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SPARC
Scheme for Promotion of Academic and Research Collaboration

SIBC
Surrey Ion-Beam Centre

UNIVERSITY OF SURREY

Scheme for Promotion of Academic and Research Collaboration
Sponsored Workshop

Semiconductors for Sustainable Technologies

12th – 13th August 2026

SEMINAR HALL

School of Physics
IISER Thiruvananthapuram

PROGRAM
TALKS AND POSTER ABSTRACTS

https://jmitra.wixsite.com/joygroup/sst-2026

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University of Surrey

Prof. Ravi Silva
Prof. Satheesh Krishnamurthy

UK INDIA ADVANCED SEMICONDUCTOR MATERIALS FORUM
for Sustainable Technologies | **University of Surrey June 2025**

Functionalising next generation 2D semiconductors for opto-electronic and catalytic applications via ion irradiation

UK: 50 participants, including 12 speakers
India: 20 participants, including 15 speakers

UK Institutes: University of Surrey, University of Cambridge, University of Swansea, National Physical Laboratory, University of Sheffield, Heriot-Watt University, University of Bristol, University of Liverpool, Foreign and Commonwealth Office.
India Institutes: IISER TVM, IIT Jodhpur, IIT Madras, IIT Ropar, National Physical Laboratory, CSIO-CSIR, IIT Delhi, NIT Durgapur, JSS Institutes, Manipal Institute of Technology, IISc, NFTDC, SRMIST, Anusandhan National Research Foundation.

Workshop Venue

Seminar Hall, School of Physics
Indian Institute of Science Education and Research Thiruvananthapuram (IISER TVM),
Maruthamala PO, Vithura, Thiruvannanthapuram – 695551, Kerala, India

Reaching IISER TVM:
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IISER TVM is about 60 km from the airport. A taxi will cost around Rs. 1800/- from the Airport to the IISER TVM campus.

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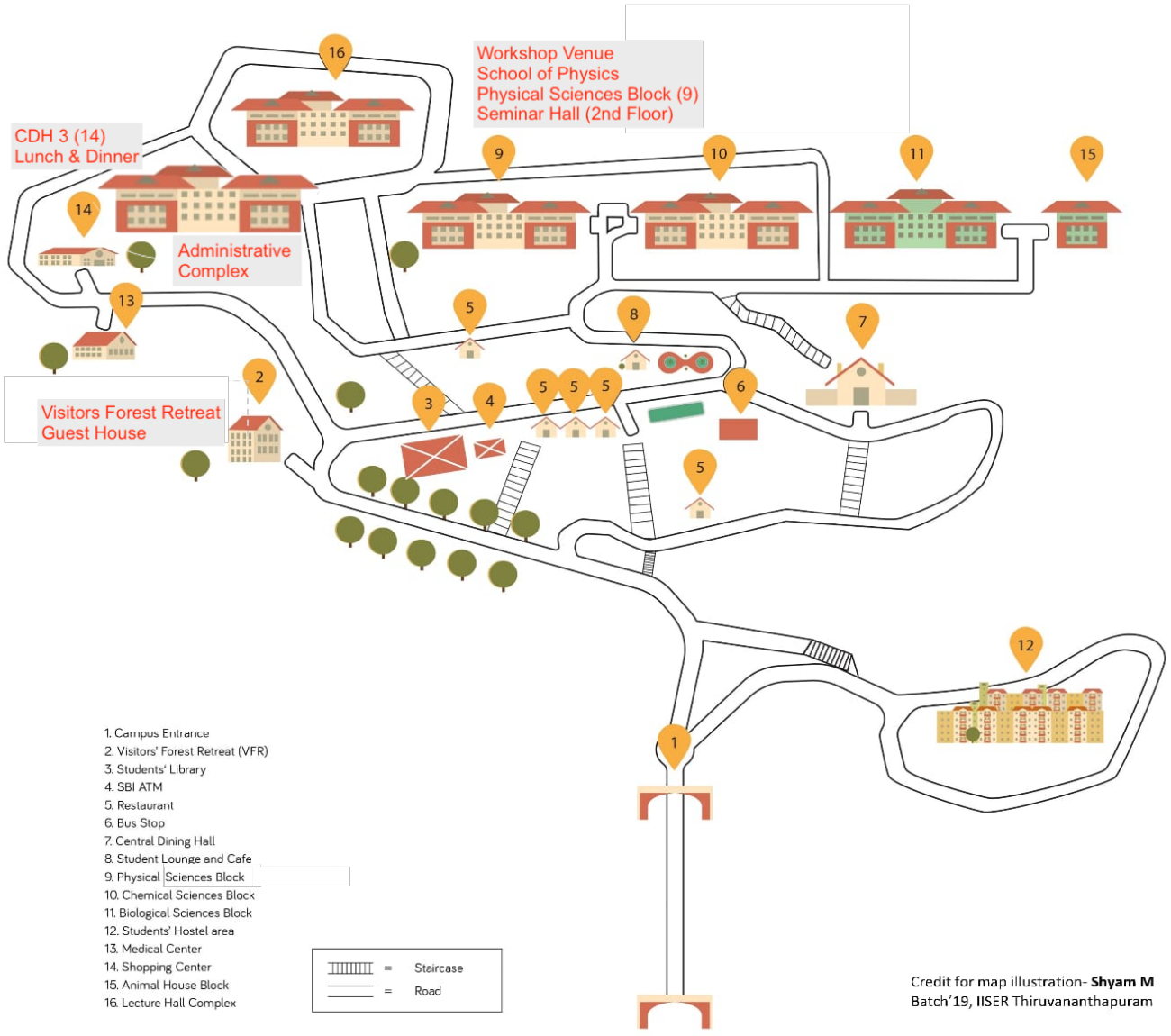

Venues:

Workshop Events	Seminar Hall and Lounge 2nd Floor, School of Physics, IISER TVM
Lunch and Dinner	Central Dining Hall 3 Shopping Complex (opposite the Health Centre), IISER TVM

Schedule

DAY 1 | Wednesday 12 August 2026	
09:15 - 9:30	Inauguration **Prof. S Murty Srinivasula (Director, IISER TVM)**

Session 1 | Chairperson: M M Shaijumon	
09:30 - 10:00	G U Kulkarni (JNCASR) **Neuromorphic Devices for Sustainable AI**
10:00 - 10:30	Ravi Silva (University of Surrey, UK) **Semiconductors for Sustainable Technologies: Building the Materials Platform for the Future**
10:30 - 11:00	Subhabrata Dhar (IIT Bombay) **Electrically Controlled Trionic Motion in WS_2 Monolayers**
11:00 -11:30	**Break**
Session 2 | Chairperson: Deepshikha Jaiswal Nagar	
11:30 - 12:00	Govind Gupta (NPL CSIR) **Discovering the potential of metal chalcogenides for innovative optoelectronic and neuromorphic devices**
12:00 - 12:30	K George Thomas (IISER TVM) **Photon Statistics in Semiconductor Nanocrystals: Unravelling Exciton and Biexciton Dynamics**
12:30 - 12:55	Suraj Soman (NIIST) **Emerging Frontiers and Innovation Pathways in Indoor Photovoltaics @CSIR NIIST**
12:55 - 14:45	**Group Photograph and Lunch Break**
Session 3 | Chairperson: Vinayak Kamble	
14:45 – 15:10	Jino George (IISER Mohali) **2D Exciton-Polaritons in Open Cavities**
15:10 - 15:35	Vijith Kalathingal (Kannur University) **Bridging Plasmonic Near-fields and Semiconductor Excitons Through Quantum Tunneling**
15:35 - 16:00	Rakhi R B (NIIST) **Engineering of Ti-Based MXenes for High-Performance Supercapacitors**
16:00 - 16:30	**Break**
Session 4 | Chairperson: Tuhin Maity	
16:30 – 16:55	Jerry Fereiro (IISER TVM) **Protein Electronics: Protein binding and orientation matter**
16:55 - 18:15	**The Bandgap Session:** Short Talks by Doctoral and Post Doctoral Fellows
19:30 - 21:00	**Dinner CDH 3**

DAY 2 | Thursday 13 August 2026	
Session 1 | Chairperson: Ravi Silva	
09:30 - 10:00	Satheesh Krishnamurthy (University of Surrey, UK) **Engineering 2D Materials and Ion-Implanted Semiconductors for Next-Generation Technologies**
10:00 -10:30	Vijaymohananan K Pillai (IISER TVM) **Impact of Two Dimensional Materials as Quantum Dots for Energy Storage**
10:30 - 10:55	Alex James (Digital University Kerala) **Two-Dimensional Materials as a Platform for Analog In-Memory Computing**
10:55- 11:25	**Break**
Session 2 | Chairperson: Satheesh Krishnamurthy	
11:25 - 11:50	Sukhendu Mandal (IISER TVM) **Atomically Precise Clusters and Cluster-Assembled Materials: From Structure to Exotic Photophysical Properties**
11:50 - 12:15	Vinayak Kamble (IISER TVM) **From Defects to Intelligence: Engineering Semiconductors for Sustainable Sensing**
12:15 - 12:40	Mainak Adhikary (IISER TVM) **Semiconductors to Smart Fields: Translating Edge-AI and IoT Technologies for Sustainable Agriculture Rovers**
12:40 - 13:00	Closing Remarks
13:00 - 14:30	**Lunch**

DAY 1 | Session 1 | 09:30

Neuromorphic Devices for Sustainable AI

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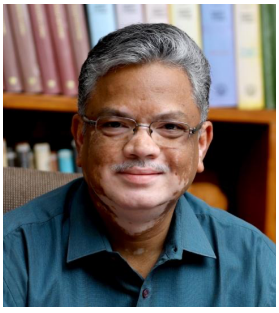
Modern computing systems, despite their remarkable speed and capabilities, remain fundamentally limited by their architecture, resulting in high power consumption. In stark contrast, the human brain achieves extraordinary cognitive feats and massive parallel processing with only about 20 W of power. This efficiency has inspired global efforts to develop artificial neural networks and neuromorphic computing platforms that emulate the brain's intelligence using advanced algorithms on high-speed computational hardware. However, even the most sophisticated computers struggle to solve complex, real-world problems in real time – tasks that biological brains routinely manage with ease. A key distinction lies in the biological synaptic junction, which seamlessly integrates processing and memory functions in parallel, a feature closely associated with neuroplasticity—the brain's ability to adapt and reorganize in response to experience. While the mechanisms linking neuroplasticity to memory and processing are still being explored, recent research increasingly focuses on replicating various forms of neuroplasticity using artificial synaptic devices. Neuromorphic computing, by mimicking neural processes, promises a paradigm shift: enabling low-power, efficient, and adaptive systems that overcome the limitations of traditional CMOS and Boolean logic architectures. The presentation will review relevant literature in the field, highlight ongoing challenges and summarize key findings. Recent results from our laboratory will also be presented.



