

# MOHAMMAD "MOSI" HEIRANIAN

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## ACADEMIC APPOINTMENTS

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**North Carolina State University, USA** *2023 - Date*

Incoming Assistant Professor (Fall 2023): Department of Mechanical and Aerospace Engineering

**Yale University, USA** *2021 - 2023*

Postdoctoral Associate: Department of Chemical and Environmental Engineering

Adviser: Professor Menachem Elimelech

## EDUCATION

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**University of Illinois at Urbana-Champaign, USA** *2016 - 2020*

PhD: Theoretical and Applied Mechanics, Department of Mechanical Science and Engineering

Adviser: Professor Narayana R Aluru

GPA: 4.0/4.0

**University of Illinois at Urbana-Champaign, USA** *2012 - 2016*

MSc: Theoretical and Applied Mechanics, Department of Mechanical Science and Engineering

Adviser: Professor Narayana R Aluru

GPA: 4.0/4.0

**University of Manitoba, Canada** *2008 - 2012*

BSc: Mechanical Engineering, Department of Mechanical Engineering

GPA: 4.2/4.5

## PUBLICATIONS

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Number of First-Author Publications: 13

Citations: >2169

H-index: 16

As of 7/24/2023

28. C. Violet, **M. Heiranian**, L. F. Villalobos, J. Zhang, B. U. Kilavuz, A. K. Ball, A. Haji-Akbari, H. Kulik, and M. Elimelech, "From Schrodinger to selectivity: implementing ion-specific binding sites for ion selective membranes", in preparation.

27. **M. Heiranian** and M. Elimelech, "Nanofluidic transport in defective graphene oxide nanoslits", in preparation.

26. **M. Heiranian**, C. Violet, M. Elimelech, "Principles of ion-ion selectivity in nanopores", in preparation.

25. **M. Heiranian**, H. Fan, L. Wang, X. Lu and M. Elimelech, "Mechanisms and models for water transport in reverse osmosis membranes: history, critical assessment, and recent developments", under review.

24. L. Wang, J. He, **M. Heiranian**, H. Fan, L. Song, Y. Li, and M. Elimelech, "Water transport in reverse osmosis membranes is governed by pore flow, not a solution-diffusion mechanism", *Science Advances*, Vol. 9, No. 15, Art. No. eadf848, **2023**. ([link](#))

In News: [WIRED](#), [Nature Water News & Views](#), [Phys.org](#), [Interesting Engineering](#), [Smart Water Magazine](#)

23. **M. Heiranian** and N. R. Aluru, "Modified Lucas-Washburn theory for fluid filling in nanotubes", *Physical Review E*, Vol. 105, No. 5, Art. No. 055105, **2022**. ([link](#))

22. **M. Heiranian**, R. M. DuChanois, C. L. Ritt, C. Violet, and M. Elimelech, "Molecular simulations to elucidate transport phenomena in polymeric membranes", *Environmental Science & Technology*, Vol. 56, No. 6, pp. 3313-3323, **2022**. ([link](#))

21. R. M. DuChanois, **M. Heiranian**, J. Yang, C. Porter, X. Zhang, and M. Elimelech, "Designing polymeric membranes with coordination chemistry for high-precision ion separations", *Science Advances*, Vol. 8, No. 9, Art. No. eabm9436, **2022**. ([link](#))

20. X. Zhou, **M. Heiranian**, M. Yang, R. Epsztein, K. Gong, C. E. White, S. Hu, J. Kim, and M. Elimelech, "Selective fluoride transport in sub-nanometer TiO<sub>2</sub> pores", *ACS Nano*, Vol. 15, No. 10, pp. 16828-16838, **2021**. ([link](#))

19. L. Song, **M. Heiranian**, and M. Elimelech, "True driving force and characteristics of water transport in osmotic membranes", *Desalination*, Vol. 15, No. 520, Art. No. 115360, **2021**. ([link](#))

18. M. T. Hwang, I. Park, **M. Heiranian**, A. Taqieddin, S. You, V. Faramarzi, A. A. Pak, A. M. van der Zande, N. R. Aluru, and R. Bashir, "Ultrasensitive detection of dopamine, IL-6 and SARS-CoV-2 proteins on crumpled graphene FET biosensor", *Advanced Materials Technologies*, Vol. 6, No. 11, Art. No. 2100712, **2021**. ([link](#))

17. **M. Heiranian**, Y. Noh, and N. R. Aluru, "Dynamic and weak electric double layers in ultrathin nanopores", *Journal of Chemical Physics*, Vol. 154, No. 13, Art. No. 134703, **2021**. ([link](#))

