Bivas Saha

Assistant Professor
International Center of Materials Science &
Chemistry and Physics of Materials Unit &
School of Advanced Materials.
Jawaharlal Nehru Center for Advanced Scientific Research

January 2021

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PROFESSIONAL EXPERIENCE

2018 – Present **Assistant Professor**, **Jawaharlal Nehru Center for Advanced Scientific Research (JNCASR)**
International Center of Materials Science (ICMS) &
Chemistry and Physics of Materials Unit (CPMU) &
School of Advanced Materials (SAMat)
Bangalore, Karnataka, 560064, India.

2014 - 2017 **Postdoctoral Scholar, University of California, Berkeley, CA, USA.**
Department of Materials Science and Engineering &
Center for Energy Efficient Electronic Sciences

- Research Topic: *Sub-threshold Nano-electronics*.
- Advisor: Prof. Junqiao Wu
- Affiliate @ Lawrence Berkeley National Laboratory (LBNL).

EDUCATION

2010 - 2014 **Ph. D. Purdue University, West Lafayette, Indiana, USA**
School of Materials Engineering & Birck Nanotechnology Center

- Dissertation Topic: *Thermal and Thermoelectric Properties of Nitride Metal/Semiconductor Superlattices.*
- Advisor: Prof. Timothy D. Sands

2007 - 2010 **M. S. Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore (JNCASR), Karnataka, India**
Chemistry and Physics of Materials Unit &
Theoretical Sciences Unit

- Dissertation Topic: *Theoretical Modeling of Nanostructured (Hf, Zr)N/(Sc, Y)N Metal/Semiconductor Superlattices for Thermoelectric Energy Conversion.*
- Advisor: Prof. Umesh Waghmare

2004 - 2007 **B. S. Jadavpur University, Kolkata, West Bengal, India**
Department of Physics (Major)

RESEARCH INTERESTS

- Heteroepitaxy of Dissimilar Materials and Metal/Semiconductor Superlattices.
- Thermoelectrics and Thermionic Emission Devices.
- Plasmonics and Nano-photonics.
- First-principles modeling of Materials.

ADMINISTRATIVE RESPONSIBILITIES

- **Faculty Director**, JNCASR Nanofabrication Laboratory. (10/2018- Cont.).
- **Faculty In-charge**, Spectroscopic Ellipsometer, Technical Research Center (TRC) (08/2019-Cont.).
- **Co-chair**, JNCASR Alumni Association, (9/2019-Cont.)
- **Coordinator,** JNC Summer Research Fellowship Program in Physical Sciences, 2020-Cont.

RESEARCH GRANTS

- Project Title: "Development of Nanocomposite Heterostructures for Thermoelectric Power Generation by Waste Heat Recycling in Power Plants"- PI: Bivas Saha, Central Power Research Institute (CPRI). **(Under-review, 2020).**

- Project Title: "Epitaxial Metal/Semiconductor Nanocomposite Metamaterials for Thermoelectrics and Terahertz Devices" PI: Bivas Saha, **Board of Research in Nuclear Sciences (BRNS)** of Department of Atomic Energy for **Young Scientist Investigator Award**. Award Number: 59/20/10/2020-BRNS/59020. (09/2020- Cont.).

- Project Title: "Determination of Phononic Bandgap and Phonon Localization in Epitaxial HfN and HfN/ScN Metal/Semiconductor Superlattice Metamaterials with Inelastic X-ray Scattering"- **Nanomission Synchrotron and Neutron Facility Project**, February, 2020.

- Project Title: "Scandium Nitride Schottky and *pn*-junction Didoes." PI: Bivas Saha (JNCASR). Submitted for Start Up Grant in **Science and Engineering Research Board** of Department of Science and Technology, India (2019) SRG/2019/000613. (01/2020- Cont.).

- Science and Engineering Research Board (SERB) **International Travel Award** (ITA) for ICMCTF, 2019 in San Diago California.

- Project: **Start-up Research Grant** from International Center for Materials Science and Sheikh Saqr Laboratory of Jawaharlal Nehru Center for Advanced Scientific Research.

- Project Title: “Exploration of functional nitride-based metal/semiconductor superlattices for applications as thermoelectric and plasmonic materials”. Co-PIs: Bivas Saha (UC Berkeley) and Magnus Garbrecht (LinkÖping University). **The Swedish Foundation** for International Cooperation in Research and Higher Education (STINT) Research Initiation Grant**,** $12,500. (2017-2018).

PATENTS

- TiN based metamaterials. **US Patent**, PCT/US2013/64057, G. V. Naik, B. Saha, T. D. Sands, V. M. Shalaev and A. Boltasseva.

AWARDS, HONORS, FELLOWSHIPS

- **Associate, Indian Academy of Sciences, (2020- Cont.)**
- **Young Scientist Research Award,** Board of Research in Nuclear Sciences (BRNS) of Department of Atomic Energy, India, 2020.
- **Outstanding Graduate Student Researcher** in Materials Engineering, Purdue University, 2014.
- Best Presentation Award, **Materials Research Society (MRS) of USA Fall 2013**.
- Best Poster Award, (a) SIGMA XI Graduate Student Research Awards Competition; Purdue University, 2013, (b) Symposium on Nanomaterial for Energy, Purdue University, April 2012, (c) Best Poster Award, Winter School on Chemistry and Physics of Material. JNCASR, Bangalore, 2009.

TEACHING EXPERIENCES

Jawaharlal Nehru Centre for Advanced Scientific Research

- JNC 208: Characterization of Materials. Fall 2019, 2020 *(Designed this Ph.D. Course)*
- JC 216: Solid State Electronics. Spring-2019.
- JC 218: Materials Laboratory. Fall 2018, 2019

Teaching Assistant (TA) in Purdue University, School of Materials Engineering.

- Fall 2013: Materials Properties Laboratory (MSE-235)
  - Student Evaluation: 4.8/5 for MSE-235-002, and 4.2/5 for MSE-235-003.

- Fall 2011: Structure and Properties of Materials (MSE-230)
  - Student Evaluation: 4.5/5 for MSE-230-003, and 4.4/5 for MSE-230-008.