Prof. G. U. Kulkarni obtained his Ph.D. from IISc Bangalore (1992), followed by postdoctoral research at IISc and Cardiff University. He joined JNCASR in 1995 and is a Professor in Materials Unit since 2008. He has served as Chair of the Materials Unit, Dean-Academic and Faculty Affairs, and was Director of CeNS (2015–2020) where he continues as Adjunct Professor. He served as the President of JNCASR during 2020-2025. He has held visiting positions at institutions including Cardiff, Tokyo, Trieste, Pisa, and Paris Sud, and was an Adjunct Professor at Purdue University (2009–11). With over 340 publications, he has mentored 37 students. He is a Fellow of all major Indian science and engineering academies, as well as of TWAS, RSC, and APAM, and also a J.C. Bose Fellow. Prof. Kulkarni has received several national and international recognitions. He is a recipient of Material Research Society of India Lecture medal, Sir C. V. Raman Young Scientist award, B. M. Birla Science prize in Chemistry, Dr Raja Ramanna State Award, The Prof. C.N.R. Rao National Prize for Chemical Research, Kannada Rajyotsava Award, Bangalore India Nano National award and the Innovation award and many more.

DAY 1 | Session 1 | 10:00

Semiconductors for Sustainable Technologies: Building the Materials Platform for the Future

Ravi P. Silva
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Semiconductors underpin the modern world, enabling technologies across energy, healthcare, communications, computing, mobility, defence, manufacturing and everyday life. As global demand accelerates towards trillion-dollar-scale markets, national programmes such as India's Semicon 2.0 highlight the strategic importance of building resilient semiconductor ecosystems. This talk introduces the role of advanced semiconductor materials — including organics, hybrids, perovskites, 2D materials and wide band-gap semiconductors — in driving the next generation of sustainable technologies. In addition to Moore's Law, More than Moore too is expected. Beyond Moore's Law, future progress will depend not only on miniaturisation, but also on new materials, low-power devices, scalable manufacturing, heterogeneous integration and application-specific innovation.

The Surrey – IISER Thiruvananthapuram SPARC workshop provides a timely platform to connect fundamental science with translational impact. By combining UK and India strengths in materials discovery, device physics, innovation and talent development, the partnership aims to contribute to sustainable semiconductor technologies with global relevance.

Prof. S. Ravi P. Silva CBE FREng is a Distinguished Professor and the Director of the Advanced Technology Institute at University of Surrey. The was Interim Director of the Institute for Sustainability (2025/26), a pan-university activity spearheading the university drive for research excellence in sustainability, and during his tenure the university 2026 QS Sustainability World ranking moved up close to 400 places to 113. He joined Surrey in 1995 after completing undergraduate and postgraduate degrees at Cambridge University. His research interests include nanotechnology, large-area electronics and renewables, and has resulted in over 720 presentations at conferences, and over 750 journal papers. He has over 35,000 citations with a google scholar H-index of 95, and won research funding in excess of £55M. He is the inventor of 50 patents, including key patents on low temperature growth of carbon nanotubes, fabrication of high-performance large area X-ray detectors and fabrication of large area nanotube-organic solar cells. He is a Fellow of the Royal Academy of Engineering, UK and a Fellow of the National Academy of Sciences Sri Lanka. He was made a Commander of the Order of the British Empire in the 2021 Queen's New Year Honours' list. He holds senior posts of distinction in a number of distinguished organisations including: FCAE (foreign academician) FISC FeurASc FNASSL DFIETI MAE FIET FinstP FRSA Ceng CPhys.

DAY 1 | Session 1 | 10:30

Electrically Controlled Trionic Motion in WS_2 Monolayers

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Today, information are processed through electronics, while they are communicated via photons between the processing hubs separated by long distances. Interconversion between electronics and photonics results in additional delays and unwanted losses of data and energy. A new paradigm of signal processing can be envisaged, where excitons act as information carriers. Such a framework is expected to be better compatible with the optical communication because excitons and photons are readily interchangeable. Moreover, the switching speed of excitonic devices is supposed to be faster than electronics. Orders of magnitude smaller size of excitons than the photons allows more compact device integration in excitonics than in photonics. Trions or charged excitons are the bound units of three particles; either two electrons plus one hole (negative trions) or two holes plus one electrons (positive trions). In the context of exciton based logic operations, trions have several advantages over another potential excitonic candidate, the spatially indirect excitons (SIDX), which has a finite dipole moment and hence can be driven electrically. Trions can also be driven as well as sensed electrically. Further, the population of these entities can be controlled either via chemical doping or gate biasing. Trions also have longer lifetime than the SIDX. In bulk semiconductors, binding energy is too low to stabilize trions at room temperature. However, in monolayers of transition metal dichalcogenides (TMD), such as MoS_2 and WS_2, much higher binding energy allows these charged excitons to survive even above room temperature. In addition, trions in TMD monolayers (1L) exhibit valley polarization, meaning they can preserve the valley character throughout their lifespan after selective creation in K/K' valleys by circularly polarized photons. There are in fact reports of TMD layers based excitonic devices operating at room temperature. However, in most of the cases, SIDX formed at the TMD hetero-interfaces are utilized as carriers. Trion based excitonic devices have rarely been reported.

Here, we investigate the origin of the patterned variation of photoluminescence (PL) intensity in truncated hexagonal 1L-WS2 islands grown by chemical vapor deposition technique. High and low PL-intensity regions are found to be populated with shallow donors (or hole traps) and acceptors (or electron traps), respectively. These defects facilitate the formation of trions that dictate the luminescence characteristics of the two regions at room temperature. The study also demonstrates that in the low PL-intensity areas, the rate of nonradiative recombination of trions is much higher than that in the brighter areas. The polarity of the trions, which is determined by the PL-microscopy carried out on the two PL-intensity zones under horizontal electric fields, is found to be negative in the brighter zones and positive in the darker areas. The study also demonstrates several hundreds of nm drift of the trions in both the zones at room temperature.

After receiving the PhD degree in physics from Jawaharlal Nehru University, New-Delhi, India in 2001, Subhabrata Dhar has spent several years as a scientist in Paul-Drude-Institute, Berlin, Germany and later in the university of Duisburg-Essen, Duisburg, Germany under the Marie-Curie excellence grant before joining the faculty of physics, Indian institute of technology Bombay in 2006. Currently, he is serving as a professor and the head of the department of physics in the institute. His research interest includes semiconductor epitaxial layers, nanostructures, 2D semiconductors, transport and excitons in semiconductors. Prof. Dhar has multiple patents. He has authored more than 130 publications in various reputed peer reviewed journals as well as several book/book chapters. 16 PhD and 5 M. Tech students have graduated under his supervision.

DAY 1 | Session 2 | 11:30

Discovering the Potential of Metal Chalcogenides for Innovative Optoelectronic and Neuromorphic Devices

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Academy of Scientific & Innovative Research (AcSIR), CSIR-HRDC Campus
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Metal chalcogenides are at the forefront of advancements in optoelectronics, sensing, and various other applications due to their exceptional properties. In this work, we leverage material engineering in these metal chalcogenides to develop state-of-the-art bipolar broadband optoelectronic devices. Strain engineering in two-dimensional semiconductors enables precise control of their electronic and optical properties. However, the impact of stacking orientation on the intrinsic strain landscape in bilayer transition-metal dichalcogenides (TMDCs) has not been thoroughly investigated. By optimizing the stacking geometry in chemical vapor deposition (CVD)-grown bilayer MoS_2, we establish a clear link between structure, strain, and material properties. Additionally, we introduce a scalable and versatile neuromorphic device made from monolayer MoS_2 , engineered to perform exceptionally well at temperatures up to 100 °C. This device stands out for its exceptional electrical performance, featuring ultra-low power consumption, rapid switching, and impressive endurance. Most importantly, it exhibits remarkable neuromorphic behavior, effectively mimicking synaptic plasticity and demonstrating the dynamic learning capabilities of biological neural networks.

Dr. Govind Gupta is the Chief Scientist and Head of the Sensor Devices and Metrology Group at CSIR-National Physical Laboratory (NPL), New Delhi, where he also serves as a Professor at the Academy of Scientific and Innovative Research. His research centres on the design and fabrication of semiconducting materials, including thin films, nanostructures, and heterostructures based on nitrides, oxides, and two-dimensional materials, with a particular focus on developing intelligent, highly responsive sensors for detecting harmful electromagnetic radiation and environmental pollutant gases. He has published over 400 articles in reputed journals, authored 12 books and book chapters, and holds a patent, reflecting a substantial and sustained contribution to materials science and sensor technology. Dr. Gupta holds fellowships from several leading scientific societies, including the Royal Society of Chemistry (FRSC), the Institute of Physics (FinstP), the Institute of Electronics and Telecommunication Engineers (FIETE), and the Electron Microscopy Society of India (FEMSI). His accolades include the Distinguished Lectureship Award from the Materials Research Society of India (MRSI), the MRSI Medal, the IETE-CEOT Award, the Young Scientist Medal from the National Academy of Sciences, India (NASI), the BOYSCAST Fellowship from the Government of India, and the Yusuf Hamied International Exchange Fellowship from the Royal Society. He has held visiting scientist positions at prestigious institutions, including Cambridge University (UK), Rutgers University (USA), and Humboldt University (Germany).

