

## Indian Academy of Sciences, Bengaluru – 89th Annual Meeting

The 89th Annual Meeting of the Indian Academy of Sciences (IASc), Bengaluru, was held at BITS-Pilani, K. K. Birla Goa Campus, from 3 to 5 November 2023. The three-day meeting comprised several talks, including inaugural lectures by fellows/associates, special lectures, public lectures and symposiums.

In the inaugural session, Umesh Waghmare (President, IASc) delivered a science-based presidential address on metavalent bonding (MVB), a unique form of bonding that explains the anomalous functional properties of group-IV chalcogenide crystals. His theoretical analysis revealed that MVB emerges in rock-salt chalcogenides due to the weakly broken symmetry of parent metallic simple-cubic crystals of group-V metalloids. Understanding MVB is crucial for designing quantum materials with thermoelectric, ferroelectric and nontrivial electronic topological properties.

In the next session, Swadin K. Mandal (IISER-Kolkata, Mohanpur) convened a symposium on ‘Catalysis for a sustainable society’. From a chemist’s perspective, he emphasized the importance of catalytic methods in achieving sustainability. Chemical industries are moving towards alternative catalysts, avoiding toxic materials, eliminating waste and using renewable resources. Mandal cited examples from the recent literature to highlight the importance of catalysis in building a sustainable society.

Matthias Driess (Technical University, Berlin, Germany) discussed the role of chemistry in meeting the needs of society. He highlighted how chemistry has helped advance civilization by transforming materials and creating a network of benefits for the Western world. However, this has come at a cost to the environment and other countries. With climate change and resource scarcity becoming more pressing, the society is looking to chemistry for innovative solutions. Driess emphasized the importance of a multidisciplinary and systemic approach to make chemistry more sustainable.

Sebastian Chirambatte Peter (JNCASR, Bengaluru) talked about catalyst designs for carbon recycling in sustainable energy. His team has converted waste CO<sub>2</sub> from carbonaceous fuel burning and the industrial sector into valuable chemicals and fuels. They have developed customized catalyst systems for targeted product conversions to meet the needs of different in-

dustries. The talk covered the development of these catalysts through various methods and their industrial viability.

In the final talk of the session, E. Balaraman (IISER, Tirupati) discussed the challenges of sustainable development, particularly energy storage and the use of abundant feedstock without contributing to the carbon footprint. His research group is focused on developing high-performance, low-cost, eco-friendly and sustainable catalytic systems using non-precious metals. They are exploring dehydrogenation chemistry for chemical synthesis, hydrogen production from renewable sources, and CO<sub>2</sub> utilization for circular catalysis. The group is also working on synthesizing electron donors for Ziegler–Natta olefin polymerization catalysis.

Following the symposium, Ramgopal V. Rao (BITS, Pilani) delivered a special lecture on ‘Connecting academic R&D with product innovation: a few case studies and a way forward’. He noted that India’s contribution to the world’s R&D is on the rise, with the country ranking among the top three in research publications in specialized areas like nanotechnology. Despite the low percentage of GDP spending on R&D, Indian researchers have excelled in terms of research output. However, India’s innovation and product development potential is lacking, as evidenced by its poor ranking on the global innovation index and the absence of significant commercial breakthroughs from research conducted by Indian academic institutions. To address this, Rao emphasized the need for a multidisciplinary approach, and a range of initiatives at the institutional and national levels to foster a culture of product innovation in the country.

In the next session, Sundargopal Ghosh (IIT-Madras) gave a talk on the coordination chemistry of diborane(4) and diborane(6). He explained that diborane compounds mimic classic organometallic complexes, and have been studied extensively for a broad understanding of chemical bonding and catalysis. Ghosh’s team has recently synthesized a bimetallic diborane(4) that mimics cotton’s dimolybdenum–alkyne complex and isolated the first classical diborane(5) (B<sub>2</sub>H<sub>5</sub>)<sup>-</sup>. They have also developed an uncatalysed synthetic pathway to generate the doubly base-stabilized symmetrical and unsymmetrical diborane(4) species.