STUDENT SUPERVISION

Ph.D. Students

- Krishna Chand Maurya (08/2018- Cont.)
- Sourjyadeep Chakraborty (08/2018- Cont.)
- Bidesh Biswas (01/2019- Cont.)
- Dheemahi Rao (07/2020-Cont.)
- Prasanna Das (09/2020- Cont.)

M.S. Students

- Dheemahi Rao (Graduated, 2020)

Postdoctoral Scholar

- Dr. Shashidhara Acharya (05/2019-Cont.)

Project Student

- Krithika Upadhaya (01/2020 – Present)
- Bidesh Biswas. (03/2018 – 12/2018)

Summer Research Fellow and Short-term Visitors

- Avari Roy (Physics, IIT Bombay- 2019)
- Indrajit Ratan (Physics, Ferguson College, Pune- 2019)
- Dheemahi Rao (JNCASR, 2018)

Student Mentorship (2008-2017)

- Don Rollings (University of Massachusetts, Amherst- 2017)
- Jane Edgington (Rensselaer Polytechnic Institute -2016)
- Liam Dougherthy (San Jose Community College, TTEREU-2016).
- Andrew Cook (University of Maryland, 2015)
- Jonathan Comparan (Purdue University, 2013-2014).
- Nelson Yaw Dzade (African University of Science and Technology, 2010)
- Jagaran Acharya (Tribhuvan University, 2008)

EVALUATION COMMITTEE

Ph.D. Qualifying Examination Committee Member

- Moinak Dutta (NCU, JNCASR)

- Payel Mondal (ICMS, JNCASR)
- Soumik Ghosh (TSU, JNCASR)
- Arabinda Bera (TSU, JNCASR)

PROFESSIONAL SERVICES

Journal Reviewer

- Physical Review Letters
- Physical Review B.
- Applied Physics Letters.
- Journal of Applied Physics
- ACS Nano
- ACS Omega
- ACS Applied Materials and Interfaces
- ACS Applied Energy Materials
- Journal of Physics D: Applied Physics
- RSC Advances
- Journal of Material Science
- Science of Advanced Materials
- Energy Conversion and Management
- Measurement (Elsevier)
- Phys. Stat. Solidi: Rapid Research Letters
- Advanced Electronic Materials
- Solid State Communication.
- Thin Solid Film.
- Physical Status Solidi A: Applications and Basic Research,
- Chemistry of Materials
- Advanced Energy Materials
- Superlattices and Microstructures,
- IEEE Transactions on Nanotechnology.
- Journal of Computational Electronics
- Materials.
- Vacuum.
- Pramana

Member

- Materials Research Society (MRS) of the USA, 2010-Cont.
- American Physical Society (APS), 2014-2017.
- American Vacuum Society (AVS), 2020-Cont.
- Research Awareness Sub-committee: Nanotechnology Students Advisory Council (NSAC), Purdue University, 2013-2014.
- Activities Committee: Nanodays, Birck Nanotechnology Center, 2012.

Others:

- Ambassador, Discovery Park, Purdue University, 2012-2013.
- Ambassador, Birck Nanotechnology Center, Purdue University. 2011-2012.
- Chair, Poster Organizing Committee: Symposium on Nanomaterial for Energy, Purdue University, April 2012.
- Reviewer, Center of Energy Efficient Electronics and Sciences (E^3S) Research Experience for Undergraduates (REU) Program 2015.

INVITED TALKS

1. Rigid-Band Electronic Structure of ScN across n-type to p-type carrier transition regime. International Conference on Materials for Advanced Technologies **(ICMAT) Singapore** June 25th 2019.
2. Schottky Barrier Height of Epitaxial TiN/(Al,Sc)N Metal/Semiconductor Superlattices for Thermionic Energy Conversion. International Conference on Materials for Advanced Technologies **(ICMAT) Singapore** June 27th 2019.
3. Metal/Semiconductor Superlattice Metamaterials: A New Paradigm in Solid-State Energy Conversion. International Conference on Metallurgical Coatings and Thin Films **(ICMCTF), American Vacuum Society (AVS), San Diego California US** May 19-24, 2019.
4. Epitaxial TiN/(Al,Sc)N Metal/Semiconductor Superlattices for Thermionic Energy Conversion, **Indus Synchrotron User Meeting**, Raja Ramanna Centre for Advanced Technology (RRCAT), March 28th 2019.
5. Engineering Schottky Barrier Height in Epitaxial TiN/(Al,Sc)N Metal/Semiconductor Superlattices. **International Workshop on Advanced Materials (IWAM), Ras Al Khaimah UAE**, February 26th 2019.
6. Sub-50 mV Nano-electromechanical Relay Switch Devices, **14th JNC Conference on Chemistry of Materials, Thiruvananthapuram, Kerala,** October 5th, 2018.
7. **Plenary Talk:** Metal/Semiconductor Heterostructure: A New Paradigm in Solid-State Energy Conversion. International Science Week, **Industrial University of Santander (UIS), Bucaramanga – Colombia**. September 21, 2018.
8. Metal/Semiconductor Superlattices: Promise for a New Paradigm in Solid-State Energy Conversion, Department of Physics, Chemistry and Biology, **Linkoping University, Linkoping**, **Sweden** March 5th 2018.
9. Metal/Semiconductor Superlattices: Promise for a New Paradigm in Solid-State Energy Conversion, Department of Metallurgical Engineering and Materials Science, **Indian Institute of Technology Bombay (IIT-Bombay)**, India July 12th 2017.
10. Sub-50 mV Nano-electromechanical Relay Switch, Department of Electrical Engineering, **Indian Institute of Technology Bombay (IIT-Bombay)**, India July 12th 2017.
11. Metal/Semiconductor Superlattices: Promise for a New Paradigm in Solid-State Energy Conversion, Department of Condensed Matter Physics and Materials Science, **Tata Institute of Fundamental Research (TIFR)**, India July 11th 2017.
12. Sub-50 mV Nano-electromechanical Relay Switch, **Center for Nano and Soft Matter (CENSE)**, Bangalore, India, July 7th 2017.