16. **M. Heiranian**, A. Taqieddin, and N. R. Aluru, "Revisiting Sampson's theory for hydrodynamic transport in ultrathin nanopores", *Physical Review Research*, Vol. 2, No. 4, Art. No. 043153, **2020**. ([link](#))

15. A. Taqieddin, **M. Heiranian**, and N. R. Aluru, "Interfacial properties of water on hydrogenated and fluorinated graphene surfaces: parametrization of nonbonded interactions", *Journal of Physical Chemistry C*, Vol. 124, No. 39, pp. 21467-21475, **2020**. ([link](#))

14. **M. Heiranian** and N. R. Aluru, "Nanofluidic transport theory with enhancement factors approaching one", *ACS Nano*, Vol. 14, No. 1, pp. 272-281, **2020**. ([link](#))

13. M. T. Hwang<sup>\*</sup>, **M. Heiranian**<sup>\*</sup>, Y. Kim<sup>\*</sup>, S. You, J. Leem, A. Taqieddin, V. Faramarzi, Y. Jing, I. Park, A. M. van der Zande, S. Nam, N. R. Aluru, and R. Bashir, "Ultrasensitive detection of nucleic acids using deformed graphene channel field effect biosensors", *Nature Communications*, Vol. 11, Art. No. 1543, **2020**. ([link](#))

In News: [Health Europa](#), [Phys.org](#), [Medical Life and Sciences](#), [EurekAlert](#), [AZO Nano](#), [Materials Today](#)

*\* these authors contributed equally to this work*

12. P. Snapp<sup>\*</sup>, **M. Heiranian**<sup>\*</sup>, M. T. Hwang<sup>\*</sup>, R. Bashir, N. R. Aluru, and S. Nam, "Current understanding and emerging applications of 3D crumpling mediated 2D material-liquid interactions", *Current Opinion in Solid State & Materials Science*, Vol. 24, No. 3, Art. No. 100836, **2020**. ([link](#))

*\* these authors contributed equally to this work*

11. S. S. Kwon, J. Choi, **M. Heiranian**, Y. Kim, W. J. Chang, P. M. Knapp, M. C. Wang, J. M. Kim, N. R. Aluru, W. Il Park, and S. Nam, “Electrical double layer of supported atomically thin materials”, *Nano Letters*, Vol. 19, No. 7, pp. 4588-4593, **2019**. ([link](#))
10. V. Nandigana, **M. Heiranian**, and N. R. Aluru, “Single ion transport with a single-Layer graphene nanopore”, *International Journal of Mechanical and Mechatronics Engineering*, Vol. 13, No. 7, pp. 479-483, **2019**. ([link](#))
9. A. Barati Farimani, **M. Heiranian**, and N. R. Aluru, “Identification of amino acids with sensitive nanoporous MoS<sub>2</sub>: towards machine learning-based prediction”, *npj 2D Materials and Applications*, Vol. 2, Art. No. 14, **2018**. ([link](#))
8. Y. Zhang, **M. Heiranian**, B. Janicek, Z. Budrikis, S. Zapperi, P. Y. Huang, H. T. Johnson, N. R. Aluru, J. W. Lyding, and N. Mason, “Strain modulation of graphene by nanoscale substrate curvatures: a molecular view”, *Nano Letters*, Vol. 18, No. 3, pp. 2098-2104, **2018**. ([link](#))
7. **M. Heiranian**, Y. Wu, and N. R. Aluru, “Molybdenum disulfide and water interaction parameters”, *Journal of Chemical Physics*, Vol. 147, No. 10, Art. No. 104706, **2017**. ([link](#))
6. A. Barati Farimani, **M. Heiranian**, K. Min, and N. R. Aluru, “Antibody subclass detection using graphene nanopores”, *Journal of Physical Chemistry Letters*, Vol. 8, No. 7, pp. 1670-1676, **2017**. ([link](#))
5. J. Feng, M. Graf, K. Liu, D. Ovchinnikov, D. Dumcenco, **M. Heiranian**, V. Nandigana, N. R. Aluru, A. Kis, and A. Radenovic, “Single-layer MoS<sub>2</sub> nanopores as nanopower generators”, *Nature*, Vol. 536, No. 7615, pp. 197-200, **2016**. ([link](#))  
In News: [VOA \(Voice of America\)](#), [Newsweek](#), [Science Daily](#), [UPI \(United Press International\)](#), [Phys.org](#)
4. A. Barati Farimani, **M. Heiranian**, and N. R. Aluru, “Nano-electro-mechanical pump: Giant pumping of water in carbon nanotubes”, *Scientific Reports*, Vol. 6, Art. No. 26211, **2016**. ([link](#))
3. G. A. Venkatesan, J. Lee, A. Barati Farimani, **M. Heiranian**, C. P. Collier, N. R. Aluru, and S. A. Sarles, “Adsorption kinetics dictate monolayer self-assembly for both lipid-in and lipid-out approaches to droplet interface bilayer formation”, *Langmuir*, Vol. 31, No. 47, pp. 12883-12893, **2015**. ([link](#))
2. **M. Heiranian**, A. Barati Farimani, and N. R. Aluru, “Water desalination with a single-layer MoS<sub>2</sub> nanopore”, *Nature Communications*, Vol. 6, Art. No. 8616, **2015**. ([link](#))  
In News: [Business Insider](#), [Quartz](#), [Yahoo News](#), [Business Standard](#), [Science Daily](#), [IEEE Spectrum](#), [Phys.org](#)
1. A. Barati Farimani\*, **M. Heiranian\***, and N. R. Aluru, “Electromechanical signatures for DNA sequencing through a mechanosensitive nanopore”, *Journal of Physical Chemistry Letters*, Vol. 6, No. 4, pp. 650-657, **2015**. ([link](#))