Vijay Kodiyalam (IMSc, Chennai) discussed the solution to Euler’s 36 officers problem. While it is commonly accepted that there is no classical solution to this problem, the speaker claimed that there exists an infinite number of unique quantum solutions to it. The talk shed light on the fascinating intersection between quantum mechanics and mathematics, providing a new perspective on a classic problem.

In the next session, Moumanti Podder (IISER, Pune) discussed combinatorial games and their connection to percolation, probabilistic automata and statistical mechanics. The focus was on percolation games on directed two-dimensional lattices and rooted random trees. The presentation highlighted the phase-transition phenomenon related to the probability of draw and explored the different parameter values, where the probability of draw is either 0 or strictly positive. The phase transitions are linked to the ergodicity of related probabilistic cellular automata/probabilistic tree automata and weak spatial mixing properties of statistical mechanics models.

In his talk, Uttam K. Gopal (Ramakrishna Mission Vidyamandira, Howrah) presented the challenge of producing environment-friendly nitrogen-based fertilizers which are essential for plant growth. Currently, most nitrogen-based fertilizers have high energy and carbon footprints. To address this issue, his laboratory has developed electrocatalytic methods for producing green ammonia, urea and nitric acid under ambient conditions. The field trial for green ammonia synthesis has been completed, and Gopal’s team is now working on technology transfer and licensing for pilot-scale production of green ammonia with a multinational company.

The day ended with a public lecture by Dean D’Cruz (Goa Foundation, Goa). He discussed the intersection of art and science in design. Although design has played a significant role in shaping our lives and aspirations over the past few decades, many still do not fully understand its impact. From fashion to architecture, design has a broad reach and can be used to create not only products that cater to user needs, but also those that set the tone for the future. Furthermore, design has become a critical tool for addressing social and environmental challenges, and is no longer just for the elite. The design process involves extensive

research, defining problems, challenging assumptions, generating ideas, prototyping solutions and testing them thoroughly before production. Like other fields that evolve with time, design is dynamic and adapts to our changing lifestyles, available materials and technologies. D'Cruz also highlighted some of the groundbreaking work done by Mozaic Design, Goa, over the past few decades.

The second day of the meeting began with a talk by Bijnan Bandyopadhyay (IIT, Jodhpur), who presented a detailed talk on modelling and controlling a large pressurized heavy water reactor. He also covered the conversion of flux equations into ordinary differential equations using nodal techniques, the application of one-and-a-half group theory to convert these equations into one-group power equations for all nodes, and presented a detailed discussion of the 70th-order of the reactor model linear design, and its 14 inputs and 14 outputs in state space.

Ganesh Nagaraju (IISc, Bengaluru) spoke about the regulation of homologous recombination (HR) during DNA replication. HR is crucial for repairing DNA double-strand breaks and maintaining genome integrity, but uncontrolled HR can hinder genome duplication and stability. He found that RTEL1, RAD51 and RAD51 paralogs regulate HR during replication recovery. Lack of RTEL1 causes hyper-recombination during replication, affecting genome-wide replication. However, RAD51 and RAD51 paralog depletion can correct this. Fork remodeler depletion and HR-defective RAD51 mutants can correct replication defects in RTEL1-deficient cells. The interaction of RTEL1 with PCNA and helicase activity restricts RAD51-mediated fork reversal and HR activity, allowing for accurate genome duplication.

Anindita Das (IACS, Kolkata) presented a novel method for producing two-dimensional (2D) structures from chromophore-conjugated poly(L-lactides) (PLLAs) using crystallization-driven self-assembly (CDSA). The PLLA homopolymers, modified with different dipolar chromophores, assemble into diamond-shaped 2D platelets in isopropanol. The attached chromophores then form a 2D-array on the platelet surface, leading to aggregation-induced enhanced emission with tunable wavelengths. The 'living' CDSA method was also discussed, which helped achieve hierarchical segmented block co-platelet structures using one of the homopolymer platelets as the 'seed' and the unimer of the other as the 'monomer reservoir'. The stereo-complex co-platelet

formation in the solution phase showed enhanced stability compared to the individual homocrystals.