13. Metal/Semiconductor Superlattices: Promise for a New Paradigm in Solid-State Energy Conversion, International Center for Materials Science and New Chemistry Unit, **Jawaharlal Nehru Center for Advanced Scientific Research (JNCASR)**, Bangalore, India July 6th 2017.
14. Metal/Semiconductor Superlattices: Promise for a New Paradigm in Solid-State Energy Conversion, Department of Materials Engineering, **Indian Institute of Science (IISc.)**, Bangalore, India July 3rd 2017.
15. Sub-thermionic Nano-electromechanical Relay Switches for Low Power Electronics and Internet of Things, **Micron Technology, Inc**. Boise, ID, June 5th, 2017.
16. Metal/Semiconductor Superlattices: Promise for a New Paradigm in Solid-State Energy Conversion, Materials Department, **UC Santa Barbara**, February 21st, 2016.
17. Materials Engineering of MEMS Relay Contact Surfaces, **NSF STC Energy Efficient Electronics Sciences Seminar, Massachusetts Institute of Technology (MIT)**, October 27, 2017.
18. Thermal and Thermoelectric Properties of Nitride Metal/Semiconductor Superlattices- **California Institute of Technology (Cal. Tech.)**, July 2014.

(Invited talks presented inside the University (JNCASR, Purdue, and UC Berkeley) while Dr. Saha is an employee or was a student are not listed here).

OUTREACH (Presentations and Tutorials)

- India International Science Festival Curtain Raiser, JNCASR, December 10,2020.
- Faculty Development Program (FDP) on "Smart Materials and their emerging technologies" – BMS Institute of Technology and Management, July 2019.
- "Hands on training on Microscopy and Thin Film Measurements"- Siddaganga Institute of Technology, April 2019.
- Samagatha, "Smart Synergy" – Emerging trends in applications of smart materials. Maharani Lakshmi Ammanni College for Woman, February 2019.
- Faculty Development Program (FDP) on "Thin Films & their applications" – RV College of Engineering, February 2019.
- Popular Science Talk on "Nanotechnology and New Materials: From Energy Security to Artificial Intelligence"- CNR Rao Hall of Science, November 2018.
- Basics of Spectroscopy and Light-Matter Interactions- Project Oriented Chemical Education (POCE) Students in JNCASR.

ONLINE PRESENTATIONS

- MRS OnDemand: "Pseudomorphic Stabilization of Cubic $Al_xSc_{1-x}N$ with High Al Concentration and Large Critical Thickness on (001) MgO Substrates with TiN as Seed Layer."
  http://www.prolibraries.com/mrs/?select=session&sessionID=2909

PUBLICATIONS - Bivas Saha

Total: 39 Peer-reviewed Journal Publications and 3 Book Chapters.
Citations: 961.
h- index: 19.
i10- index: 23.

Google Scholar: https://scholar.google.com/citations?user=m0gvp6EAAAAJ&hl=en&oi=ao
Researcher ID: http://researchid.co/bivas-saha

10 Recent Highlights and Most Relevant Publications.

1. D. Rao, B. Biswas, E. Flores, , A. Chatterjee, M. Garbrecht, Y. R. Koh, V. Bhatia, A. Pillai, P. Hopkins, M. M. Gonzalez, and **B. Saha**, "High mobility and high thermoelectric power factor in epitaxial ScN deposited with plasma assisted molecular beam epitaxy" ***Appl. Phys. Lett., 116, 152103 (2020). (Editor's Pick)***

   (ScN thin films have attracted significant interest in recent years for its potential thermoelectric applications. However, until recently, no reports on the thermoelectric properties of MBE-deposited ScN was reported. In this work, we deposited high-quality epitaxial and nominally single-crystalline ScN thin films with PA-MBE and demonstrated high electrical mobility and large thermoelectric power factor for the first time in MBE-deposited ScN film. This work will further ScN's potential as a thermoelectric material.)

2. S. Nayak, S. Acharya, B. Baral, M. Garbrecht, T. Ganguli and **B. Saha**, "Schottky barrier height of epitaxial lattice-matched TiN/AlScN metal/semiconductor superlattice interfaces for thermionic energy conversion." ***Appl. Phys. Lett., 115, 251901, (2019).***

   (Measurement of Schottky barrier height in epitaxial metal/semiconductor superlattices are extremely challenging with traditional current-voltage (IV) methods due to intrinsic defects and fabrication induced leakage currents. In this work, we used photoemission spectroscopy (UPS and XPS) analysis as well as first-principles modeling to determine the Schottky barrier height of lattice-matched TiN/AlScN metal/semiconductor superlattices for the first time. This

work is an important step towards the practical devices with metal/semiconductor superlattices.)

3. S. Nayak, M. Baral, M. Gupta, J. Singh, M. Garbrecht, T. Ganguly, S. M. Shivaprasad and **B. Saha**, "Rigid-Band Electronic Structure of scandium nitride across the *n*–type to *p*–type carrier transition regime." ***Phys. Rev. B. Rapid Communications 99, 161117(R) (2019)***.

   (Intentional doping and unintentional impurities create defect states inside the bandgap of semiconductors and limits its application. In this work, we demonstrated that unintentional oxygen impurities (n-type) and intentional Mg doping (p-type) in ScN do not introduce defect states inside its bandgap and that its electronic structure remain unchanged. Since most III-V semiconductors exhibit defect states inside its bandgap, ScN, therefore, is a unique material and could pave the way for important devices.)

4. B. Biswas and **B. Saha**, "Development of semiconducting ScN" ***Phys. Rev. Materials, 3, 020301 (2019).***

   (Epitaxial rocksalt ScN thin films have attracted significant interest in recent years for various applications. However, until very recently, there was no concise progress article that could summarize ScN research for the community. In this comprehensive review, we have discussed various aspects of ScN research, development of p-type ScN and ScN-based superlattices, etc. which has attracted great interest from other researchers.)

5. K. C. Maurya, B. Biswas, M. Garbrecht, and **B. Saha**, "Wave-vector Dependent Raman Scattering from Coupled Plasmon- Longitudinal Optical Phonon Modes and Fano Resonance in *n*-type ScN." ***Phys. Status Solidi RRL, 13, 1900196 (2019).***

   (Raman Scattering from coupled plamson- longitudinal optical phonon modes are an effective tool to determine the carrier concentration and carrier dynamics of semiconductor in without making a contact. In this article, we have demonstrated wave-vector dependent Raman scattering from coupled plasmon-LO phonon mode in ScN thin films. In addition, Fano resonance in ScN was also demonstrated that arises due to the interaction of discreet phonon modes with continuum of electronic states.)

