on crystalline Silicon Solar Cells, Boston, MA, November 2011.
11. **A. E. Morishige**, N. D. Mueller, J. S. Gerber, J. J. Sheehan, J. A. Foley, and L. R. Lynd. “Assessing the Potential to Intensify Pastureland Use,” American Geophysical Union Fall Meeting, San Francisco, CA, Dec. 2010.

Service & Teaching

Graduate Resident Tutor, MacGregor House, MIT **2013-present**

- Mentor students by providing academic and personal guidance
- Foster a supportive, safe, and positive living environment
- Build a community atmosphere among undergraduates

Teaching Assistant, Electronics for Mechanical Systems, MIT **Spring 2015**

Graduate Student Mentor, Solar Energy REU, ASU **Summer 2012, 2013**

- Tutor undergraduate students in solar cell fabrication and device physics

Treasurer, Ashdown House Graduate Student Dorm, MIT **2011**

- Help build sense of community
- Oversee the house’s budget, coordinate reimbursements, organize proposals for funding from outside sources

Teaching Assistant, Distributed Systems and Fields, Dartmouth **Fall 2010**

Languages

Spanish (10 years), limited working proficiency