DAY 1 | Session 2 | 12:00

Photon Statistics in Semiconductor Nanocrystals: Unravelling Exciton and Biexciton Dynamics

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Semiconductor nanocrystals provide an attractive platform for investigating exciton and biexciton dynamics, as well as the charge delocalization behavior of photogenerated carriers. A few selected recent contributions from our group in this area are listed in References 1–10. Herein, I present three unpublished results demonstrating how excitation energy,[11] doping,[12] and plasmonic fields[13] can be employed to engineer the photon statistics of CdSe nanoplatelets. The first part of the presentation will discuss the effect of excitation energy on biexciton dynamics in CdSe-based nanoplatelets (NPLs), investigated using ensemble and time-resolved single-particle spectroscopy. By varying the excitation energy from 3.1 eV to 2.1 eV, the biexciton-to-single-exciton quantum yield increases from 36% to 75%. These results indicate that the non-radiative Auger recombination process is largely independent of the excitation energy. In the second part, I will describe the influence of plasmonic fields on the photoluminescence (PL) properties of CdSe NPLs coupled to Au nanofilms, achieved by precisely controlling the separation distance between the two components. I will further discuss how plasmonic coupling modifies PL lifetimes associated with first- and second-exciton recombination in a cascade two-photon emission process. The third part of the presentation focuses on the impact of Ag^+ ion doping on the PL dynamics of CdSe NPLs. In addition to the sharp band-edge emission of CdSe NPLs, doping with 1 atom% Ag^+ introduces a broad, red-shifted emission. The observed anticorrelated switching between the band-edge and dopant-mediated emission channels suggests a dynamic exchange between these two recombination pathways.

[1] E. K. Vishnu et al., Journal of Physical Chemistry C, 125, 25706-25716 (2021). [2] E. M. Thomas et al., Physical Chemistry Chemical Physics, 24, 17250-17262 (2022) [3] E M. Thomas et al., ACS Energy Letters, 7, 2856-2863 (2022) [4] A. Garai et al., Journal of the American Chemical Society, 145, 13989−13999 (2023). [5] E. K. Vishnu et al., Journal of Physical Chemistry C, 128, 4373-4382 (2024). [6] M. P. Varghese et al., Journal of Physical Chemistry C, 128, 10945–10954 (2024). [7] S. Bera et al., Journal of the American Chemical Society, 146, 20300−20311 (2024). [8] T. Titus E. K. Vishnu, et al., Nano Letters, 24, 10434-10442 (2024). [9] L. Paul et al., Chemical Science, 15, 20263-20273 (2024). [10] D. Rajan et al., ACS Energy Letters, 10, 3700-3728 (2025). [11] T. Titus et al., (under publication) [12] M. P Varghese, K. Sandeep et al., (under publication). [13] Livin Paul, K. Sandeep et al., (under publication).

George Thomas, Emeritus Professor (since June 2026) at the School of Chemistry, IISER Thiruvananthapuram, has made substantial contributions to the field of photosciences. He received his PhD in Chemistry from the University of Kerala and subsequently worked as a Senior Scientist in the Photosciences and Photonics Section of the CSIR–National Institute for Interdisciplinary Science and Technology from July 1994 to April 2010. In May 2010, he accepted an invitation from the newly established Indian Institute of Science Education and Research (IISER) Thiruvananthapuram and joined as a Professor. His academic contributions extend beyond his institution, as reflected in his tenure as President of the Asian and Oceanian Photochemistry Association (APA) from 2019 to 2021. He is the recipient of several awards and distinctions, most notably the J. C. Bose National Fellowship (2014–2024) and the Shanti Swarup Bhatnagar Prize in Chemical Sciences (2006). He is an elected Fellow of the Indian National Science Academy, New Delhi (2015), and the Indian Academy of Sciences, Bengaluru (2007). Under his mentorship, thirty-three scholars have completed their doctoral degrees, many of whom now hold esteemed faculty positions in leading universities in India and abroad.

DAY 1 | Session 3 | 12:30

Emerging Frontiers and Innovation Pathways in Indoor Photovoltaics @CSIR-NIIST

Suraj Soman
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In the realm of third-generation molecular light-harvesting technologies, at CSIR-NIIST, our research focuses on dye-sensitized solar cells (DSCs) and perovskite solar cells (PSCs), with the objective of developing high-efficiency, stable, and scalable photovoltaic systems for emerging applications such as self-powered Internet of Things (IoT), flexible electronics, underwater photovoltaics and space technologies. DSCs stands out for their high efficiency, exceeding 40%, and their suitability for indoor use due to their lower cost, stability and ease of production.1-2 Recent innovations from our team, such as co-sensitization approach, introduction of dual-species copper-based electrolytes replacing traditional iodide systems, use of bilayer TiO2-ZnO nanostructured electrodes, have addressed recombination issues, enhancing performance of these innovative nano-photovoltaic devices under indoor and ambient lighting conditions.1-4 In parallel, perovskite solar cells have revolutionized the photovoltaic landscape, achieving certified power conversion efficiencies exceeding 25% within just over a decade of development. At CSIR-NIIST, our efforts are directed toward advancing stable, flexible, and scalable perovskite photovoltaics, with particular emphasis on indigenous materials, device architectures, and fabrication methodologies.

My presentation will highlight CSIR-NIIST's pursuit of self-reliance in indoor light-harvesting technologies underscored by advancements in the domain of DSCs and PSCs and the lab to land transition being realized developing indigenous scale-up production equipment's and innovative self-powered products at CSIR-NIIST. By nurturing capabilities, CSIR-NIIST strives to establish a formidable position in the global indoor photovoltaic landscape, and propelling India towards self-sufficiency in emerging photovoltaic sectors.

[1] Journal of Materials Chemistry A, 2024, 12, 32721-32734
[2] Journal of Materials Chemistry A, 12, 2024, 1081-1093.
[3] Journal of Materials Chemistry A, 11, 2023, 14748-14759.
[4] Journal of Materials Chemistry A, 6, 2018, 22204.

Dr. Suraj received his Ph.D. from Dublin City University, Ireland, and pursued postdoctoral research at Caltech, USA and Michigan State University, USA. He joined CSIR-NIIST in 2014 and currently serves as a Scientist-E (Principal Scientist) at the Centre for Sustainable Energy Technologies (C-SET). His research focuses on the indigenous development of indoor solar cells using third-generation molecular light-harvesting technologies such as dye-sensitized and perovskite solar cells, aiming to replace one-time use primary batteries realizing self-powered gadgets. Dr. Suraj established a state-of-the-art Molecular Photovoltaic Laboratory at CSIR-NIIST, where he has successfully managed research funding of more than ₹25 crores since 2014. He has published over 65 research papers, with an h-index of 26, and has contributed two book chapters and five patents. Dr. Suraj is a recipient of several prestigious awards, including the Solar Challenge Award (2023), CSIR Young Scientist Award (2020), INSA Medal for Young Scientist (2020), Kerala State Young Scientist Award (2018) and BRICS Young Scientist Award (2017).

DAY 1 | Session 3 | 14:45

2D Exciton-Polaritons in Open Cavities

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Strong light-matter coupling in molecular systems is very intriguing. [1-3] For example, half-photon-half-exciton states can be generated at room temperature using atomic monolayers. These states show delocalisation of a cavity photon and excitons through the so-called photonic degree of freedom. The photoluminescence of polaritonic states can be fine-tuned by varying the photon-exciton mixing fractions.[4] We recently studied these systems in an open cavity configuration and generated clean data that are quantised in polarisation, momentum, and energy.[5] Further, we used spatially separated donor-acceptor pairs to test long-range energy transfer in strong coupled system.[6, 7] We are now exploring optical spin-orbit interaction in 2D exciton open cavities.[8] During the talk, I will introduce the concept of strong coupling in 2D materials and show some of its exotic signatures.

1) K. Kaur, J. Dutta, J. George, *J. Chem. Phys.* **2025**, *163*, 050902.
2) J. George, J. Singh, *ACS Catal.* **2023**, *13*, 2631-2636.
3) F. J. Garcia-Vidal, C. Ciuti, T. W. Ebbesen, *Science* **2021**, *373*, eabd0336.
4) J. Dutta, N. Yadav, B. Johns, J. George, *Adv. Opt. Mater.* **2025**, *13*, e02324.
5) B. Johns, N. Yadav, A. Vinod, K. Kaur, J. George, *Adv. Opt. Mater.* **2026**, *14*, e02143.
6) P. Bhatt, J. Dutta, K. Kaur, J. George, *Nano Lett.* **2023**, *23*, 5004-5011.
7) J. Dutta, N. Yadav, P. Bhatt, K. Kaur, D. E. Gómez, J. George, *J. Phys. Chem. Lett.* **2024**, 8211-8217. K. Banerjee, B. Johns, N. Yadav, Anil Shaji, J. George, **2026** [*Manuscript under preparation*].

Dr Jino George is an experimental physical chemist by training. He received his PhD in "chiral plasmonics" (2012) from CSIR-NIIST Thiruvananthapuram (Prof. George Thomas Group). Later, he had a short stint as a visiting research fellow in Hsinchu, Taiwan (Prof. Hiroshi Masuhara Group). Subsequently, he spent five years at the University of Strasbourg, France, as a post-doctoral fellow (Prof. Thomas Ebbesen Group). In Strasbourg, he studied the effect of strong light-matter interaction on the chemical and physical properties of molecules and materials. In 2017, he joined IISER Mohali as a faculty member in the Department of Chemical Sciences, and his research focuses on understanding the properties of hybrid light-matter states and their application to controlling chemical reaction rates. At IISER Mohali, he independently developed the idea of cavity catalysis, that a chemical reaction can be precisely controlled (bond-selectively) at the molecular level through vibrational strong coupling. He is also interested in studying the fundamentals of transport behaviour of light-matter states, known as polaritronics. He handles projects to integrate photons with functional materials and develop next-generation optoelectronics and photonics devices.

DAY 1 | Session 3 | 15:10

Bridging Plasmonic Near-fields and Semiconductor Excitons Through Quantum Tunneling

Vijith Kalathingal
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The active optical responses of semiconducting transition-metal dichalcogenides (TMDs) are dominated by excitons at room temperature, making these materials a promising platform for investigating strong exciton–photon coupling. Plasmon–exciton interactions in van der Waals (vdW)–metal hybrid systems offer various nonlinear optical functionalities [1,2], enabling responses beyond those achievable with standalone passive plasmonic components. Here, we explore the energy exchange between plasmonic modes and excitonic states by investigating a noble-metal–TMD–graphene tunnel junction.