6. M. Garbrecht, L. Hultman, M. H. Fawey, T. D. Sands, and **B. Saha**. "Void-mediated coherency-strain relaxation and impediment of cubic-to-hexagonal transformation in epitaxial metastable metal/semiconductor TiN/$Al_{0.72}Sc_{0.28}N$ multilayers" ***Phys. Rev. Materials 1, 033402, (2017).***

   (*During his graduate studies, Dr. Saha developed the first epitaxial single-crystalline* TiN/$Al_{0.72}Sc_{0.28}N$ *metal/semiconductor superlattices for a range of thermionic energy conversion. Semiconducting* $Al_{0.72}Sc_{0.28}N$ *was stabilized in rocksalt crystal structure inside the* TiN/$Al_{0.72}Sc_{0.28}N$ *superlattice in metastable phase. In this work, coherency strain relaxation and critical thickness of* $Al_{0.72}Sc_{0.28}N$ *to be stable in rocksalt phase was determined.)*

7. **B. Saha**, A. Shakouri and T. D. Sands, "Rocksalt nitride metal/semiconductor superlattices: A new class of artificially structured materials". ***Appl. Phys. Rev. 5, 021101 (2018) Editors Pick, Feature Article, Cover Picture, and Most Downloaded Paper.***

   (In this invited review article, comprehensive details about the development of epitaxial single-crystalline metal/semiconductor superlattices are reviewed. The review article has attracted significant interests and several research groups have started to contribute on metal/semiconductor heteroepitaxy research.)

8. **B. Saha**, J. A. Perez-Taborda, J. Bahk, Y. R. Koh, , A. Shakouri, M. M. Gonzalez, and T. D. Sands, "Temperature-dependent thermal and thermoelectric properties of *n-type* and *p*-type $Sc_{1-x}Mg_xN$." ***Phys. Rev. B 97, 085301 (2018).***

   (Having demonstrated the p-type ScN thin films, in this work, we demonstrated large thermoelectric power factors in n-type and p-type ScN thin films doped with Mg as hole-doping. Moreover, it was demonstrated that the large thermoelectric power factor in ScN persists across the n-type to p-type carrier transition regime.)

9. **B. Saha**, M. Garbrecht, J. A. Perez-Taborda, M. H. Faway, Y. R. Koh, M. M. Gonzalez, A. Shakouri, L. Hultman, and T. D. Sands, "Compensation of native donor doping in ScN: Carrier concentration control and *p*-type ScN", ***Appl. Phys. Lett. 110, 252104 (2017).***

   (Preferential and controlled electron (n-type) and hole (p-type) doping in semiconductors are essential for its applications in electronic, optoelectronic and thermoelectric devices. As-deposited ScN thin films exhibit large n-type carrier concentrations due to the presence of unwanted n-type oxygen impurities and nitrogen vacancies. In this work, we developed p-type ScN thin films for the first time and demonstrated its electronic properties. A large (p-type) hole-concentration of 2×10^{20} cm^{-3} was demonstrated. This was a major milestone in ScN research.)

10. **B. Saha**, Y. R. Koh, J. P. Feser, S. Sadasivam, T. S. Fisher, A. Shakouri, and T. D. Sands, "Phonon wave effects in the thermal transport of epitaxial TiN/(Al,Sc)N metal/dielectric superlattices." ***J. Appl. Phys. 121, 015109 (2017).***

    (Wave effects in phonon transport are challenging to probe due to the collective nature of lattice vibrations. In this work, we demonstrated phonon wave-effects in thermal transport of epitaxial metal/semiconductor superlattices for the first time by employing thermal conductivity measurements as a function of the period thickness in superlattices and detailed first-principles modeling analysis.)

All Peer-Reviewed Publications

JOURNAL PUBLICATIONS

1. D. Rao, B. Biswas, S. Acharya, V. Bhatia, A. I. K. Pillai, M. Garbrecht and **B. Saha**, "Effects of adatom mobility and Ehrlich-Schwoebel barrier on heteroepitaxial growth of scandium nitride (ScN) thin films " ***Appl. Phys. Lett, 117, 212101 (2020).***

2. K. C. Maurya, V. M. Shalaev, A. Boltasseva and **B. Saha**, "Reduced Optical Losses in Refractory Plasmonic Titanium Nitride (TiN) Thin Films Deposited With Molecular Beam Epitaxy" ***Opt. Mater. Express. 10, 2679 (2020).***

3. S. Chakraborty, H. Uchiyama, M. Garbrecht, V. Bhatia, A. I. K. Pillai, J. P. Feser, D. Adroja, S. Langridge and **B. Saha**. "Phononic Bandgap and Phonon Anomalies in HfN and HfN/ScN Metal/Semiconductor Superlattices Measured with Inelastic X-ray Scattering." ***Appl. Phys. Lett. 117, 111901 (2020). Editor's Pick.***

4. E. Rathore, K. Maji, D. Rao, **B. Saha** and K. Biswas, "Charge Transfer in the Heterostructure of CsPbBr3 Nanocrystals with Nitrogen Doped Carbon Dots " ***J. Phys. Chem. Lett. 11, 8002 (2020).***

5. S. Acharya, A. Chatterjee, A. Seema, M. Gupta and **B. Saha** "Influence of Sc flux on Molecular Beam Epitaxy Growth of Wurtzite Al1-xScxN thin films on Sapphire Substrates. "***Bull. Mater. Sci. 43, 316 (2020).***

6. B. Biswas, S. Nayak, V. Bhatia, A. I. K. Pillai, M. Garbrecht, M. H. Modi, M. Gupta and B. Saha, "Interfacial Chemistry and Electronic Structure of Epitaxial Lattice-matched TiN/$Al_{0.72}Sc_{0.28}N$ Metal/Semiconductor Superlattices Determined with Soft X-Ray Scattering" ***J. Vac. Sci. Technol. A 38, 053201 (2020).***