*\*these authors contributed equally to this work*

## RESEARCH ACCOMPLISHMENTS

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- Developed membrane material design principles for ion-ion selective transport using extensive multiscale computational tools and machine learning techniques.
- Developed several nanofluidic transport theories through analytical and computational modifications of continuum-based hydrodynamic theories such as Hagen-Poiseuille, Sampson, and Lucas-Washburn laws.

- Guided experimentalists by molecular-scale modeling as a co-first author on a project that led to the patented discovery of crumpled graphene channel field effect biosensors for ultrasensitive detection of nucleic acids and disease biomarkers.
- Discovered MoS<sub>2</sub> as a novel material for potential applications in water desalination, nanopower generation, and single-biomolecule detection by using extensive multiscale computational tools and machine learning techniques.

## GRANTS AND PROPOSALS

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### Research Grant Proposals:

3. Currently contributing to a **National Science Foundation (NSF)** proposal in the Elimelech Lab by conceptualizing research ideas and writing several sections of the proposal document, in preparation.
2. Contributed to "EFRC: A Center for Enhanced Nanofluidic Transport (**CENT<sup>2</sup>**)", **US Department of Energy (DOE)**, by conceptualizing research ideas and writing several sections of the proposal document, awarded, 2022-2026.
1. Contributed to "MRSEC: Illinois Materials Research Center", **National Science Foundation (NSF)**, awarded, 2018-2022.

### Computational Resource Proposals:

9. Wrote "Computational nanoscience: fundamental studies of chemical and morphological functionalization of 2D materials", **XSEDE (Stampede2 and Comet)**, awarded, 2020-2021.
8. Wrote "Large-scale simulations of soft/hard interfaces: interfacial science, ionic conductivity and fluidic transport", **Blue Waters**, 435,000 node-hours awarded, 2019-2020.
7. Wrote "Computational studies in nanofluidic transports, heterogeneous biological and 2D materials, modeling of Lennard-Jones mixtures, proton and ion oxide transports in SOEC and electronic structure of graphene nano ribbons", **XSEDE (Stampede2 and Comet)**, awarded, 2019-2020.
6. Wrote "Large-scale simulations of biological and 2-dimensional heterogeneous nano-interfaces, nanopores and nanochannels", **Blue Waters**, 377,800 node-hours awarded, 2019-2020.
5. Wrote "Computational nanoscience: fundamental studies in ion conductors, synthetic membranes, dissipation mechanisms and exfoliation of 2D materials", **XSEDE (Stampede2 and Comet)**, awarded, 2018-2019.
4. Wrote "Machine learning assisted protein sequencing with highly sensitive MoS<sub>2</sub> nanopore", **Blue Waters**, 135,000 node-hours awarded, 2017-2018.
3. Wrote "Systematic thermodynamically consistent structural-based coarse graining of room temperature ionic liquids", **Blue Waters**, 200,000 node-hours awarded, 2017-2018.
2. Wrote "Large-scale simulations of droplet interface bilayers with functional imbedded protein channels", **Blue Waters**, 975,000 node-hours awarded, 2016-2017.
1. Wrote "Large-scale simulations of DNA nanostructures for drug delivery and applications of novel synthetic membranes for protein/DNA integration", **Blue Waters**, 700,000 node-hours awarded, 2015-2016.