In plasmonic near fields, large-wave-vector contributions dominate the energy-exchange processes, in contrast to the near-zero momentum transfer associated with far-field optical illumination [1]. Inelastic electron 14unnelling (IET)-mediated near-field excitation of high-momentum excitonic states in van der Waals heterostructures can induce nonvertical interband transitions and thereby contribute to electron–hole (e–h) generation in two-dimensional materials. The IET process may be viewed as an effective dipole source localized within the 14unnelling region, capable of exciting the electromagnetic modes supported by the junction. IET therefore provides direct access to the near-field excitation of high-momentum excitonic states and offers a versatile platform for investigating energy-transfer processes between plasmonic modes and excitonic states. The energy-transfer rate from the IET-induced dipole to the TMD–graphene heterostructure is proportional to the power dissipated by the dipole. This study investigates various aspects of the charge- and energy-transfer processes associated with plasmon–exciton interactions in the near-field regime. These findings highlight IET-driven near-field excitation as a powerful approach for probing and controlling plasmon–exciton energy transfer in vdW heterostructures, with potential applications in nanoscale optoelectronics and active quantum photonic devices.

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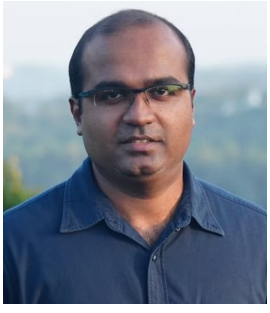

Dr. Vijith Kalathingal is an Assistant Professor in the Department of Physics at Kannur University, Kerala, India. He received his Ph.D. from the Indian Institute of Science Education and Research (IISER) Thiruvananthapuram in 2017, where his doctoral research focused on light emission from nanoscale plasmonic tunnel junctions. He then moved to National University of Singapore for his postdoctoral research (2018-2023) on electrically driven plasmonic components for high-speed electronics. His research interests span plasmonics, nanophotonics, quantum tunnelling devices, van der Waals materials, nonlinear plasmonics, and plasmonic–2D material hybrid systems. His work has resulted in publications in leading journals including Nature Nanotechnology, Light: Science & Applications, Advanced Science, ACS Nano, and Physical Review B, along with multiple patent applications in plasmonic and optoelectronic technologies. Dr. Kalathingal is currently the Principal Investigator of an ANRF–Prime Minister Early Career Research Grant, investigating quantum tunnelling devices for polaritonics.

DAY 1 | Session 3 | 15:35

Engineering of Ti-Based Mxenes for High-Performance Supercapacitors

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Two-dimensional Ti-based Mxenes, particularly Ti_2CT_x and $Ti_3C_2T_x$, are promising electrode materials for advanced energy storage owing to their high electrical conductivity, layered structure, and tunable surface chemistry. This presentation focuses on strategies to enhance the electrochemical performance of Ti-based Mxenes for supercapacitor applications. Controlled thermal treatments were employed to tailor surface terminations and improve charge-storage behavior. Further enhancement was achieved by integrating Mxenes with transition-metal oxides (MnO_2, CuO and Fe_3O_4) and conducting polymers (polyaniline and polypyrrole), which effectively reduced layer restacking and introduced additional redox-active sites. The resulting hybrid electrodes exhibited improved capacitance, energy density, and cycling stability compared with pristine Mxenes. The practical applicability of these materials was demonstrated through screen-printed micro-supercapacitors with high areal capacitance, flexibility, and stable long-term operation. Overall, the work highlights Mxene-based hybrid architectures as promising electrode platforms for next-generation supercapacitors and compact energy-storage devices.

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3. AS Pillai, SM Varghese, RB Rakhi, SK Peethambharan, (2024) Chemical Engineering Journal 495, 153495
4. SM Varghese, AS Pillai, SK Peethambharan, RB Rakhi (2026) Journal of Materials Chemistry A 14 (17), 10159-10177

Dr. Rakhi R.B. is currently a Scientist-F at the Centre for Sustainable Energy Technologies of CSIR–NIIST. She completed her MSc in Physics with first rank from University of Kerala in 2000. She received her Ph.D. in Physics with the best thesis award, from the Indian Institute of Technology Madras (IITM), Chennai in July 2009. She completed her postdoctoral research training from King Abdullah University of Science and Technology (KAUST), Kingdom of Saudi Arabia. Prior to joining CSIR-NIIST, she worked as a UGC-Assistant Professor (June 2019 – August 2021) at the Department of Physics, University of Kerala. Dr. Rakhi is the recipient of the Ramanujan fellowship in 2016, International SABIC Postdoctoral Fellowship Award consecutively for 2013 and 2014, MRSI medal in 2024, Woman Achiever in Science Award in 2025. Her name is included in the compendium on CSIR Women Achievers in STEM released in 2023. Her name has been included in the list of top 2% scientists published by Elsevier, based on the study conducted by Stanford University consecutively for the last seven years (2019, 2020, 2021, 2022, 2023, 2024 and 2025). She has published more than 100 articles in international peer reviewed journals with more than 10500 citations and has an h-index of 48. Her current research interests include functional nanomaterials, nanocomposites, layered materials, nanotechnology-enabled energy storage devices (supercapacitors and hybrid devices), electrocatalysis, and electrochemical sensors.

DAY 1 | Session 4 | 16:30

Protein Electronics: Protein Binding and Orientation Matter

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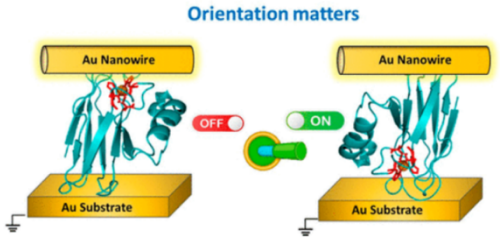
Molecules have been proposed to act as the building blocks for the ultimate level of device miniaturization[1,2]. Among different functional possibilities of using molecules as part of electronic circuits, molecular diodes are the most important ones since they play a central role in assembling higher-order electronic components[3]. A molecular rectifier must include an asymmetric feature along the charge transport direction[4]. A necessary condition for that is observing the direction of rectification is switched upon reversing the orientation of the molecular components within the device, while maintaining the same electrode orientation, i.e., current rectification should depend upon molecular orientation and not on the device structure[4]. Here we show bias-induced switching of conductance via a blue copper protein azurin mutant, N42C Az, with a nearly 25-fold increase at |V| > 0.8 V than at lower bias. No such switching is found for wild-type azurin, WT Az up to |1.2 V|, beyond which irreversible changes occur. The N42C Az mutant will, when positioned between electrodes in a solid-state Au-protein-Au junction, have an orientation opposite to that of WT Az with respect to the electrodes. Current(s) via both proteins are temperature independent, consistent with quantum mechanical tunnelling as dominant transport mechanism. No noticeable difference is resolved between the two proteins in conductance and inelastic electron tunnelling spectra at < |0.5 V| bias voltages. Switching behaviour persists from 15 K up to room temperature. Our results indicate the key roles that protein's orientation and binding nature to the electrodes play in determining the electron transport tunnel barrier.



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Dr. Jerry Alfred Fereiro is an Assistant Professor in the School of Chemistry, IISER Thiruvananthapuram. He received his Ph.D. from the University of Alberta, Canada, followed by postdoctoral research at the Weizmann Institute of Science, Israel, and the Technical University of Munich (TUM), Germany. His research interests include biomolecular electronics, molecular charge transport, and biohybrid electronic materials.

DAY 2 | Session 1 | 09:30

Engineering 2D Materials and Ion-Implanted Semiconductors for Next-Generation Technologies

Satheesh Krishnamurthy
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As conventional silicon technology approaches physical and thermodynamic scaling limits, the development of next-generation electronic, optoelectronic, and energy devices relies heavily on atomic-scale material engineering. Low-dimensional nanomaterials such as two-dimensional (2D) transition metal dichalcogenides (TMDs), Mxenes, and borophene offer unparalleled electro-optical, chemical, and mechanical properties. However, realising their full technological potential requires precise control over electronic band structures, point defects, and surface functionalization. This work outlines advanced strategies for tailoring low-dimensional nanomaterials and wide-bandgap semiconductors using state-of-the-art ion implantation and ion-beam processing. By leveraging controlled ion bombardment and post-annealing regimes, we demonstrate deterministic defect complex engineering and carrier activation in challenging semiconductor matrices, including diamond. Furthermore, we showcase how surface engineering, metallic/non-metallic doping, and defect architecture in 2D systems modulate interfacial charge transport, catalytic reactivity, and ion diffusion pathways. These integrated processing techniques provide a robust framework for designing scalable, high-performance materials for application in next-generation microelectronics, quantum materials, energy storage systems, and environmental wastewater treatment and sensing platforms. Particular emphasis will also be placed on the opportunities and challenges in moving from single-ion-precision laboratory demonstrations to manufacturable, defect-engineered platforms for next-generation electronic and quantum materials, and on the value of international collaboration between the UK and India, in particular, in accelerating this translation.

Prof. Satheesh Krishnamurthy FRSC FIMMM is Director of the UK National Ion Beam Centre at the University of Surrey and a leading voice at the intersection of materials science, semiconductor physics, and advanced nanotechnology. His research spans two-dimensional materials (including Mxenes), wide-bandgap semiconductors, single-ion implantation, and defect engineering using EPR/ODMR techniques tailored for quantum technologies and high-performance electronic device and catalytic systems. He is passionate in bridging fundamental surface characterisation with scalable device translation, Prof. Krishnamurthy has secured over £40 million in research funding as Principal or Co-Investigator, authored more than 120 peer-reviewed publications cited over 15,000 times, and received the UK-India Research Excellence Award in 2017. He brings a wide-ranging, cross-institutional perspective to conversations on global semiconductor innovation, cross-border research collaboration, and the commercialisation of nanoscale technologies. Under his leadership, the National Ion Beam Centre hosts more than 45 companies working across photonics, III-V semiconductors, quantum technologies, and a broad range of ion beam analysis applications, and serves researchers from over 40 UK universities each year. Over the past five years, the Centre has underpinned more than £150 million in EPSRC-funded research across UK institutions.

