Md Hafijur Rahman

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Education

- **The Pennsylvania State University** — Pennsylvania, USA
  Ph.D. - Mechanical Engineering; CGPA: 4.00/4.00 — *Jan 2023 - Present*
- **University of Alberta** — Edmonton, Alberta, Canada
  M.Sc - Mechanical Engineering; CGPA: 4.00/4.00 — *Jan 2021 - Dec 2022*
- **Bangladesh University of Engineering and Technology** — Dhaka, Bangladesh
  B.Sc - Mechanical Engineering; CGPA: 3.81/4.00 — *July 2014 - Oct 2018*

Graduate Courses

Physics of Radiation Damage, Manufacturing Methods in Microelectronics, Continuum Mechanics, Macro Fracture Mechanics, Fundamentals of Engineering Numerical Analysis, Applied Computational Intelligence for Engineers, Mechanics and Design of Composite Materials.

Research Interests

My research focuses on **defect mitigation**, **radiation resilience**, and **microstructural modification** in materials and semiconductor devices. I specialize in low-temperature annealing using **Electron Wind Force (EWF)** to mitigate defects in **wide-bandgap (WBG) semiconductors** (**GaN**, **SiC**, etc.) and structural alloys (FeCrAl, ZrTi). My work involves advanced characterization techniques such as **EBSD, XRD, TEM, FIB**, and **Raman spectroscopy**. In addition, I focus on **mathematical modeling of composite systems using continuum mechanics**, with higher gradient models further implemented and solved using **Finite Element Analysis (FEA)**. I also have experience in **molecular dynamics (MD) simulation**, and maintain strong research interests in **machine learning** and **fracture mechanics**, integrating data-driven approaches with physics-based models to investigate defect evolution and failure mechanisms.

Research Experience

- **The Pennsylvania State University** — Pennsylvania, USA
  Graduate Research Assistant – Haque Research Group — *Jan 2023 – Present*
  - **Low-Temperature Defect Engineering via Electron Wind Force (EWF)**: Leading NSF-funded research to develop EWF as an alternative to conventional annealing. Designed electropulsing systems, implemented in-situ probing, and established protocols to mitigate defects in both structural alloys and semiconductor devices.
  - **EWF-Driven Defect Mitigation in Structural Alloys**: Developed low-temperature electropulsing protocols was applied to various alloys including FeCrAl and ZrTi. Demonstrated elimination of low-angle grain boundaries, grain boundary realignment, and formation of textured α-lath structures, (confirmed by *EBSD, XRD, Raman Spectroscopy and TEM*).
  - **In-situ TEM**: Performed in-situ TEM electropulsing of high-entropy alloys, capturing real-time defect annihilation, establishing EWF as a room-temperature defect recovery mechanism.
  - **Radiation Effects in Wide-Bandgap Semiconductors**: Investigated gamma and heavy-ion radiation effects on wide-bandgap (WBG) semiconductors (GaN HEMTs, SiC MOSFETs, and Zener diodes), focusing on EWF-based defect annihilation as an alternative to conventional thermal annealing.
  - **Restorative and preemptive EWF Annealing of WBG semiconductors**: Demonstrated high resilience to Gamma radiation damage in SiC MOSFETs using repititive in-situ EWF pulses. In addition, EWF annealing at room temperature rejuvenates degraded GaN HEMTs, outperforming conventional high-temperature annealing in restoring carrier mobility. Moreover, reducing pre-existing defects via EWF prior to irradiation improves post-radiation resilience, providing a novel preventive defect engineering strategy.

- **University of Alberta** Edmonton, Alberta, Canada
  Graduate Research Assistant - Theoretical and Applied Mechanics Laboratory *Jan 2021 - Dec 2022*
  - **Second Strain Gradient Continuum Model for the Mechanics of Fiber-Reinforced Composites**: Developed a continuum-based second strain gradient model to analyze elastic materials reinforced with uni/bi-directional fibers, addressing the complexities of finite plane deformations. Solved sixth-order non-liner partial differential equation using **finite element analysis** tool FEniCS. This work can be found here .
  - **Fracture criteria accounting for T -stress**: The effect of T -stress on crack tip plastic zone has been investigated.
  - **Heart disease prediction using Computational Intelligent model**: Used various machine learning models (K-Nearest Neighbor (KNN), Multi-Layer Perceptron (MLP), and Kernel Support Vector Machine (KSVM)) to classify and predict heart disease using Cleveland heart disease dataset.