## PATENTS

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M. Hwang, R. Bashir, **M. Heiranian**, S. Nam, N. Aluru, A. van der Zande, C. J. Murphy, J. Choi, Y. Kim, "Ultrasensitive Biosensor Using Bent and Curved Field Effect Transistors by Debye Length Modulation", **World Intellectual Property Organization (WIPO)**, Publication No. WO/2021/174068, Serial No. PCT/US2021/020006, Publication Date 09/02/2021.

## AWARDS

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- *Nature Water* Best Poster Award at the Lake Tahoe 2022 Nanofluidics Conference 2022
- Michael Sutton Memorial Award for Outstanding Research in Mechanical Engineering 2018
- John Shewchuk Engineering Design Award 2012
- Shell Canada Mechanical and Manufacturing Design Competition Award 2012
- International Undergraduate Student Scholarship 2012
- University of Manitoba Students' Union (UMSU) Scholarship 2012
- International Undergraduate Student Scholarship 2011
- University of Manitoba Students' Union (UMSU) Scholarship 2011
- Randy Futros Memorial Award 2011
- Technical Communication Report Prize in Engineering 2011
- International Undergraduate Student Scholarship 2009
- International Undergraduate Student Entrance Scholarship 2008

## ORAL PRESENTATIONS

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17. **M. Heiranian**, "Physical mechanism of water transport in reverse osmosis membranes: Solution diffusion or pore flow?", *NAMS 2023 Conference*, 2023.
16. **M. Heiranian**, "Understanding Material-Fluid Interactions for Design at the Water-Energy Nexus", Department of Mechanical and Aerospace Engineering, North Carolina State University, 2023.
15. **M. Heiranian**, "Understanding Material-Fluid Interactions for Design at the Water-Energy Nexus", Department of Mechanical and Industrial Engineering, University of Illinois Chicago, 2023.
14. **M. Heiranian**, "Understanding Material-Fluid Interactions for Materials Design at the Water-Energy Nexus", Department of Materials Science and Engineering, MIT, 2023.
13. **M. Heiranian**, "Nanoscale fluid mechanics and molecular transport for applications at the water-energy nexus", Department of Mechanical and Industrial Engineering, Northeastern University, 2023.
12. **M. Heiranian**, "Lucas-Washburn theory revisited for capillary rise in nanotubes", *APS DFD Conference*, 2022.
11. **M. Heiranian**, "Revisiting Hagen-Poiseuille law for flow in nanopores", *Statistical Thermodynamics and Molecular Simulations (STMS) Virtual Seminar Series*, 2022.
10. **M. Heiranian**, "Nanoscale fluidic theory for flow in carbon-based nanopores", *Soft, Fluid, and Living Matter Seminars*, Department of Mechanical Engineering & Materials Science, Yale University, 2022.
9. **M. Heiranian**, "Nanoscale fluid mechanics and molecular transport for applications at the water-energy nexus", *Mechanical Engineering & Materials Science Seminars*, Department of Mechanical Engineering & Materials Science, Washington University in St. Louis, 2022.

8. **M. Heiranian** and N. R. Aluru, "Nanofluidic transport theory with enhancement factors approaching one", *Fluid Mechanics Seminars*, Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, 2020.
7. **M. Heiranian**, "Molecule transport in nanopores with applications to water purification, power generation, and disease diagnosis", Department of Chemical & Environmental Engineering, Yale University, 2020.
6. **M. Heiranian** and N. R. Aluru, "Thickness dependent nanofluidic transport in nanopores and nanochannels", *APS March Meeting*, 2019.
5. **M. Heiranian**, A. Barati Farimani and N. R. Aluru, "Protein identification using a single-layer MoS<sub>2</sub> nanopore: towards machine learning-based predictive models", *APS March Meeting*, 2018.
4. **M. Heiranian**, J. Feng, M. Graf, K. Liu, D. Ovchinnikov, D. Dumcenco, V. Nandigana, N. R. Aluru, A. Kis and A. Radenovic, "Single-layer MoS<sub>2</sub> nanopores as power generators", *NCSA Blue Waters Symposium for Petascale Science and Beyond*, 2017. [Watch Online](#)
3. **M. Heiranian**, Y. Wu and N. R. Aluru, "Parameterization of nonbonded interactions between molybdenum disulfide and water", *APS March Meeting*, 2017.
2. **M. Heiranian**, A. Barati Farimani and N. R. Aluru, "Molybdenum disulfide (MoS<sub>2</sub>) as a novel 2D nano-porous membrane for water desalination", *NCSA Blue Waters Symposium for Petascale Science and Beyond*, 2016. [Watch Online](#)
1. **M. Heiranian**, A. Barati Farimani and N. R. Aluru, "Water purification across MoS<sub>2</sub> nano-porous membranes", *APS Division of Fluid Dynamics*, 2015.