DAY 2 | Session 1 | 10:00

Impact of Two Dimensional (2D) Materials as Quantum Dots for Energy Storage

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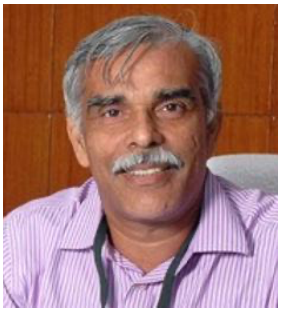
Preparation of different types of materials (monolayers to monolayer protected nanoclusters, nanowires and eventually polymer-nanocomposites) blending the synthetic skills of a Chemist with atomic molecular level characterization tools of condensed matter physicist is important for electrochemical storage of energy. We have been working on diverse type of materials including zero dimensional (quantum dots), one dimensional (Carbon nanotubes), and two dimensional (e.g., phosphorine) systems and their composites tailored for energy storage applications emphasising on their size/shape dependent properties. For example, most of the Two Dimensional materials have a finite van der Waals gap (v-gap) in between the layers which provides a clear separation between the in-plane and through plane electronic interactions. Although the carrier transport and associated unique features are studied in accurately prepared and precisely characterized monolayers, many applications use multilayers which are conveniently prepared using inexpensive and scalable chemical methods. For example, among various two-dimensional (2D) materials, graphene possesses similar interlayer spacing of multiwalled carbon nanotubes (0.32−0.35 nm) which could be modulated by several strategies such as the intercalation of cations and anions, the nature of the solvent, and surface functionalization. The resultant graphene nanoribbons (~40 nm diameter) formed by the ionic liquid-assisted transformation of multiwalled carbon nanotubes of an average diameter (~21 nm) along with graphene quantum dots having an emission wavelength of 445 nm are more useful for some of the specific applications. The tunability of this spacing depends on the nature of the ionic liquid, the size of the incoming ions, the applied potential, and the time. In this lecture several examples of electrochemically prepared 2D materials, their heteroatom doping and surface modification possibility will be discussed using both elemental and compound 2D quantum dots like Graphene, Phosphorene, carbon nitride, Molybdenum Sulphide, Bismuthene and graphitic- carbon nitride for specific applications like electrocatalysis and battery storage.



Prof. Vijayamohanan K. Pillai is a leading Indian electrochemist with over four decades of research and institutional leadership. He earned his B.Sc. from Fatima Mata National College, Kollam (1980), M.Sc. from University College, Thiruvananthapuram (1982), and Ph.D. from IISc Bangalore (1989), followed by nearly two decades at CSIR-National Chemical Laboratory, Pune. He has authored over 285 publications and 28 patents, advised around 28 Ph.D. students, and authored two books, including the recent "Multi-functional Electrocatalysis" (RSC, 2025). His research spans materials electrochemistry, nanostructured electrocatalysts for fuel cells, and 2D materials for energy storage. His honours include Fellowships of the Indian Academy of Sciences (2008) and the Indian National Science Academy (2018), the CRSI Silver Medal (2020), and numerous endowment lectures and awards across Indian universities and scientific societies. He has lectured widely across the US, Europe, and Asia. Prof. Pillai served as Director of CSIR-CECRI (2012–2018), with additional charge at CSIR-NCL, Pune (2015–2016). After joining IISER Tirupati in 2019, he became a J.C. Bose Fellow (2020) and received the CRS Lifetime Achievement Award (2025).

DAY 2 | Session 1 | 10:30

Two-Dimensional Materials as a Platform for Analog In-Memory Computing

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Machine learning's energy budget is dominated by moving data between memory and processors. Analog in-memory computing removes this bottleneck by mapping synaptic weights to memristor conductances in crossbar arrays, where Ohm's and Kirchhoff's laws perform a matrix–vector multiplication in a single step. Two-dimensional materials are especially well suited to this approach. In layered MoS_2, hexagonal boron nitride, and metal phosphorus trichalcogenides, switching arises from identifiable atomic-scale mechanisms: vacancies, substitutional atoms, intercalated metal ions, or ferroelectric dipoles. Because these processes occur within crystals only a few layers thick, devices can offer sub-nanometre active volumes, femtojoule switching, and gradual conductance modulation. Van der Waals interfaces also enable layer-by-layer integration of switching media, selectors, and electrodes, followed by low-temperature transfer onto finished CMOS. This talk surveys the device families available and their roles in crossbars: non-volatile filamentary cells for weight storage; interfacial and Schottky-barrier devices for linear, symmetric updates; ferroelectric tunnel junctions and FeFETs for low-current, multilevel retention; volatile threshold and diffusive switches for selectors and integrate-and-fire neurons; and gate-tunable memtransistors that separate reading from writing. Network architectures impose distinct requirements. Fully connected and convolutional networks prioritize linearity and uniformity; recurrent and LSTM networks demand endurance and dedicated multiplier and activation circuits; spiking, hierarchical-temporal-memory, and reservoir networks can exploit stochasticity and volatility; and associative memories benefit from native crossbar search. From a systems perspective, usable resolution—not nominal analog behavior—sets accuracy and may require multiple devices per node. On-chip learning demands co-designed analog backpropagation. Variability, wire resistance, sneak paths, and converter overhead must be treated as primary design parameters. The most compelling target is milliwatt-scale edge inference, near sensors, where low power, modest precision, and error tolerance matter more than peak throughput. Remaining challenges include wafer-scale growth, defect control, array-level yield, and hardware-aware training that models atomic stochasticity instead of treating it as failure.

Prof. Alex James is a Professor of AI Hardware and Controller of Examinations at Digital University Kerala. He earned his PhD from the Queensland Micro and Nanotechnology Centre, Griffith University, Australia, completed in a swift two years. Over the years, he has held multiple administrative roles, including Dean (Academics), Dean (External Linkages and Projects), Associate Dean (Research), and Department Chair.His research centres on analog memristive computing, translating applied innovations into prototypes and products. He heads Maker Village, one of India's largest hardware incubators with over 80 startups, along with the Centre for Excellence in Intelligent IoT Sensors and the India Innovation Centre for Graphene. He is a founding board member of India's first Digital Science Park and has spun out several startups from his research group, alongside publishing over 250 papers and teaching more than 60 courses in chip design and AI. His honours include the IEEE Kerala Section Best Researcher Award (2022), the Kairali Gaveshana Puraskaram (2022), the 2024 IEEE TCAS Guillemin-Cauer Best Paper Award, and the Dr. Satyajit Chakraborty Memorial Research Award (2026). He was the founding chair of IEEE CASS Kerala, which won back-to-back Chapter-of-the-Year awards (2023, 2024), and currently serves as an IEEE CASS Board of Governors Member-at-Large (2026–28), Associate Editor-in-Chief of IEEE Open Journal of Circuits and Systems, and a Senior Fellow of IET, BCS, and HEA.

DAY 2 | Session 2 | 11:25

Atomically Precise Clusters and Cluster-Assembled Materials: From Structure to Exotic Photophysical Properties

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Atomically precise metal nanoclusters (NCs) are an emerging class of materials comprising tens to hundreds of metal atoms. These clusters exhibit unique structures, high stability, and remarkable properties. Following the extensive study of Au NCs, recent research has increasingly focused on Ag and Cu NCs. However, synthesising and characterising them pose challenges due to the high reactivity of their zero-valent states.[1] To address these challenges, we have designed an innovative synthesis strategy for assembling the Ag NCs, which will be discussed in detail. In the assembled structures, the NCs exhibit unique photophysical and electronic properties, establishing atomic-level structure-property correlations (Fig 1).[2-4]

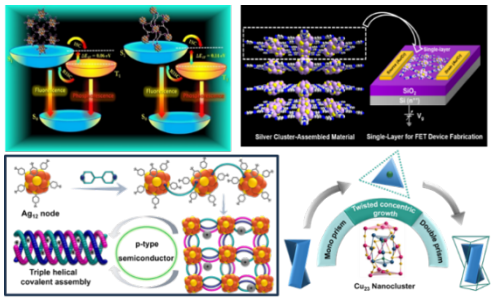

Fig 1 Structural illustration of the newly synthesized cluster assembly.

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Sukhendu received his Doctoral degree from the Solid State and Structural Chemistry Unit, Indian Institute of Science, Bangalore, India, in 2007, and was a post-doctoral research scholar at The Pennsylvania State University, USA, from 2008 to 2012. He joined the Indian Institute of Science Education and Research Thiruvananthapuram (IISER TVM), Kerala, India, in 2012 as an Assistant Professor in the Department of Chemistry. Currently, he is a professor. His primary research interest is in atom-precise metal nanoclusters and metal-organic frameworks, exploring their photophysical and chemical properties with an emphasis on energy and the environment. He has published more than 140 papers in international peer-reviewed journals and contributed to 5 book chapters. He is the recipient of the CRSI Bronze medal in 2021 and was inducted as a Fellow of the Royal Society of Chemistry through the leader in the field in 2021. He was inducted as an Associate Fellow of the Indian National Science Academy, New Delhi, India, in 2024.

DAY 2 | Session 2 | 11:50

From Defects to Intelligence: Engineering Semiconductors for Sustainable Sensing

Vinayak Kamble
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Semiconducting materials offer a powerful platform for developing sustainable sensing technologies, where defects, interfaces, and charge transport govern device functionality. This talk explores our efforts to engineer semiconductor materials and heterostructures for sensitive, selective, and energy-efficient sensing. We demonstrate how defect and interface engineering can tailor electronic transport and surface interactions in metal oxides, two-dimensional materials, and hybrid structures, enabling room-temperature chemical sensing and multifunctional devices. By integrating sensor arrays with machine learning, we move from conventional detection toward intelligent identification and quantification.

Dr. Vinayak B. Kamble is an Associate Professor at the School of Physics, IISER Thiruvananthapuram and leads the Smart Materials & Sensors Research Group (SMaRT Lab). His research focuses on semiconductor materials, electronic transport, chemical sensors, thermoelectric devices, and intelligent sensing. He has received several accolades for his research and academic contributions and is a member of the Indian National Young Academy of Sciences (INYAS) and the National Academy of Sciences, India (NASI).

DAY 2 | Session 2 | 12:15

Semiconductors to Smart Fields: Translating Edge-AI and IoT Technologies for Sustainable Agriculture Rovers

Mainak Adhikari
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The convergence of semiconductor technologies, Edge Artificial Intelligence, and the Internet of Things is creating new opportunities for sustainable and intelligent agriculture. This presentation explores how advances in semiconductor-based sensing, processing, communication, and AI acceleration can be translated from laboratory research into field-deployable autonomous agricultural systems. The proposed approach integrates energy-efficient edge processors, multimodal sensors, IoT connectivity, and on-device AI to enable agriculture rovers to perform real-time crop monitoring, soil assessment, and disease detection, and environmental sensing without relying continuously on cloud infrastructure. Edge computing reduces communication latency, bandwidth requirements, and energy consumption while enabling faster and more privacy-aware decision-making at the field level. The presentation further highlights the role of translation research in transforming semiconductor and AI innovations into affordable, scalable, and robust agricultural solutions suitable for diverse Indian farming environments. By connecting silicon-level innovation with soil-level impact, the work demonstrates how semiconductor-enabled Edge AI can contribute to precision agriculture, resource optimization, and water usage, and ultimately a more sustainable and technology-driven agricultural ecosystems.