7. D. Rao, B. Biswas, E. Flores, , A. Chatterjee, M. Garbrecht, Y. R. Koh, V. Bhatia, A. Pillai, P. Hopkins, M. M. Gonzalez, and **B. Saha**, "High mobility and high thermoelectric power factor in epitaxial ScN deposited with plasma assisted molecular beam epitaxy" ***Appl. Phys. Lett. 116, 152103 (2020). (Editor's Pick)***

8. M. Garbrecht, I. McCarroll, L. Yang, V. Bhatia, B. Biswas, D. Rao, J. Cairney, and **B. Saha**, "Thermally stable epitaxial ZrN/carrier-compensated $Sc_{1-x}Mg_xN$ metal/semiconductor multilayers for thermionic energy conversion" ***J. Mater. Sci. 55, 1592 (2020) (Editor's Pick).***

9. S. Fathipour, S. F. Almeida, Z. A. Ye, **B. Saha**, F. Niroui, T. J. K Liu, and J. Wu, "Reducing adhesion energy of nano-electro-mechanical relay contacts by self-assembled Perfluoro (2, 3-Dimethylbutan-2-ol) coating" ***AIP Advances 9, 055329 (2019).***

10. S. Nayak, S. Acharya, B. Baral, M. Garbrecht, T. Ganguli and **B. Saha**, "Schottky barrier height of epitaxial lattice-matched TiN/AlScN metal/semiconductor superlattice interfaces for thermionic energy conversion." ***Appl. Phys. Lett., 115, 251901, (2019).***

11. K. C. Maurya, B. Biswas, M. Garbrecht, and **B. Saha**, "Wave-vector Dependent Raman Scattering from Coupled Plasmon- Longitudinal Optical Phonon Modes and Fano Resonance in *n*-type ScN." ***Phys. Status Solidi RRL, 13, 1900196 (2019).***

12. S. Nayak, M. Baral, M. Gupta, J. Singh, M. Garbrecht, T. Ganguly, S. M. Shivaprasad and **B. Saha**, "Rigid-Band Electronic Structure of scandium nitride across the *n*–type to *p*–type carrier transition regime." ***Phys. Rev. B. Rapid Communications 99, 161117(R) (2019)***.

13. B. Biswas and **B. Saha**, "Development of Semiconducting Scandium Nitride" ***Phys. Rev. Materials, 3, 020301 (2019).***

14. B. Osoba, **B. Saha**, S. F. Almeida, J. Patil, L. E. Brandt, M. E. D. Roots, E. Acosta, J. Wu and T. J. K. Liu, "Variability Study of Low-Voltage Micromechanical Relay Operation" ***IEEE Transactions on Electron Devices, 65, 1529 (2018).***

15. **B. Saha**, J. A. Perez-Taborda, J. Bahk, Y. R. Koh, , A. Shakouri, M. M. Gonzalez, and T. D. Sands, "Temperature-dependent thermal and thermoelectric properties of *n-type* and *p*-type $Sc_{1-x}Mg_xN$." ***Phys. Rev. B 97, 085301 (2018).***

16. K. Dong, H. S. Choe, X. Wang, H. Liu, **B. Saha**, C. Koh, Y. Deng, K. B. Tom, S. Lou, L. Wang, C. P. Grigoropoulos, Z. You, J. Yao and J. Wu, "A 0.2-Volt Microelectromechanical Switch Enabled by a Phase Transition." ***Small 14, 1703621 (2018). (Cover Picture).***

17. **B. Saha**, A. Shakouri and T. D. Sands, "Rocksalt nitride metal/semiconductor superlattices: A new class of artificially structured materials". ***Appl. Phys. Rev. 5, 021101 (2018) Editors Pick, Feature Article, Cover Picture, and Most Downloaded Paper.***

18. M. Garbrecht, L. Hultman, M. H. Fawey, T. D. Sands, and **B. Saha**, "Tailoring of surface plasmon resonances in TiN/$(Al_{0.72}$,$Sc0._{28})$N multilayers by dielectric layer thickness variation", ***J. Mater. Sci. 53, 4001 (2018).***

19. M. Garbrecht, L. Hultman, M. H. Fawey, T. D. Sands, and **B. Saha**. "Void-mediated coherency-strain relaxation and impediment of cubic-to-hexagonal transformation in epitaxial metastable metal/semiconductor TiN/$Al_{0.72}Sc_{0.28}$N multilayers" ***Phys. Rev. Materials 1, 033402, (2017).***

20. **B. Saha**, M. Garbrecht, J. A. Perez-Taborda, M. H. Faway, Y. R. Koh, M. M. Gonzalez, A. Shakouri, L. Hultman, and T. D. Sands, "Compensation of native donor doping in ScN: Carrier concentration control and *p*-type ScN", ***Appl. Phys. Lett. 110, 252104 (2017).***

21. M. Garbrecht, **B. Saha**, J. L. Schroeder, L. Hultman, and T. D. Sands, "Dislocation-pipe diffusion in nitride superlattices observed in direct atomic resolution." ***Sci. Rep. 7, 46092 (2017).***

22. **B. Saha,** A. Peschot, B. Osoba, C. Ko, L. Rubin, T. J. K. Liu and J. Wu, "Reducing adhesion energy of mirco-relay electrodes by ion beam synthesized oxide nanolayers." ***APL Materials, 5, 036103, (2017).***

23. **B. Saha**, Y. R. Koh, J. P. Feser, S. Sadasivam, T. S. Fisher, A. Shakouri, and T. D. Sands, "Phonon wave effects in the thermal transport of epitaxial TiN/(Al,Sc)N metal/dielectric superlattices." ***J. Appl. Phys. 121, 015109 (2017).***

24. **B. Saha**, S. Saber, E. Stach, E. P. Kvam, and T. D. Sands "Understanding the Rocksalt-to-Wurtzite phase transformation through microstructural analysis of (Al,Sc)N epitaxial thin films. ***Appl. Phys. Lett. 109, 172102 (2016).***

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32. **B. Saha**, S. Saber, G. V. Naik, A. Boltasseva, E. Stach, E. P. Kvam, and T. D. Sands, "Development of epitaxial $Al_xSc_{1-x}N$ for artificially structured metal/semiconductor superlattice metamaterials." ***Phys. Status Solidi B, 252, 251 (2015). (Editor's Choice and Cover Article, Purdue MSE News).***