## POSTER PRESENTATIONS

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3. **M. Heiranian**, R. M. DuChanois, X. Zhou, and M. Elimelech "Role of ion-membrane interactions in selective ion transport", *Lake Tahoe 2022 Nanofluidics Conference*, 2022.
2. **M. Heiranian**, M. T. Hwang, N. R. Aluru, and, R. Bashir, "Manipulating ions and nucleic acids distribution on deformed graphene channel field effect transistor", *I-MRSEC*, 2019.
1. **M. Heiranian**, A. Barati Farimani, and N. R. Aluru, "Functionality of MscL in Droplet Interface Bilayer", *Biophysical Society*, 2015.

## TEACHING AND MENTORING

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### Teaching at North Carolina State University:

- Instructor for MAE 208, Engineering Dynamics, August 2023-December 2023

### Teaching at the University of Illinois at Urbana-Champaign:

- Teaching Assistant for TAM 335, Introductory Fluid Mechanics, Jan 2013-May 2013
- Teaching Assistant for TAM 210/211, Statics, Aug 2013-Dec 2013
- Teaching Assistant for TAM 210/211, Statics, Aug 2017-Dec 2017
- Teaching Assistant for TAM 210/211, Statics, Aug 2019-Dec 2019
- Teaching Assistant for ME 200, Thermodynamics, Jan 2020-May 2020

### Research Mentoring at the University of Illinois at Urbana-Champaign:

- Paul Arghyadeep, ME PhD Student



- Yechan Noh, ME PhD Student
- Hananeh Oliaei, ME PhD Student
- Payam Dibaenia, ME PhD Student
- Yao Xiao, ME MSc Student
- Qiangqiang Huang, ME MSc Student
- Chengfang Duan, ME MSc Student
- Mohan Teja Dronadula, ME MSc Student
- Anshul Saxena, ME MSc Student

#### **Research Mentoring at Yale University:**

- Xuechen Zhou, ChemE and EnvE PhD Student
- Ryan DuChanois, ChemE and EnvE PhD Student
- Camille Violet, ChemE and EnvE PhD Student
- Junwei Zhang, ChemE and EnvE PhD Student

### **ACADEMIC SERVICES AND LEADERSHIP**

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- Frequent reviewer for scholarly journals of *Science Advances*, *PNAS*, *Microfluidics and Nanofluidics*, *Desalination*, *The Journal of Physical Chemistry*, and *Advanced Theory and Simulations*.
- Consulted the board of [International Alliance for Ability in Science](#) regarding engineering topics for the development of educational materials and student researcher aid to make engineering and STEM more accessible for disabled students and disabled lower-income students.  
The International Alliance for Ability in Science is a 501(c)(3) non-profit organization run by disabled women in STEM with aims to provide academic and financial aid to disabled students and researchers in STEM fields.
- Served as a PhD student volunteer and organizer with I-MRSEC to device science demos for middle school students from lower income families.
- Provided mentorship for undergraduate students as a part of I-MRSEC Research Experiences for Undergraduates (REU).
- Served by generating supplemental educational materials and individualized course notes for disabled students. Received the Randy Futros Memorial Award for outstanding service for disabled students at the University of Manitoba.
- Collaborated with the International Alliance for Ability in Science to develop 1:1 tutoring programs for students of all ages in STEM courses who have specific learning disabilities, such as dyscalculia and dyslexia.
- Aided in grant writing consultation and fundraising for the International Alliance for Ability in Science, which has resulted in an incoming \$15,000. These funds have been used to provide scholarships and financial aid for disabled student researchers across the globe.

### **CENTER INVOLVEMENT AND COLLABORATIONS**

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- Center for Enhanced Nanofluidic Transport ([CENT](#)) *2020-Date*
- Illinois Materials Research Science and Engineering Center ([I-MRSEC](#)) *2018-2020*

### **PROFESSIONAL SOCIETIES MEMBERSHIP**

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- North American Membrane Society (NAMS) *2023-Date*
- Biophysical Society (BPS) *2015-Date*
- American Physical Society (APS) *2015-Date*