Dr. Mainak Adhikari is an Assistant Professor in the School of Data Science at the Indian Institute of Science Education and Research Thiruvananthapuram (IISER TVM). He received his Ph.D. from IIT (ISM) Dhanbad and has research experience in distributed systems, edge/fog computing, IoT, distributed and federated learning, Edge AI, TinyML, and AI-enabled 5G/6G networks. His research focuses on translating emerging AI, and edge-computing technologies into real-world applications, including smart agriculture, autonomous systems, and intelligent IoT. He leads research on decentralized intelligence and resource-efficient AI systems for sustainable and field-deployable technologies. He has received several recognitions and research grants, including the ANRF, DBT, ISRO, significant funding from the Department of Telecommunications/Telecom Centres of Excellence, and recognition as a World Top 2% Scientist in 2022, 2023, and 2024. He is a Senior Member of IEEE and INAE and serves on the editorial boards of several IEEE journals.

DAY 1 | Session 4 | 16:50

The Bandgap Session

T1: Tunnel-rate controlled local heat distribution in mesoscopic circuits

Parvathy Gireesan
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Solid-state quantum technologies including qubits and quantum metrology circuits demand milli-Kelvin operation. While the negligible electron-phonon coupling is the major impediment, reaching ~50 mK electron temperature within mesoscopic circuits realised on two-dimensional electron gas (2DEG) in semiconductor heterostructures is further suffered by the high electrical resistance and sub-micron-scale dimensions of typical devices, limiting conventional heat dissipation. This work demonstrates gate-tuneable control over heat flow between two points in a GaAs/AlGaAs 2DEG, using the discrete energy spectrum and tuneable tunnel rate of a quantum dot in between. Temperature differences of up to ~650 mK are demonstrated to be maintained across a separation of ~400 nm, suggesting prospects for tuneable, on-chip methods for local heat distribution in mesoscopic circuits. We also demonstrate a gate-pulsing method that enables a direct experimental estimate of the electron temperature difference across the quantum dot.

T2: Understanding Interfacial Defect Physics with Residual PbI2 Distribution in Sequentially Deposited FAPbI3 Solar Cells

Roshni Benny
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Sequentially deposited $FAPbI_3$ perovskite solar cells often exhibit residual PbI_2, whose role in device operation remains controversial. Here, we demonstrate that the spatial distribution of residual PbI_2, rather than its overall amount, governs interfacial defect formation, ionic migration, and charge recombination. By systematically varying the PbI_2 precursor concentration from 1.5 to 1.8 M, we reveal a concentration-dependent redistribution of residual PbI_2 toward the film surface. At the optimum concentration, the surface-localised PbI_2 forms an in-situ quasi-2D HA_2PbBr_3 capping layer during post-treatment, effectively suppressing interfacial defects and iodine loss. Electrical spectroscopy reveals reduced trap density, suppressed ionic charge accumulation, diminished field screening, and slower non-radiative recombination, leading to carrier recombination approaching the bimolecular limit. Consequently, the optimised devices achieve a reproducible power conversion efficiency of 20.62% and negligible hysteresis. These findings establish depth-dependent residual PbI_2 distribution as a key design parameter for efficient sequentially deposited perovskite solar cells.

T3: Frequency multipliers based on quantum point contact to RF tank circuit

Hari Krishnan S
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Conventional RF components such as generators, mixers, and multipliers rely on nonlinear devices like diodes and transistors, which are typically unsuitable for cryogenic operation due to their power requirements and degraded performance. In contrast, quantum point contacts

(QPCs) formed in high-mobility two-dimensional electron gases exhibit nonlinear conductance and quantized conductance steps at low temperatures, operating in the ballistic regime with minimal power dissipation. In this work, we demonstrate that the inherent nonlinearity of QPCs can be exploited for harmonic generation, resulting in a tuneable RF frequency comb. We investigate the influence of biasing conditions on comb characteristics such as amplitude, frequency spacing, and the number of generated harmonics. Furthermore, by integrating the QPC with a resonant RF tank circuit, we achieve frequency up-conversion, effectively mixing low-frequency signals with a high-frequency carrier defined by the tank circuit's resonance. These results highlight the potential of QPC-based devices for low-power, cryogenically compatible RF signal generation and processing, offering a promising alternative to conventional room-temperature electronics for highly integrated in-situ quantum information processing.

T4: Functionalising creases in the monolayer 2D semiconductors.

Soumyadip Hazra
Doctoral Fellow, CAMRIE & School of Physics, IISER TVM, soumyadip22@iisertvm.ac.in

Wrinkles and nanobubbles are an integral and often unavoidable part of integrating 2D semiconductors into actual device architectures. Despite their ubiquitous nature, quantitative correlation between spatially non-uniform strain features and modifications to the local electronic structure remains challenging. Here, density functional theory (DFT) is combined with a recurrent neural network (RNN) to reconstruct the spatially resolved local electronic structure of a monolayer MoS_2 from strain maps. Atomic force microscopy (AFM) topography and Raman spectral maps offer two experimental routes to estimate local strain, with the former offering nm scale resolution. DFT results reveal that biaxial bending-induced strain is significantly more effective in modifying electronic and dielectric properties than both uniaxial bending or in-plane strain. For example, bending induced 0.35% biaxial strain results in 22% reduction in band gap and 7% increase in dielectric constant, whereas comparable uniaxial bending results in 5% reduction in band gap and 1% increase in dielectric constant. Importantly, the spatially non-uniform band structure creates carrier density inhomogeneities, concentrating charge in regions of high strain. Here, non-uniform strain is induced in monolayer MoS_2 by conformal draping of the flake a top a substrate patterned with an array of nanopillars or nanoholes. We show that the wrinkle characteristics, i.e., width, length, amplitude, and density, are controlled by the geometry of the patterned nanostructure, material stiffness, and substrate interaction. A combination of spatially resolved spectroscopic maps, photoluminescence peak energy, Raman spectral shifts, and AFM conductance (dI/dV) maps corroborates the theoretical predictions of the DFT calculations, extrapolated by the RNN across all strain values. The experimental results show that strain features (wrinkles and nanobubbles) commonly present in real devices not only influence the band gap, carrier distribution, and dielectric response of the material, which favourably affect electrical transport in the system. Further, by investigating wrinkle formation on amorphous and atomically flat substrates, we show significant differences in wrinkle characteristics, which are used to quantify sample-substrate interaction, an otherwise non-trivial property to estimate. This understanding has been further applied to explore the more complex and hierarchical wrinkles formed on differentially strained suspended bilayer MoS_2. The framework developed here can be readily extended to other 2D materials and heterostructures, offering a multi-physics route for studying and exploiting strain effects.

T5: Architecture-Dependent Emergence of Self-Powered Gas Sensing in Junction Engineered WSe2 Device

Dipanjana Mondol

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Self-powered gas sensors capable of operating without an external energy supply represent a critical frontier for next-generation environmental monitoring and Internet-of-Things platforms. Here, we present a systematic investigation of Chemical Vapor Deposition (CVD) grown WSe2-based devices across three distinct architectures: a monolayer single-flake channel, a controlled twisted-stacked few-layer single-flake system, and a multi-domain flake network. This study elucidate that how structural complexity governs charge transport, broadband photodetection and gas-sensing behaviour within a single material system. The multi-domain network, comprising a heterogenous assembly of monolayer, few-layer, and twisted WSe2 domains, exhibits robust ultra-broadband (280-850 nm) photoresponse in self-driven condition with a detectivity of 1.5×10^{9} Jones and response/recovery time of <200 msec. Furthermore, the device exhibits highest photocurrent compared to the other two devices. Strikingly, this same network architecture enables NO2 detection at concentrations as low as 10 PPM at 0 V in the dark. Moreover, at a low bias of few millivolts the limit of detection is ~1 PPM, and further improved to sub-ppm sensitivity under light illumination. This behaviour is attributed to a network of nanoscale junctions, where spatially distributed built-in electric fields enable carrier separation, while gas adsorption modulates interflake barrier heights and carrier pathways. By contrast, the stacked device exhibits a weak but measurable response for ~200 PPM of NO2 at zero and dark bias condition, which enhanced under light illumination. While, the monolayer device is entirely insensitive at 0 V in dark, exhibiting only marginal response under finite bias and phot-activation. These reveals a clear mechanistic hierarchy from bulk-dominated transport in the monolayer device to interface-mediated response in the stacked few layer device, and ultimately to junction-controlled transport in heterogenous network device. This architecture-dependent engineering of device in a single 2D material system establishes a compelling design paradigm for simultaneously self-powered, broadband- photoresponsive, and ultrasesnsitive gas sensors.

T6: Environmental Aging and Defect Evolution in 2D MoS_2: From Photoluminescence Degradation to Synaptic Functionality

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The long-term environmental stability of two-dimensional (2D) materials remains a major challenge, as prolonged exposure to ambient conditions introduces defects and gradually degrades their optical and electronic properties. Here, we investigate aging-induced degradation in CVD-grown MoS_2 and demonstrate that its effect strongly depends on the morphology. Room-temperature photoluminescence and temporal photoresponse measurements show that continuous monolayer films undergo stronger degradation than isolated triangular monolayer flakes. The films exhibit greater photoluminescence quenching, a broader excitonic emission, an increased trion-to-exciton intensity ratio, a higher dark current, and slower carrier relaxation. Interestingly, the degraded photoluminescence can be substantially restored through moderate-temperature air annealing. Oxygen-mediated passivation of sulfur vacancies suppresses defect states and re-establishes radiative recombination pathways. Extending this concept to multilayer MoS_2 devices, we demonstrate that aging-induced defects can be harnessed to enable useful optoelectronic functionality. A pristine device initially exhibits a fast photodetector response, whereas aging-induced trap states lead to slower relaxation, persistent photoconductivity, and enhanced responsivity. These characteristics enable the aged device to emulate various optoelectronic synaptic functionalities, including short-term memory, long-term memory, learning and forgetting behavior, Pavlov's classical conditioning theory, basic optical logic operations, and Morse

code decoding. Air annealing passivates the defect states and restores the device toward its initial fast photodetector behavior, demonstrating a reversible transition between photodetection and synaptic functionality.