33. G. V. Naik, **B. Saha**, J. Liu, S. M. Saber, E. Stach, J. M. K. Irudayaraj, T. D. Sands, V. M. Shalaev and A. Boltasseva, "Epitaxial superlattices with titanium nitride as a plasmonic component for optical hyperbolic metamaterials." ***Proc. Natl. Acad. Sci.* 111, *7546 (2014). (Chosen for Issue Highlight, Purdue News).***

34. **B. Saha**, G. Naik, V. Drachev, A. Boltasseva, E. E. Marinero, and T. D. Sands, "Electrical and optical properties of ScN and Mn-doped ScN deposited by dc-magnetron sputtering." ***J. Appl. Phys., 114, 063519 (2013).***

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BOOK CHAPTERS

1. S. Acharya, D. Rao and **B. Saha**, Book Name: Frontiers of Materials Science, Chapter Title: "Advances in Heterostructure Metamaterials for Solid-State Energy Conversion." ***World Scientific Publishing Co. Pte. Ltd. (2020).***

2. S. Acharya and **B. Saha**, Book Name: Coatings and Thin-Film Technologies, Chapter Title: "Epitaxial Nitride Thin Film and Heterostructures: From Hard Coating to Solid State Energy Conversion". ***Intech Open (2018)***.

3. **B. Saha,** and J. Wu, Center for Energy Efficient Electronics Sciences (E3S) Electronic Book on Low Voltage Switches, Chapter 6: "Role of Adhesion in Nanoelectromechanical Relay Switch Devices" ***UC Berkeley (2017)***.

CONFERENCE PUBLICATIONS

1. M. Garbrecht, I. McCarroll, V. Bhatia, A. Indiradevi Kamalasanan Pillai, L. Yang, J. M. Cairney, and **B. Saha**, *Diffusion along defects in nitride multilayer thin films as observed by state-of-the-art (S)/TEM and APT methods,* **EMC Kopenhagen 2020.**
2. M. Garbrecht, V. Bhatia, I. McCarroll, A. Indiradevi Kamalasanan Pillai, L. Yang, J. M. Cairney, and **B. Saha**, *Diffusion phenomena in nitride multilayer thin films as observed directly by aberration-corrected TEM methods,* **ACMM Canberra 2020.**
3. M. Garbrecht, I. McCarroll, L. Yang, **B. Saha**, and J. Cairney, *Correlative STEM-EDS and APT study of dopants in a metal-semiconductor nitride superlattice at the atomic scale,* **PICO 2019, Kasteel Vaalsbroek, Netherlands.**
4. M. Garbrecht**, B. Saha**, *Quantitative atomic scale analysis of diffusion phenomena in nitride multilayer thin films as observed by STEM,* **AMAS Melbourne, Australia, 2019.**
5. M. Garbrecht, **B. Saha**, *Tailoring of surface plasmon resonances in TiN/(Al,Sc)N superlattices for applications in energy-harvesting devices,* **IMC 2018, Sydney, Australia.**
6. M. Garbrecht, **B. Saha**, *STEM-based direct observation of dislocation-pipe diffusion in metal/semiconductor nitride superlattice thin films,* **IMC 2018, Sydney, Australia.**
7. M. Garbrecht, L. Hultman, T. D. Sands, **B. Saha**, *Dislocation-pipe diffusion in nitride superlattice thin films as observed by STEM in direct atomic resolution*, **MC 2017, Lausanne, Switzerland.**
8. M. Garbrecht, L. Hultman, M. H. Fawey, T. D. Sands, **B. Saha**, *Tailoring of plasmon resonances in TiN/(Al,Sc)N superlattices for applications in energy-harvesting devices*, **MC 2017, Lausanne, Switzerland.**
9. M. Garbrecht, L. Hultman, T. D. Sands, **B. Saha**, *Dislocation-pipe diffusion in nitride superlattices observed in direct atomic resolution*, **PICO Symposium 2017, Kasteel Vaalsbroek, Netherlands.**
10. M. Garbrecht, J. L. Schroeder, L. Hultman, J. Birch, **B. Saha**, T.D. Sands, *HRTEM Exploration and Development of Metal/Semiconductor Superlattice Thin Films*, **Scandem 2016, Trondheim, Norway.**
11. M. Garbrecht, J. L. Schroeder, L. Hultman, J. Birch, T. D. Sands and **B. Saha**, "Microstructural evolution and thermal stability of nitride-based metal/semiconductor superlattices for thermoelectric and hard-coating applications." **European Microscopy**

Congress 2016: Proceedings, pp.237-238

12. J. Suh, **B. Saha**, J. Wu. "Novel device functionalities enabled by substitutional doping against native propensity in 2D semiconductors" **Energy Efficient Electronic Systems (E3S), 2015 Fourth Berkeley Symposium**, September 6-11, 2015.
13. M. Garbrecht, J. L. Schroeder, **B. Saha**, T. D. Sands, J. Birch. "Combined HR(S)/TEM and EDX Characterization of Nanostructured Metal/Semiconductor Superlattices." **Microscopy Conference Gottingen**, September 6-11, 2015.
14. G. V. Naik, **B. Saha**, T. D. Sands, A. Boltasseva, "A Titanium Nitride Based Metamaterial for Applications in the Visible Spectral Range." **4th International Topical Meeting on Nanophotonics and Metamaterials (NANOMETA 2013),** Seefeld, Austria, January 2-6, 2013.
15. G. V. Naik, **B. Saha**, J. Liu, S. M. Saber, E. Stach, J. Irudayaraj, T. D. Sands, V. M. Shalaev, and A. Boltasseva, "A Titanium Nitride based Metamaterial for Applications in the Visible," ***Lasers and Electro-Optics (CLEO) and Quantum Electronics and Laser Science Conference (QELS), 2013 Conference on*. IEEE, 2013.**

PRESENTATIONS (ORAL and POSTER)