- **Bangladesh University of Engineering and Technology** Dhaka, Bangladesh
  Undergraduate Thesis with Dr. Mohammad Nasim Hasan *Aug 2017 - Oct 2018*
  - **Condensation Characteristics of Argon Vapor on Nano-Structured Surfaces: A Molecular Dynamics Study**: Conducted non-equilibrium molecular dynamics simulations to investigate the condensation behavior of argon vapor on platinum nano-structured surfaces. Explored the effects of surface geometry, solid–liquid interfacial wettability, and wall temperature on condensation performance. Findings demonstrated that nano-structures enhance condensation, though the improvement diminishes with increasing wettability and higher wall temperatures.

Teaching Experience

- **The Pennsylvania State University** Pennsylvania, USA
  Graduate Teaching Assistant – ME 460: Mechanical Design II *Jan 2023 – May 2023*
  - **Instructional Support**: Assisted course instructor in delivering lectures and guiding students through advanced concepts in mechanical design, including stress analysis, fatigue, and design optimization.
  - **Assessment and Grading**: Prepared assignments, exam questions, and provided detailed grading and feedback for a class of 40 students.
  - **Student Mentorship**: Held weekly office hours to provide one-on-one academic support, clarifying course content and design methodologies.
  - **Course Contribution**: Contributed to improving student engagement and understanding through interactive problem-solving sessions and structured feedback.

- **University of Alberta** Edmonton, Alberta, Canada
  Graduate Teaching Assistant *Aug 2021 – Dec 2022*
  - **MEC E 301 – Mechanical Engineering Laboratory I**: Served as GTA for four academic terms (Fall 2021, Winter 2022, Spring/Summer 2022, Fall 2022). Supervised lab sessions, ensured safe and accurate experimental execution, and graded reports with detailed feedback.
  - **EN PH 131 – Mechanics**: Provided instructional support in Winter 2022, including problem-solving tutorials, exam question preparation, and grading.
  - **Mentorship and Student Support**: Supported more than 300 undergraduate students through office hours, tutorials, and one-on-one guidance to strengthen conceptual understanding and technical writing.

- **Bangladesh Army University of Science and Technology** Saidpur, Bangladesh
  Lecturer/Instructor – Department of Mechanical Engineering *Nov 2019 – Dec 2020*

  Undergraduate Courses Taught

  - **ME 1181: Basic Mechanical Engineering**
    Winter 2020 – CSE Dept., Sec. A: 65 students, Sec. B: 72 students
    Fall 2020 – EEE Dept., 21 students

- **ME 1263: Fundamentals of Mechanical Engineering**
  Fall 2020 – EEE Dept., 34 students
- **ME 2103: Engineering Mechanics I**
  Winter 2020 – ME Dept., 52 students
- **ME 2203: Engineering Mechanics II**
  Winter 2020 – ME Dept., 15 students
- **ME 3111: Numerical Analysis**
  Fall 2020 – ME Dept., 15 students

Laboratory Courses Supervised

- **ME 1264: Fundamentals of Mechanical Engineering Sessional**
  Fall 2020 – EEE Dept., 34 students
- **ME 1110: Mechanical Engineering Shop Practice**
  Winter 2020 – Civil Eng. Dept., 20 students
- **ME 2104: Engineering Mechanics Sessional**
  Winter 2020 – ME Dept., 52 students
- **ME 3108: Measurement, Instrumentation and Quality Control Sessional**
  Fall 2020 – ME Dept., 14 students

Publications (Peer-Reviewed Journal)

Names of mentees are highlighted in blue.

19. **Rahman, M.H.**, Al-Mamun, N.S., Stepanoff, S.P., Haque, A., Ren, F., Pearton, S.J., Wolfe, D.E. Room Temperature Rejuvenation Technology for Irradiated Gallium Nitride Transistors. *Advanced Materials Technologies*, **2025**, e00874. DOI

18. **Rahman, M.H.**, Chavda, C., Al-Mamun, N.S., Stepanoff, S.P., Haque, A., Wolfe, D.E., Ren, F., Pearton, S.J. Repeated Rejuvenation of SiC MOSFETs for Unprecedented Ionizing Radiation Resilience. *APL Electronic Devices*, **2025**, 036103. DOI

17. **Rahman, M.H.**, Cooper, F., Crespillo, M.L., Hattar, K., Haque, A., Ren, F., Pearton, S., Wolfe, D. Improving radiation tolerance with room temperature annealing of pre-existing defects. *Applied Physics Express*, **2025**, 18, 17001. DOI