T7: Ga Alloying Enables Efficient Single-Photon Emission in InGaP/ZnS Quantum Dots

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In this work, we exploit the interplay among precursor reactivity, cation exchange, and reaction temperature to control the growth of InP-based nanostructures using two synthetic approaches: a heat-up protocol and a hot-injection strategy. The heat-up method yields InP/GaP/ZnS multishell QDs with poor optical quality, whereas the hot-injection approach produces InGaP/ZnS alloyed core–shell QDs suitable for single-photon emission. These InGaP/ZnS QDs exhibit high ensemble PLQY and strongly suppressed blinking at the single-particle level upon Ga alloying. Pronounced photon antibunching confirms single-photon emission per excitation pulse. Blinking dynamics show a significant increase in ON-time fraction with increasing Ga incorporation. Using change-point analysis combined with Bayesian state clustering, we find that the number of emissive states decreases with higher Ga concentration, indicating improved band-edge recombination. These results demonstrate that Ga alloying via partial In substitution effectively enhances single-photon-emission properties.

T8: 2D Iontronic Memtransistors for Energy-Efficient Neuromorphic Computing

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The rapid expansion of artificial intelligence (AI), edge computing, and the Internet of Things (IoT) is increasing the demand for energy efficient computing technologies. Neuromorphic computing offers a promising approach for energy-efficient computing by emulating the memory, learning, and adaptive functions of the human brain. Here, we report the versatile, high-performance memtransistor of a solid polymer electrolyte-gated few-layer thick two-dimensional molybdenum disulfide (2D MoS2) channel. Transfer characteristics exhibit anti-clockwise hysteresis, confirming n-channel enhancement-mode operation, supported by the low-voltage drain characteristics under the influence of the electrical double layer (EDL) formed by iontronic gating. The memtransistor shows a reproducible non-volatile memory window in its transfer characteristics with multilevel conductance retention exceeding 10^3 s and endurance beyond 10^3 switching cycles. Mechanistic studies reveal coupled slow ion migration and dipolar relaxation processes coexisting with purely electronic transport in the 2D material channel, highlighting mixed ionic-electronic carrier dynamics. Using tailored input-output pulse schemes, the device demonstrates key synaptic and cognitive functionalities with lower energy consumption per event and response speed down to the microsecond regime. Furthermore, higher-order behaviors such as Atkinson-Shiffrin-type memory behavior, Pavlovian associative learning, and logic gate operations are achieved. These results highlight 2D iontronic memtransistors as promising building blocks for energy-efficient neuromorphic hardware and sustainable edge-computing technologies.

Posters

P1: Enhanced Antiferromagnetic Coupling and Improved Charge Transport in La-Doped $Sm_2Ru_2O_7$ for Sustainable Electronic Technologies

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Developing energy-efficient functional oxides with tunable magnetic and electrical properties is crucial for sustainable technologies. Here, we demonstrate that La substitution in pyrochlore $Sm_{2-x}La_xRu_2O_7$ (SLRO7) provides an effective chemical-pressure route to engineer the interplay between spin and charge transport. La doping strengthens the antiferromagnetic exchange interactions by modifying the Ru–O–Ru bonding network while simultaneously reducing the electrical resistivity and activation energy, leading to improved charge transport. The coexistence of enhanced antiferromagnetic ordering and lower resistance enables efficient control of magnetic and electronic functionalities within a single material. Such tunability is highly desirable for low-power electronics, spintronic devices, and other energy-efficient technologies. These results establish SLRO7 as a promising multifunctional oxide and highlight chemical substitution as a simple, scalable strategy for designing materials for next-generation sustainable electronic technologies.

P2: Simulation of Hybrid Polymer Waveguides for Sustainable Photonics

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Conventional semiconductor manufacturing is a carbon-intensive process that requires high-temperature vacuum processing. To explore an energy-efficient alternative, this work simulates on-chip optical routing based on sustainable Chalcogenide Hybrid Inorganic/Organic Polymers (CHIPs) [1]. CHIPs can be synthesized with sulphur, an abundant and cost effective industrial byproduct thereby reducing the carbon footprint of the fabrication process. To study the optical mode confinement in CHIPs, modeled a hybrid polymer waveguide (n = 1.90) with dimension of 1.0 μm × 1.0 μm on a silicon dioxide substrate (n = 1.444) using COMSOL Multiphysics. Simulations employing the finite element method (FEM) confirms strong fundamental mode confinement with a well-guided effective index of 1.6834 at the 1550 nm telecom wavelength. The simulated electric field profile indicates that the light is isolated in the waveguide effectively, as a result low substrate leakage is observed. This study further emphasize that the high-performance photonic interconnects can be fabricated from low-cost, solution-processed waste-derived polymers instead of energy-intensive crystals, providing a low-carbon roadmap for sustainable semiconductor technologies.

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P3: Effect of core size on the single-particle blinking dynamics of Ga incorporated InP QDs

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Controlling fluorescence intermittency (“blinking”) in semiconductor quantum dots (QDs) is essential for optimizing their performance in optoelectronic and bioimaging applications. However, inherent trap states and poor photostability limit the use of InP QDs as non-toxic alternatives to Cd-based systems. Incorporating Ga into the InP core via cation exchange reduces lattice mismatch with the ZnS shell, improving passivation and enabling more stable InGaP/ZnS QDs. In this study, we examine the effect of core size on single-particle blinking dynamics by systematically growing InP cores to obtain small, medium, large, and giant InGaP QDs. Structural characterization using TEM and XRD confirms Ga incorporation and the formation of zincblende alloy cores. Photophysical analysis at both ensemble and single-particle levels reveals that blinking decreases from small to large QDs but increases again in giant QDs. These findings highlight the interplay between core size, composition, and photostability, and demonstrate Ga incorporation as an effective strategy to tune defect dynamics without modifying the shell.

P4: Nanostructured Semiconductor Materials for Sustainable Energy Storage

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The highly increasing demand for a clean and sustainable energy has shifted the focus on advanced energy storage technology. Nanostructured semiconductor materials will be a promising electrode materials owing to their unique electrical, optical, and electrochemical properties. Their high surface area, tunable band gap, short ion diffusion pathways, and enhanced charge transport significantly improve energy storage performance. Combining semiconductor nanostructures with highly conductive materials such as graphene further enhances electrical conductivity, cyclic stability, and specific capacitance. This review highlights recent advances in nanostructured semiconductor materials for sustainable energy storage, focusing on synthesis approaches, electrochemical properties, challenges, and future prospects. These materials are expected to play an essential role in developing efficient, environmentally friendly, and high-performance energy storage devices for renewable energy systems and next-generation electronic technologies.

P5: Resonance Energy Transfer from 2D Semiconductor Nanocrystals Ensemble to Single-Particle Level

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One-dimensionally confined semiconductor nanoplatelets (NPLs), with high oscillator strength and large extinction coefficient, are suitable candidates for efficient photosensitization and attenuation-free energy transfer. Förster resonance energy transfer (FRET) is a non-radiative process in which energy is transferred from a donor to an acceptor via dipole–dipole coupling, excitation of the donor, and subsequent emission from the acceptor. To explore this process, we investigated FRET in CdSe-based NPLs using a CdSe-based NPL as the donor and an organic fluorophore dye as the acceptor. Ensemble-level investigations revealed more than 75% energy transfer efficiency in all the donor-acceptor pairs. More mechanistic insight into this nonradiative energy transfer process is drawn by conducting spectroscopic studies at the single-particle level. The temporal evolution of the donor and

acceptor emission intensities is monitored, showing a clear crossover between their intensities. These investigations corroborate the promising prospects of utilising NPLs as efficient energy donors in conjunction with suitable organic fluorophores as acceptors.

P6: Modulating the Single- and Two-Photon Emission Dynamics in Semiconductor Nanocrystals

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Quantum materials exhibiting high photoluminescence quantum yield (PLQY), significant absorption coefficient, wide tunable PL, and narrow emission line widths have gained attention in the past few years and are utilized for a plethora of optoelectronic applications. However, detailed understanding on the dynamics of radiative multiexciton recombination at the single-particle level is essential for utilizing them for various display device applications. Here, we employ single-particle spectroscopy to investigate the single and two-photon emission dynamics in CdSe nanoplatelets by varying the excitation wavelength from 405 nm (higher energy) to 593 nm (near-band gap energy). Upon higher wavelength excitation, the PLQY increases, alongside an appreciable rise in the biexciton quantum yield is observed. Our findings at the single-particle level suggest that the Auger recombination rate remains invariant under different wavelength excitation. Based on excitation energy dependent optical properties of CdSe/CdZnS core-gradient shell nanoplatelets, it is concluded that suppressing trap state has a crucial role in enhancing biexciton emission.

P7: From order to disorder: magnetic phase evolution of diluted triangular lattice Ba3CoNb2O9

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Triangular lattices are geometrical frustrated systems that provide an ideal platform to investigate the presence of unconventional magnetic phases through magnetic dilution. In this case, we have investigated the impact of non-magnetic Zn2+ doping on an effective spin (Jeff) - ½ geometrically frustrated triangular lattice Ba3CoNb2O9 (BCNO). Our results highlight the role of magnetic dilution in tuning the balance between frustration and exchange interactions, offering insight into such field-driven behavior of quantum magnets.

P8: Hot Electron Relaxation in CdSe Nanoplatelets: Electron Wave Function Delocalization Matters

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The highly energetic excitons generated in a semiconductor nanocrystal, under supra-band edge excitations, are expected to be persistent due to the weak exciton-phonon coupling, generating a phonon bottleneck. Contrary to the expected results, ultrafast cooling is observed in these quantum-confined systems, often attributed to the efficient Auger-type energy transfer between the coupled electron and hole in the hot excitons. Previous studies have established the influence of confinement and hole decoupling on intra-band cooling in quantum dots, further concretizing the notion of Auger-type energy transfer. Herein, we modulate the electron wave function in hot excitons through suitable band-gap engineering in CdSe-based core–shell heterostructures, enabling a detailed understanding of hot-carrier cooling kinetics using transient absorption spectroscopy. We further extend these investigations to hot-electron extraction using an external acceptor, with the aim of harvesting

the excess energy of hot electrons without energy loss, thereby advancing their potential for photovoltaic applications.

