Alok Ranjan

Division of Nano and Bio Physics, Department of Physics

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Academic Qualifications and Research Experiences

Post-doctoral Researcher **Nov. 2021 – Present**

Division of Nano and Bio Physics, Department of Physics

Chalmers University of Technology, Gothenburg, Sweden – 487 372

- Corelating structure and material property in 2D materials using TEM
- Probing breakdown in emerging 2D layered dielectrics

Postdoc Mentor – Prof. Eva Olsson

Post-doctoral Researcher **Sept. 2019 – Nov. 2021**

Engineering Product Development Pillar, Singapore University of Technology and Design, 8 Somapah Road, Singapore – 487 372

- Reliability of resistive random access memory (RRAM) devices
- Scanning probe microscopy for resistive switching studies

Postdoc Mentor – Prof. Nagarajan Raghavan

PhD in Semiconductor Device Reliability **Sept. 2014 – Aug. 2019**

(a) Engineering Product Development Pillar, Singapore University of Technology and Design, 8 Somapah Road, Singapore – 487 372

(b) Institute of Materials Research and Engineering, Agency for Science Technology and Research, 2 Fusionopolis Way, Singapore – 138 634

Thesis: *Nanoscale noise spectroscopy and breakdown studies in hafnium dioxide (HfO_2) and 2D hexagonal boron nitride (h-BN) dielectrics*

Supervisor – (a) Prof. Pey Kin Leong (SUTD), and (b) Dr. Sean O' Shea (IMRE, A*STAR)

B. Tech in Electrical and Electronics Engineering **July 2010 – May 2014**

National Institute of Technology Nagaland

Chumukedima, Dimapur, Nagaland, India – 797 103

Awards and Honours

Year	Award
2023	**Chalmerska forskningsfonden** Awarded a travel grant of SEK 17,000 by Chalmerska forskningsfonden for attending Microscopy and Microanalysis 2023 symposium
2020	**Best Paper Award**: IEEE International Reliability Physics Symposium (IRPS) IRPS is one of the well-established top-tier annual international conferences organized by IEEE in the field of semiconductor reliability and the event sees a very strong participation from key global semiconductor industries. The best paper was selected from across the whole range of research work that has been submitted in year 2019 to IRPS (1 out of >350 submissions).

2019	**Best Research Poster Competition Award**: Mentor/Siemens, Singapore Fostering Industrial Research Success Together (FIRST) is an annual event organized by SUTD and leading industries partners in Singapore. The best research poster award (and prize money of S$500) was given by Mentors/Siemens for research work in "the art of failure analysis in the emerging 2D hexagonal boron nitride gate dielectrics".
2019	**Research Opportunities Week**: Technical University of Munich The ROW is an annual event organized by TUM Munich which provides an opportunity to the top 50 PhD/postdoctoral researchers across the globe to visit in TUM in person and established new research collaborations with the chairs/faculties at TUM. The fellowship provided a fully funded one-week research trip to TUM.
2017	**Graduate Research Competition Award**: Applied Materials, Singapore The best graduate research competition award (and a prizemoney of S$ 500) was given by Applied Materials (Singapore) during FIRST Industry workshop for research work in "Nanoscale reliability in high-κ HfO_2 gate dielectrics". This research provided an approach to reliably measure the nanoscale electrical characteristics at grain and grain boundary in HfO_2 using state-of-the-art scanning tunneling microscopy techniques.
2014	**President Graduate Fellowship**: Ministry of Education, Singapore The President Graduate Fellowship (PGF) is the most competitive research fellowship awarded by MOE Singapore to the international students to pursue the graduate research work. The fellowship provides a monthly stipend of S$ 3,000 for 5 years and ensures a secured funding of S$ 16,000 for conference participations and student exchange opportunities.
2014	**Academic Gold Medal**: National Institute of Technology Nagaland, India The Gold Medal is awarded by National Institute of Technology Nagaland, India (An Institute of National Importance) for the academic excellence. The medal is awarded to the student for securing top position in Electrical and Electronics Engineering department in Bachelor of Technology (B.Tech).
2013	**Summer Research Visiting Fellowship**: Indian Academy of Sciences, India The summer research visiting fellowship is one of the most competitive undergraduate research fellowships at a national level in India and is awarded by the Indian academy of Sciences (IAS) for pursuing research work during undergraduate studies. The programme is fully funded and provided opportunity to work along with the top researchers across India.