16. **Rahman, M.H.**, Rasel, M.A.J., Smyth, C.M., Waryoba, D., Haque, A. Radiation Damage Mitigation in FeCrAl Alloy at Sub-Recrystallization Temperatures. *Materials*, **2025**, 18, 124. DOI

15. **Rahman, M.H.**, Chavda, C., Warner, L., Stafford, S., Carvajal, J., Haque, A., Ren, F., Pearton, S., Wolfe, D.E. Room Temperature Annealing of Gamma Radiation Damage in Zener Diodes. *ECS Journal of Solid State Science and Technology*, **2025**, 14, 025003. DOI

14. **Rahman, M.H.**, Oh, H., Waryoba, D., Haque, A. Microstructural modification and enhanced mechanical properties in Zr50–Ti50 alloy via low temperature electron wind force annealing. *Materials Characterization*, **2024**, 215, 114188. DOI

13. **Rahman, M.H.**, Todaro, S., Waryoba, D., Haque, A. Synergistic Thermal and Electron Wind Force-Assisted Annealing for Extremely High-Density Defect Mitigation. *Materials (Basel)*, **2024**, 17, 3188. DOI

12. **Rahman, M.H.**, Todaro, S., Warner, L., Waryoba, D., Haque, A. Elimination of Low-Angle Grain Boundary Networks in FeCrAl Alloys with the Electron Wind Force at a Low Temperature. *Metals (Basel)*, **2024**, 14, 331. DOI

11. **Rahman, M.H.**, Glavin, N., Haque, A., Ren, F., Pearton, S.J. Effect of High Current Density Pulses on Performance Enhancement of Optoelectronic Devices. *ECS Journal of Solid State Science and Technology*, **2024**, 13, 25003. DOI

10. **Rahman, M.H.**, Warner, L., Bae, J., Kim, J., Haque, A., Ren, F., Pearton, S.J., Wolfe, D.E. Improving radiation resilience of Zener diodes through preemptive and restorative electron wind force annealing. *Physica Scripta*, **2024**, 100, 015904. DOI

9. **Rahman, M.H.**, Al-Mamun, N.S., Glavin, N., Haque, A., Ren, F., Pearton, S., Wolfe, D.E. Rejuvenation of Degraded Zener Diodes with the Electron Wind Force. *Applied Physics Express*, **2024**, 17, 47001. DOI

8. **Rahman, M.H.**, Oh, H., Waryoba, D., Haque, A. Room Temperature Control of Grain Orientation via Directionally Modulated Current Pulses. *Materials Research Express*, **2023**, 10, 116521. DOI

7. **Rahman, M.H.**, Yang, S., Kim, C. Il. A Third Gradient-Based Continuum Model for the Mechanics of Continua Reinforced with Extensible Bidirectional Fibers Resistant to Flexure. *Continuum Mechanics and Thermodynamics*, **2023**, 35, 563–593. DOI

6. **Rahman, M.H.**, Islam, S., Yang, S., Kim, C. Il. A Shear Lag Theory Integrated with Second Strain Gradient Continuum Model for the Composite Reinforced with Extensible Nano-Fibers. *Acta Mechanica*, **2023**, 234, 4269–4296. DOI

5. Thomas, M.P., Schoell, R., Rasel, M.A.J., **Rahman, M.H.**, Kuo, W., Watt, J., House, S., Hattar, K., Windes, W., Haque, A. An In Situ Transmission Electron Microscopy Study on the Synergistic Effects of Au-Ion Irradiation and High Temperature on Nuclear Graphite Microstructure. *Materials Research Express*, **2024**, 11, 45601. DOI

4. Thomas, M.P., Schoell, R., Rasel, M.A.J., **Rahman, M.H.**, Kuo, W., Watt, J., House, S., Hattar, K., Windes, W., Haque, A. Lateral NiO/AlN Heterojunction Rectifiers with Breakdown Voltage >11 kV. *ECS Advances*, **2024**, 3, 33502. DOI

3. Liu, G., Oh, H., **Rahman, M.H.**, Du, J., Windes, W., Haque, A. Low-Temperature Annealing of Nanoscale Defects in Polycrystalline Graphite. *Carbon*, **2024**, 10(3), 76. DOI

2. **Rahman, M.H.**, Al-Mamun, N.S., Stepanoff, S.P., Haque, A., Ren, F., Pearton, S.J., Wolfe, D.E. Rethinking Annealing: Achieving Microstructural Enhancements at Sub-Zero Temperatures. *Acta Materialia*, **2025** (Under Review)