P9: Semiconductor Nanocrystals on Au Nanofilms: Temporal Compression of Two-Photon Emission

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CdSe nanoplatelets having confinement along one direction, i.e., along their thickness, emerged as an interesting candidate among semiconductor nanocrystals, due to their high biexciton efficacy. Due to their large lateral dimension, these systems exhibit suppressed Auger recombination, thereby promoting radiative emission of two photons in a cascade fashion. This sequential emission of photons is especially significant in the realm of quantum technologies, where entangled photon pairs are needed to exhibit correlations in various degrees of freedom, including polarization, position, time, or energy. Extensive research efforts have been devoted to reducing the temporal separation between sequentially emitted photons in a cascade emission process. Herein, we are exploring how the plasmonic fields modify the photoluminescence (PL) lifetimes associated with the recombination of biexcitons and single excitons in the cascade two-photon emission process. The plasmonic structure is engineered by depositing a thin Au nanofilm on a glass substrate. CdSe/CdZnS nanoplatelets are chosen as the emitters, and the coupling strength between the Au film and the emitters is precisely tuned by varying the polymer spacer thickness. The independent analysis of photon cascade events from individual nanocrystals revealed that the PL decay profiles for both excitonic states were well described by single-exponential functions. Interestingly, the biexciton lifetime remains essentially unchanged, whereas the single-exciton lifetime is markedly shortened as the emitter approaches the plasmonic structure. Since the ratio of biexciton to single-exciton lifetime has a direct proportionality to the biexciton quantum yield, the decrease in single-exciton lifetime is attributed to an increase in the biexciton quantum yield. Consistent with our findings, the Auger recombination rate is suppressed as the distance between the emitter and the plasmonic structure is reduced. Theoretical investigations are also performed, and they corroborate the experimental results. Thus, plasmonic platforms are excellent candidates for improving the optical properties of nanocrystals, and thus, nanocrystals can act as on-demand sources for entangled photon pairs.

P10: Ca-Doped ITZO Thin-Film Transistors for High-Mobility Amorphous Oxide Semiconductor Applications

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Calcium-doped indium tin zinc oxide (ITZCaO) thin films were deposited via RF magnetron sputtering and systematically annealed from 200°C to 400°C to evaluate their structural, optical, and electrical properties for thin-film transistor (TFT) applications. GIXRD patterns confirmed an amorphous structure across all annealing conditions, corroborated by TEM/SAED diffuse ring patterns, attributed to Ca^{2+} ionic radius mismatch suppressing crystallization. AFM analysis revealed increasing surface roughness with annealing temperature. Optical transmittance remained high in the visible range across all samples. Hall measurements showed carrier concentration and mobility both increasing with annealing temperature, while resistivity decreased correspondingly, indicating improved carrier transport. Transfer characteristics revealed a clear dependence of turn-on voltage, on-current, and switching behavior on annealing temperature, reflecting the tunability of device performance. These results establish Ca-doped ITZO as a promising amorphous oxide

semiconductor channel material for high-performance, low-temperature-processed TFT applications.

P11: High-Performance Amorphous Oxide Thin-Film Transistors for Sustainable Next-Generation Display Technologies

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Amorphous oxide semiconductor (AOS) thin-film transistors have emerged as the leading backplane technology for next-generation flat-panel, AMOLED, transparent, and flexible displays owing to their high carrier mobility, optical transparency, low-temperature processing, and excellent uniformity over large-area substrates. This poster presents an overview of recent advances in high-performance AOS TFTs, highlighting material innovations, device architecture, charge transport mechanisms, interface engineering, and operational reliability. The influence of semiconductor composition, defect engineering, dielectric interfaces, and fabrication processes on key electrical parameters such as mobility, threshold voltage stability, subthreshold swing, and ON/OFF current ratio is discussed. Current challenges, including long-term stability, scalability, and environmentally sustainable manufacturing, are also addressed. The poster outlines future opportunities for developing energy-efficient and reliable oxide semiconductor devices that support high-resolution displays and emerging transparent and flexible electronic technologies.

P12: Tailoring spectroscopic properties of MoS_2 via He^+ ion Irradiation

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This study systematically explores how the vibration modes and optical transitions in monolayer (ML) and few-layer (FL) molybdenum disulfide (MoS2) changes via He+ ion irradiation. By modulating ion fluence, we observed change in sulfur vacancy (Vs) density in ML and FL MoS2, this gives a platform for the defect engineering of spectroscopic properties. Quantitative characterization shows significant spectral shifts in E12g and A1g vibrational modes and the emergence of disorder-induced modes whose intensities correlates with the density of Vs. In the photoluminescence (PL) spectrum A and B exciton emission quenches and peak position shifts for both ML and FL MoS2. Furthermore, low temperature PL analysis reveals defect bound peaks 200meV below A exciton in ML MoS2, a signature of robust exciton localization, which is a critical factor for making single photon emitters (SPEs) and photodetectors. We did not observed any significant defect bound PL peak in FL MoS2. This work offers a pathway for design and fabrication of localized SPEs and next-generation MoS2 based photodetectors and sensors.

P13: Strain-induced Orbital Ordering and Large Magnetoresistance in epitaxially grown $Pr_{0.67}Sr_{0.33}MnO_3$ Thin Film

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Rare earth manganites (R 1-x A x MnO 3 ; R= La, Pr, Sm,... and A= Ca, Sr, Ba, Pb,...) are promising materials in magnetic recording, sensors, and magneto-electronic devices due to their large magnetoresistance (MR), arising from a sharp drop in resistance under a magnetic field. The transport properties of these materials depend on the interplay of charge, spin, lattice, and orbital degrees of freedom, with significant contributions from grain boundary disorder. In this study, we investigate the effect of strain-induced orbital ordering on magnetic and

magnetotransport properties of $Pr_{0.67}Sr_{0.33}MnO_3$ (PSMO) epitaxial thin film grown on a $LaAlO_3$ substrate with a compressive strain of ~ 2% using pulsed laser deposition. This epitaxial strain effects the Mn-O bond length and Mn-O-Mn bond angle which directly control the double exchange mechanism responsible for magnetic and electronic behaviour. The XRD pattern confirms epitaxial growth. XPS verifies the mixed valence state of the Mn 3+ /Mn 4+ . This PSMO film exhibits an insulating behaviour. Magnetic characterisation reveals a ferromagnetic ordering. A large magnetoresistance of ~ 87% at 9T and 100K is observed due to electron localisation at the Mn^{3+}site, arising from strain-induced Jahn-Teller (JT) distortion, which results in orbital splitting and orbital ordering in this PSMO thin film, confirmed through the existence of Bg modes in temperature-dependent Raman spectroscopy. These results demonstrate that the substrate-induced strain and orbital ordering tune the electronic and magnetic ground state of manganites with a large MR value due to their anisotropy. Our experimental findings highlight the potential of strained PSMO thin films for future applications in spintronics and magneto-electronics devices.

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P14: Defect Stabilized and Band Gap Engineered, Mult-Cationic Ce^{3+} doped $Y_2La_2Bi_2Al_2O_{12}$ Garnet: A Down Conversion White Emission Phosphor

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Defect-stabilized, cost-effective, colour-tunable, and thermally stable single- component phosphors are highly desirable for next-generation solid-state lighting. In this study, Ce^{3+} doped $Y_2La_2Bi_2Al_2O_{12}$ was synthesized by a solid-state reaction method and systematically investigated for its structural, electronic, and optical properties. The successful incorporation of Ce^{3+} ions into the multi- cationic $Y_2La_2Bi_2Al_2O_{12}$ host was confirmed through structural and spectroscopic analyses. Under UV excitation at 459 nm, Ce3+ doped $Y_2La_2Bi_2Al_2O_{12}$ exhibits an ultrabroad emission spanning 450-824 nm, attributed to multiple luminescent centres, providing excellent spectral coverage across the visible region. With color coordinates and correlated color temperature (CCT) falling within the ideal range for solid-state lighting, the resulting emission permits the production of warm-white light. Unlike conventional Ce^{3+}-activated garnet phosphors, which generally exhibit relatively narrow green-yellow emission, Ce^{3+} doped $Y_2La_2Bi_2Al_2O_{12}$ offers broader spectral coverage and improved colour tunability without requiring additional red-emitting components. These characteristics demonstrate the potential of Ce^{3+} doped $Y_2La_2Bi_2Al_2O_{12}$ as a single-component UV-excited down-conversion phosphor for advanced solid-state lighting and optoelectronic applications.

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P15: Escalating OH- Desorption in Bimetallic HER Electrocatalyst for Anion Exchange Membrane Water Electrolysis

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Ruthenium-based nanoclusters are emerging as promising electrocatalysts for alkaline hydrogen evolution reaction (HER), owing to their strong water dissociation capability.[1] However, their catalytic performance is often limited by the strong adsorption of hydroxide ions (OH^-), which is crucial for anion exchange membrane water electrolyser (AEMWE) for achieving the amperes level current density.[2] To address this limitation, we have designed a ruthenium–cobalt bimetallic nanocluster anchored on a nitrogen-doped carbon matrix, which improves the OH^- desorption from Ru sites, lowers water dissociation energy, resulting in enhanced HER kinetics. The improved OH^- desorption has been validated by cyclic voltammetry and in situ Raman spectroscopy in 1.0 M KOH. In particular, an anion exchange membrane electrolyser has been assembled for the practical implementation of Ru-Co-NC as a cathode, which shows the industrial level current density of 2 A cm-2 at 2.35 volts and high stability over 140 hours. The high cell efficiency of 61.7% and low cost H2 production of $1.08 per GGE H_2 at 0.5 A cm^2 demonstrate the potential of Ru-Co-NC for green hydrogen production on an industrial scale. The density functional theory (DFT) calculations provide mechanistic insights, revealing reduced water dissociation energy, favourable hydrogen binding energy, and mitigated OH^- adsorption on the Ru-Co-NC surface. These results highlight the importance of concurrently engineering water activation and OH^- desorption to optimize HER activity for industrial-level current density.

Keywords: Water splitting, Hydrogen evolution reaction, AEM Water Electrolyser, OH-desorption, Density functional theory.

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