Publications

1. "*Molecular bridges link monolayers of hexagonal boron nitride during dielectric breakdown*" by A. Ranjan, S.J. O'Shea, A. Padovani, T. Su, P. L. Torraca, Y.S. Ang, M.S. Munde, C. Zhang, X. Zhang, M. Bosman, N. Raghavan, K.L. Pey, **ACS Applied Electronic Materials**, (2023).
2. "*Probing resistive switching in HfO_2/Al_2O_3 bilayer oxides using in-situ transmission electron microscopy*", by A. Ranjan, H. Xu, C. Wang, J. Molina, X. Wu, H. Zhang, L. Sun, J. Chu, K.L. Pey, **Applied Materials Today**, (2023).
3. "*Robust resistive switching characteristics of AlO_x CBRAM using simple and cost-effective thermal evaporation process*", by A. Deogaonkar, M. Seal, A. Senapati, S. Ginnaram, **A. Ranjan,** S. Maikap, and N. Raghavan, **Microelectronics Reliability**, (2022).
4. "*Spatially Controlled Generation and Probing of Random Telegraph Noise in Metal Nanocrystal embedded HfO_2 using Defect Nanospectroscopy*" by **A. Ranjan**, F.M. Puglisi, J. Molina, P. Pavan. S.J. O'Shea, N. Raghavan and K.L. Pey, **ACS Applied Electronic Materials**, (2022).

5. “*Dielectric Breakdown in Single-crystal Hexagonal Boron Nitride*” by **A. Ranjan**, N. Raghavan, M. Holwill, K. Watanabe, T. Taniguchi, K.S. Novoselov, K.L. Pey, S.J O’Shea, **ACS Applied Electronic Materials**, Vol. 3, Issue 8, (2021).
6. “*Decoupling the Sequence of Dielectric Breakdown in Single Device Bilayer Stacks by Radiation-Controlled, Spatially Localized Creation of Oxide Defects*” by F.L. Aguirre, **A. Ranjan**, N. Raghavan, A. Padovani, S.M. Pazos, N. Vega, N. Müller, M. Debray, J. Molina, K.L. Pey and F. Palumbo, **Applied Physics Express**, Vol. 14, Issue 12, (2021).
7. “*Localized Probing of Dielectric Breakdown in Multilayer Hexagonal Boron Nitride*” by **A. Ranjan**, S.J O’Shea, M. Bosman, N. Raghavan and K.L. Pey, **ACS Applied Materials & Interfaces**, Vol. 12, Issue 49, (2020).
8. “*The Interplay between Drift and Electrical Measurement in Conduction AFM*” by **A. Ranjan**, K.L. Pey and S.J. O’Shea, **Review of Scientific Instruments**, Vol. 90, Issue 07, 073701, pp. 1-10, (2019).
9. “*Boron Vacancies Causing Breakdown in 2D Layered Hexagonal Boron Nitride Dielectrics*” by **A. Ranjan**, N. Raghavan, F.M. Puglisi, S. Mei, A. Padovani, L. Larcher, K. Shubhakar, P. Pavan, M. Bosman, X.X. Zhang, S.J. O’Shea and K.L. Pey, **IEEE Electron Device Letters**, Vol. 40, Issue 08, pp. 1-4, (2019).
10. "*Random Telegraph Noise in 2D Hexagonal Boron Nitride Dielectric Films*" by A**. Ranjan**, F. Puglisi, N. Raghavan, S.J. O'Shea, K. Shubhakar, and K.L. Pey, **Applied Physics Letters**, Vol. 112, No. 13, 133505, (2018).
11. "*Conductive Atomic Force Microscope Study of Bipolar and Threshold Resistive Switching in 2D Hexagonal Boron Nitride Films*" by **A. Ranjan**, N. Raghavan, S.J. O'Shea, S. Mei, M. Bosman, K. Shubhakar, and K.L. Pey, **Scientific Reports**, Vol. 8, No. 1, 2854, pp. 1-9, (2018).
12. “*Sb_2Te_3 and Its Superlattices: Optimization by Statistical Design*” by J. Behera, X. Zhou, **A. Ranjan**, R.E. Simson, **ACS Applied Materials and Interfaces**, Vol. 10, Issue 17, pp. 15040-15050, (2018).
13. “*Localized Characterization of Charge Transport and Random Telegraph Noise at the Nanoscale in HfO_2 Films Combining Scanning Tunneling Microscopy and Multi-Scale Simulations*” by R. Thamankar, F.M. Puglisi, **A. Ranjan**, N. Raghavan, K. Shubhakar, J. Molina, L. Larcher, A. Padovani, P. Pavan, S.J. O’Shea and K.L. Pey, **Journal of Applied Physics**, Vol. 122, Issue 2, 024301, (2017).
14. “*Resistive Switching Characteristics of MIM Structures based on Oxygen-variable Ultra-thin HfO_2 and Fabricated at Low Temperature*” by J. Molina, R. Torres, **A. Ranjan** and K.L. Pey, **Material Science in Semiconductor Processing**, Vol. 66, pp. 191-199, (2017).
15. “*Analysis of Quantum Conductance, Read Disturb and Switching Statistics in HfO2 RRAM using Conductive AFM*” by **A. Ranjan**, N. Raghavan, J. Molina, S.J. O’Shea, K. Shubhakar and K.L. Pey, ***Microelectronics Reliability***, Vo. 64, pp. 172-178, (2016).
16. “*Conductive Filament Formation at Grain Boundary Locations in Polycrystalline HfO_2 based MIM Stacks – Computational and Physical Insight*” by K. Shubhakar, S. Mei, M. Bosman, N. Raghavan, **A. Ranjan**, S.J. O’Shea and K. L. Pey, **Microelectronics Reliability**, Vo. 64, pp. 204-209, (2016).