1. **Rahman, M.H.**, Al-Mamun, N.S.,Oh, H., Haque, A. Athermal Defect Recovery in Metallic Systems: Real-Time Evidence from In-situ TEM. *Scripta Materialia*, **2025** (Under Review)

Conference Presentations

2. **Rahman, M.H.** Defect and Microstructure Control of Materials Using the Electron Wind Force. *Materials Science & Technology (MS&T) Technical Meeting and Exhibition, Processing and Performance of Materials Using Microwaves, Electric and Magnetic Fields, Ultrasound, Lasers, and Mechanical Work – Rustum Roy Symposium*, **2024**, Pittsburgh, PA, USA. (Oral Presentation)

1. **Rahman, M.H.** Enhancing Radiation Resilience of Wide-Bandgap Semiconductors and Alloys via Electron Wind Force Annealing. *Materials Science & Technology (MS&T) Technical Meeting and Exhibition, Processing and Performance of Materials Using Microwaves, Electric and Magnetic Fields, Ultrasound, Lasers, and Mechanical Work – Rustum Roy Symposium*, **2025**, Columbus, OH, USA. (Accepted, Upcoming Oral Presentation)

Invited Talks

- **Rahman, M.H.** Defect and Microstructure Control of Materials Using the Electron Wind Force. *Low Carbon Energy Systems (LCES) Talk Series, Organized by the LCES Research Super Group, College of Engineering, The Pennsylvania State University*, **2024**.

Mentorship and Student Supervision

Over the course of my Ph.D., I have supervised six undergraduate researchers and trained four junior graduate students. Several mentees have co-authored multiple papers and gone on to graduate programs (e.g., Purdue University) or received research awards.

- **Undergraduate Researchers**
  - **Hajin Oh** Spring 2023 – Fall 2023
    - **Project:** Low-temperature microstructural control in alloys via Electron Wind Force (EWF).
    - **Publications:** 3 published journal papers, 1 under review.
    - **Achievement:** Admitted to Ph.D. program, **Purdue University**.
  - **Sarah Todaro** Spring 2024 – Fall 2024
    - **Project:** Rapid defect mitigation in FeCrAl alloy using EWF.
    - **Publications:** 2 journal papers.
  - **Felix Cooper** Fall 2024 – Spring 2025
    - **Project:** Preemptive EWF treatment of Zener diodes for radiation resilience.
    - **Publications:** 1 journal paper.
  - **Luke Warner** Spring 2024 – Summer 2025
    - **Project:** Radiation effects in WBG semiconductors and EWF recovery.
    - **Publications:** 3 journal papers.
    - **Recognition: 2025 Dr. John P. Karidis Department Head's Award (ME)**.
  - **Patel Chaitanya** Spring 2025 – Present
    - **Project:** Sub-zero direct-current processing of metals.
  - **Lorenzo Adrian Zamel** Spring 2025 – Present
    - **Project:** Enhancing harsh-environment resilience of GaN transistors via EWF rejuvenation.
- **Junior Graduate Students (Training & Onboarding)**
  - Mentored **Adnan Mahathir**, **Fahim Mahtab Abir**, **Xinwei Wang**, and **Felix Nikhil Kumar (M.S.)** in early-stage research, covering safety/SOPs, electropulsing hardware, EBSD/XRD/TEM workflows, data analysis, and manuscript preparation.

Honors and Awards

- **Harry G. Miller Fellowship in Engineering**, Penn State College of Engineering, Fall 2025 — Awarded for interdisciplinary research and travel support to present at MS&T25.
- **Dean's List Award**: Department of Mechanical Enginneering, Bangladesh University of Engineering and Technology. (Session: 2016-2018)
- **University Merit Scholarship**: Bangladesh University of Engineering and Technology. (Session: 2015-2018)

Trainings and Workshops

- Objective-Based Education: Challenges and Confronts — (2020)
- Safety and Operation Management of VVER-1200 Reactors — (2019)

Leadership and Volunteering

- **Vice President**, Bangladesh Student Association (BSA), The Pennsylvania State University— (2025)
- Coordinator, Student Seminar Series, Bangladesh Army University of Science and Technology — (2020)
- Co-Coordinator, Annual Student Sports Competition, Bangladesh Army University of Science and Technology — (2020)
- Organizer, Regional Mathematics Quiz for College Students — (2019)