1. Poster: D. Rao, B. Biswas and B. Saha, "MBE deposited Scandium Nitride (ScN) for Thermoelectric Applications" International Winter School, JNCASR, December 4th, 2019.
2. Poster: B. Biswas, D. Rao and B. Saha, "High Thermoelectric Power Factor in MBE Deposited Scandium Nitride", JNC Annual Faculty Meeting and In-house Symposium, November 13, 2019.
3. Poster: S. Nayak, S. Acharya and B. Saha, "Schottky Barrier Height in Epitaxial Lattice-matched TiN/AlScN Metal/Semiconductor Superlattice Interfaces for Thermionic Energy Conversion." JNC Annual Faculty Meeting and In-house Symposium, November 13, 2019.
4. Poster: B. Biswas, D. Rao and B. Saha, "High Thermoelectric Power Factor in MBE Deposited Scandium Nitride", 15th JNC Conference on Chemistry of Materials, Thiruvananthapuram, Kerala, October, 2019.
5. Poster: K. C. Maurya, D. Rao and B. Saha, "Refractory Plasmonics for Solar Energy conversion" Chemistry and Physics of Materials: Glorious Past and Exciting Future, JNCASR, Bangalore February 23, 2019.
6. Poster: S. Nayak, S. Acharya and B. Saha, "Schottky Barrier Height in Epitaxial Lattice-matched TiN/AlScN Metal/Semiconductor Superlattice Interfaces for Thermionic Energy Conversion." Chemistry and Physics of Materials: Glorious Past and Exciting Future, JNCASR, Bangalore February 23, 2019.

7. Poster: K. C. Maurya, B. Biswas and B. Saha, "Wave-vector Dependent Raman Scattering from Plasmon-LO phonon modes in *n*-type ScN" International Winter School, Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore, India December 4th 2018.
8. Poster: D. Rao, S. Acharya and B. Saha, "Plasmon Enhanced Solar Energy Conversion with Metal/Semiconductor Heterostructures." JNCASR Annual Faculty Meeting and In-house Symposium, Bangalore India, November 2018.
9. Poster: K. C. Mourya, B. Biswas and B. Saha, "Wave-vector Dependent Raman Scattering from Plasmon-LO phonon modes in *n*-type ScN" JNCASR Annual Faculty Meeting and In-house Symposium, Bangalore India, November 2018.
10. Poster: B. Saha**,** B. Osoba, T. J. K. Liu and J. Wu, Materials Engineering of Micro-relay Contact Surfaces for milli-Volt Switches. 5th Berkeley Symposium on Energy Efficient Electronic Systems and Steep Transistors Workshop, Berkeley, CA October 19th, 2017.
11. Poster: B. Saha**,** B. Osoba, T. J. K. Liu and J. Wu, Materials Engineering of Micro-relay Contact Surfaces for milli-Volt Switches. IEEE S^3S conference, San Francisco, CA October 17th, 2017.
12. Oral: B. Saha, B. Osoba, T. J. K. Liu and J. Wu, Sub-50 mV Nanoelectromechanical Relay Switches. NSF STC Energy Efficient Electronics Sciences Annual Review Meeting, Massachusetts Institute of Technology (MIT), Boston, MA, September 7th, 2017.
13. Poster: B. Saha, B. Osoba, T. J. K. Liu and J. Wu, Materials Engineering of Micro-relay Contact Surfaces for milli-Volt Switches. NSF STC Energy Efficient Electronics Sciences Annual Review Meeting, Massachusetts Institute of Technology (MIT), Boston, MA, September 7th, 2017.
14. Poster: B. Saha, "Metal/Semiconductor Superlattices: Development of an Elusive Heterostructure", 42nd Electronic Materials Symposium, Menlo Park, California, May 5th 2017.
15. Oral: B. Saha, M. Garbrecht, and T. D. Sands, Defects in Epitaxial Metal/Semiconductor Superlattices, Materials Research Society (MRS) Fall Meeting, Boston, MA November 30, 2016.
16. Oral: B. Saha, A. Peschot, B. Osoba, T. J. K. Liu, and J. Wu, Engineering Adhesion Properties of Micro Relay Contacts Through Surface Engineering, Materials Research Society (MRS) Fall Meeting, Boston, MA December 1, 2016.
17. Poster: B. Saha, Yee Rui Koh, A. Shakouri and T. D. Sands, Phonon wave-effects in the thermal transport of epitaxial TiN/(Al,Sc)N metal/semiconductor superlattices, Materials Research Society (MRS) Fall Meeting, Boston, MA, November 29, 2016.
18. Poster: B. Saha, B. Osoba, T. J. K. Liu, and J. Wu, Contact Surface Material Engineering Toward millivolt Relays, IEEE S^3S conference, San Francisco, CA October 2016.
19. Oral and Poster: B. Saha, B. Osoba, L. Dougherty, J. Edgington, C. Qian, F. Niroui, J. H. Lang, V. Bulovic, T. J. K. Liu and J. Wu, Sub-50 mV NEM Relay enabled by Self-assembled Molecular Coating. NSF STC Energy Efficient Electronics Sciences Annual Review Meeting, UC Berkeley, CA, September 2016.