17. "*An SEM/STM based Nanoprobing and TEM Study of Breakdown Locations in HfO_2/SiO_x Dielectric Stacks for Failure Analysis*" by K. Shubhakar, M. Bosman, O.A. Neucheva, Y.C. Loke, N. Raghavan, R. Thamankar, **A. Ranjan**, S.J. O'Shea and K.L. Pey, **Microelectronics Reliability**, Vol. 55, Issue 9-10, pp. 1450-1455, (2015).

Conference Proceedings

1. "*Correlation between Adhesion and Dielectric Breakdown in Silicon Dioxide Thin Films*" by **A. Ranjan**, S.J. O'Shea, M. Bosman, J. Molina, N. Raghavan and K.L. Pey, **IEEE International Reliability Physics Symposium (IRPS)**, March (2020).
2. "*New Physics of Breakdown in 2D Hexagonal Boron Nitride and its Potential Applications*" by K.L. Pey, **A. Ranjan**, N. Raghavan and S.J. O'Shea, **IEEE International Symposium on Next-Generation Electronics (ISNE)**, pp. 1-4, (2019).
3. "*Dielectric Breakdown in 2D Layered Hexagonal Boron Nitride – The Knowns and the Unknowns*" by K.L. Pey, **A. Ranjan**, N. Raghavan, K. Shubhakar and S.J. O'Shea, **IEEE IRPS**, pp. 1-12, (2019).
4. "*Spatio-Temporal Defect Generation Process in Irradiated HfO_2 MOS Stacks: Correlated versus Uncorrelated Mechanisms*" by F.L. Aguirre, A. Padovani, **A. Ranjan**, N. Raghavan, N. Vega, N. Müller, S.M. Pazos, M. Debray, J. Molina, K.L. Pey and F. Palumbo, **IEEE IRPS,** pp. 1-8, (2019).
5. "*Electric Field Effects in Chalcogenides*" by L. Chew, W. Dong, **A. Ranjan**, J.K. Behera, L. Lu and R.E. Simpson, **MRS Advances**, Vol. 3, Issue 57-58, (2018).
6. "*Mechanism of Soft and Hard Breakdown in Hexagonal Boron Nitride 2D Dielectrics*" by **A. Ranjan**, N. Raghavan, S.J. O'Shea, S. Mei, M. Bosman, K. Shubhakar and K.L. Pey, **IEEE IRPS**, pp. 1-6, (2018).
7. "*Nanoscale Investigations of Soft Breakdown Events in Few Layered Fluorinated Graphene*" by **A. Ranjan**, N. Raghavan, B. Liu, S.J. O' Shea, K. Shubhakar, C.S. Lai and K.L. Pey, , **IEEE IRPS**, pp. 1-6, (2017).
8. "*Recent Key Developments in Nanoscale Reliability and Failure Analysis Techniques for Advanced Nanoelectronics Devices*" by K.L. Pey, S. Mei, **A. Ranjan**, K. Shubhakar, N. Raghavan, S.J. O'Shea and M. Bosman, , **International Conference on Semiconductor Technology for Ultra-Large-Scale Integrated Circuits and Thin Film Transistors**, (2017).
9. "*Observation of Resistive Switching by Physical Analysis Techniques*" by K.L. Pey, S. Mei, **A. Ranjan**, N. Raghavan, K. Shubhakar, R. Thamankar, M. Bosman and S.J. O'Shea, **International Symposium on Next-Generation Electronics (ISNE)**, (2016).
10. "*CAFM based Spectroscopy of Stress-induced Defects in HfO_2 with Experimental Evidence of the Clustering Model and Metastable Vacancy Defect State*" by **A. Ranjan**, N. Raghavan, K. Shubhakar, R. Thamankar, J. Molina, S.J. O'Shea, M. Bosman and K.L. Pey, , **IEEE IRPS,** (2016).
11. "*Localized Random Telegraphic Noise Study in HfO_2 dielectric stacks using Scanning Tunneling Microscopy — Analysis of Process and Stress-induced Traps*" by **A. Ranjan**, K. Shubhakar, N. Raghavan, R. Thamankar, M. Bosman, S.J. O'Shea and K.L. Pey, **International Symposium on the Physical and Failure Analysis of Integrated Circuits (IPFA)**, (2015).

Book Chapter

1. **A. Ranjan**, N. Raghavan, K. Shubhakar, S.J. O'Shea and K.L. Pey, "Random Telegraph Noise Nano-Spectroscopy in High-k Dielectrics using Scanning Probe Microscopy Techniques" in book titled '***Noise in Nanoscale Semiconductor Devices***' edited by Prof. Tibor Grasser, ***Springer***, (2020).

Invited Presentations

1. **A. Ranjan,** "Advances in Applications of Conduction AFM Techniques for Gate Oxide Reliability Analysis at Nanoscale", **27th International Symposium on the Physical and Failure Analysis of Integrated Circuits**, Singapore, (2020).