20. Poster: B. Saha, B. Osoba, T. J. K. Liu and J. Wu, Reduction of Adhesion Energy on Mirco Relay Contacts Through Surface Engineering, NSF STC Energy Efficient Electronics Sciences External Review Meeting, UC Berkeley, CA, January 2016.
21. Poster: B. Saha, B. Osoba, T. J. K. Liu and J. Wu, Advanced Materials Engineering for NEM Relays, NSF STC Energy Efficient Electronics Sciences Annual Review Meeting, Massachusetts Institute of Technology (MIT), Boston, MA, September 12th, 2015.
22. Poster: B. Saha and J. Wu, Disorder and Defects in Epitaxial Materials, Singapore-Berkeley Research Initiative for Sustainable Energy (SinBeRISE) Workshop, National University of Singapore (NTU), CREATE Towers, Singapore, July 28th, 2015.
23. Poster: B. Saha, "Metal/Semiconductor Superlattices …… at Last", Purdue University Prospective Future Faculty Workshop, West Lafayette, IN, March 2, 2015.
24. Oral: B. Saha, Yee Rui Koh, A. Shakouri and T. D. Sands, Effect of Period Thickness on the Cross-plane Thermal Transport of (Ti,W)N/(Al,Sc)N Metal/Dielectric Superlattices, International Thermoelectric Society, Nashville, TN, July 6-10, 2014.
25. Oral: B. Saha, Yee Rui Koh, A. Shakouri and T. D. Sands, Heat Conduction through (Ti,W)N/(Al,Sc)N Metal/Semiconductor Superlattices, Electronic Materials Conference, University of California, Santa Barbara, CA, June 2014.
26. Oral: B. Saha, Yee Rui Koh, A. Shakouri and T. D. Sands, Thermal transport in TiN/(Al,Sc)N metal/dielectric superlattices. Materials Research Society Spring Meeting, San Francisco, CA, USA, April 21-25 2014.
27. Oral: B. Saha, E. Marinero and T. D. Sands, Electronic and optical properties of ScN and (Sc,Mn)N thin films deposited by dc-magnetron sputtering, American Physical Society (APS) March Meeting, Denver, CO, March 3-7, 2014.
28. Poster: B. Saha, S. Saber, E. Kvam, E. Stach, and T. D. Sands**,** Pseudomorphic stabilization of cubic $Al_xSc_{1-x}N$ with high Al concentration and large critical thickness on (001) MgO substrates with TiN as a seed layer, Materials Research Society (MRS) Fall Meeting, Boston, MA, USA, December 2-6, 2013. (**Awarded best research presentation in the Fall MRS meeting, and Nominated for the Best Poster Award**).
29. Oral: B. Saha, G. V Naik, A. Boltasseva and T. D. Sands, TiN/(Al,Sc)N metal/dielectric superlattices as hyperbolic metamaterials in the visible range. Electronic Materials Conference, University of Notre Dame, IN, June 26-28, 2013.
30. Poster: B. Saha, T. D. Sands, TiN/(Al,Sc)N metal/dielectric superlattices as hyperbolic metamaterials in the visible range. School of Materials Engineering External Advisory Board Meeting, Purdue University, IN, April 25-26, 2013.
31. Oral: B. Saha, G. V Naik, A. Boltasseva and T. D. Sands, TiN/(Al,Sc)N metal/dielectric superlattices as hyperbolic metamaterials in the visible range. Materials Research Society Spring Meeting, San Francisco, CA April 1-5, 2013.
32. Poster: B. Saha, and T. D. Sands, TiN/(Al,Sc)N metal/dielectric superlattices as hyperbolic metamaterials in the visible range. SIGMA XI Graduate Student Research Awards Competition; Purdue University, IN, February 13, 2013. (**Best Poster Award**)

33. Poster: B. Saha, E. Marinero and T. D. Sands, Growth, characterization and optoelectronic properties of Mn-doped ScN. **B**rick Nanotechnology Center Annual Review Meeting, Purdue University, IN, October 10, 2012.

34. Oral: B. Saha, E. Marinero and T. D. Sands, Growth, characterization and optoelectronic properties of Mn-doped ScN. Electronic Materials Society. Penn. State Convention Center, Pennsylvania, June 20-22, 2012.

35. Oral: B. Saha, and T. D. Sands, Growth, characterization and optoelectronic properties of MN-doped Scan. Materials Science and Engineering Annual Day 2012, Purdue University, IN, May 2012.

36. Poster: B. Saha, and T. D. Sands, Growth, characterization and optoelectronic properties of Mn-doped ScN. Symposium on Nanomaterial for Energy, Burton. D. Morgan Center for Entrepreneurship, Purdue University, IN, April 2012. (**Best Poster Award**).

37. Poster: B. Saha, and T. D. Sands, Growth, characterization and optoelectronic properties of MN-doped Scan. The Society of Sigma Xi, Graduate Student & Post-doctoral Researcher Poster Competition, Stewart Center, Purdue University, IN, February 2012.

38. Poster: B. Saha, and T. D. Sands, Nanostructured thermoelectric for automotive waste heat recovery, Materials Science and Engineering Annual Day 2011, Purdue University, IN, May 2011.

39. Poster: B. Saha, T. D. Sands, and U. V. Wag mare, Nanostructured (Hf,Zr)N/(Sc,Y)N metal/semiconductor superlattices for thermoelectric energy conversion: Materials Research Society Spring Meeting 2010, San Francisco, California, April 5-9, 2010.

40. Oral: B. Saha, and U. V. Waghmare Ordering tendency of nitrogen in N doped MgO for spintronic Applications: Joint INDO-EU meeting on Advanced Materials, HRI, Allahabad, India, January 2010.

41. Oral: B. Saha, T. D. Sands, and U. V. Waghmare, Nitride metal/semiconductor superlattices and alloys for thermoelectric and thermionic applications: Joint INDO-EU meeting on Advanced Materials, HRI, Allahabad, India, January 2010.

42. Oral: B. Saha, T. D. Sands, and U. V. Waghmare, Nitride metal/semiconductor superlattices and alloys for thermoelectric and thermionic applications. Annual Faculty Meeting, JNCASR, India, November 2009.

43. Oral: B. Saha, T. D. Sands, and U. V. Waghmare, Metal/semiconductor superlattices for solid-state energy conversion. TSU In-house symposium. JNCASR, India August 2009.

44. Poster: B. Saha, T. D. Sands, and U. V. Waghmare, Nitride metal/semiconductor superlattices and alloys for thermoelectric and thermionic applications. Winter School on Chemistry and Physics of Materials, JNCASR, November 30 –December 6, 2009. **(Best Poster Award)**

45. Poster: B. Saha, T. D. Sands, and U. V. Waghmare, Strain, electronic structure, phonons and thermal Properties of ZrN/ScN and HfN/ScN metal/semiconductor superlattices. Indo-US Joint Conference on Advanced Materials Research. JNCASR 2009.

46. Poster: B. Saha, T. D. Sands, and U. V. Waghmare, Strain, electronic structure, phonons and thermal Properties of ZrN/ScN and HfN/ScN metal/semiconductor superlattices. CPMU In-house symposium. JNCASR 2009.

47. Poster: B. Saha, T. D. Sands, and U. V. Waghmare, Strain, electronic structure, phonons and thermal Properties of ZrN/ScN and HfN/ScN metal/semiconductor superlattices. Frontiers and Directions in Condensed Matter Physics. Indian Institute of Science, Bangalore 2009.