Biswarup Mukhopadhyaya (IISER-Kolkata, Mohanpur) presented a comprehensive overview of the concept of dark matter. He covered various aspects of this mysterious substance, including its properties, composition, and potential implications for our understanding of the universe. He also highlighted several unresolved issues and challenges associated with studying dark matter, particularly the difficulties in extracting information from extraterrestrial data about the particles that make up this elusive substance.

The lectures were followed by a symposium on 'Landscape and seascape of Western India and beyond,' which was convened by Rajiv Kumar Chaturvedi (BITS-Pilani, Goa). He discussed forest monitoring studies in the Western Ghats, with a goal to assess the impact of global change. His team has established a 1 ha vegetation-monitoring plot in Netravali Wildlife Sanctuary, Goa, which consists of 5375 individuals, holds 260 tonnes of carbon in vegetation and soils, and demonstrates high tree biodiversity with 84 tree species. They are working with the International Institute for Applied Systems Analysis, Vienna, Austria, to develop a plot-based dynamic vegetation model named 'Plant-FATE', and are undertaking a range of additional measurements in the plot.

C. P. Singh (ISRO, Ahmedabad) emphasized that monitoring plant phenology is crucial in regulating biosphere functions and as an indicator of climate change. With satellite remote sensing, we can monitor subtle changes in greenness and understand ecosystem dynamics. This has important implications for forest fires, CO<sub>2</sub> fluxes, and energy and mass exchange. Using time-series satellite remote sensing observations validated with Phenocam network data, we can gain a deeper understanding of ecosystem dynamics. ISRO's Geosphere and Biosphere Programme is implementing the PhenoMet network to cover major forest types and generate phenological matrices to investigate the drivers of changes in the forest ecosystem.

In the next talk, M. A. Atmanand (IIT-Madras, Chennai) presented his findings on the warming of the Indian Ocean, which is happening faster than the other oceans due to its landlocked nature. To understand heat transfer and predict cyclones, increasing ocean observations in this region is crucial. Two observation platforms exist: Lagrangian and Eulerian. Measuring un-

derwater, surface and above-water data from moored observatories is essential. Various types of floats and autonomous underwater vehicles are used for these measurements. All data are transmitted on-line through a satellite to relevant agencies for dissemination.

V. Sunil (NCPOR, Goa) delivered a talk on mapping the hidden features and potential hazards in the exclusive economic zone (EEZ) of India. The EEZ extends 200 nautical miles from the coastline and is rich in resources. The Government of India has initiated a project to comprehensively map EEZ, with the National Centre for Polar and Ocean Research, Goa, leading the project. The primary focus is to conduct a multibeam swath bathymetric survey and gather marine geophysical data. Over 90% of the deep-water blocks have been surveyed, revealing numerous morphological features and potential geohazards. Accurate charting of these features is crucial for ensuring safe navigation and the sustainable development of India's maritime territory.

Following the symposium, Rajiv Sinha (IIT, Kanpur) presented his research on the Ghaggar-Hakra river system and its relation to the Harappan civilization. He found that the Harappan settlements were built on an abandoned river valley as the paleo-Sutlej river was not flowing in the region. The paleo-Yamuna played a role in feeding the Ghaggar-Hakra river system, but its impact on the growth and decline of the Harappan settlements is still debated. Recent analysis of sediment cores across the paleochannels of the Yamuna revealed that the river underwent significant drainage reorganization at least 10,000 years before the westward shift of the paleo-Sutlej river. This indicates that the Ghaggar-Hakra system was already flowing with a much-reduced discharge during the Early Holocene and became completely defunct much before the decline of the Harappan civilization.

Bibin G. Anand (SRM Institute of Science and Technology, Chennai) discussed the molecular mechanisms behind protein and metabolite cross-catalysis and coalescence. Amyloid fibrils, which are stable structures characterized by cross- $\beta$  structures, are formed when proteins convert from their native form into aggregates. Nearly 50 proteins and peptides are known to form toxic amyloid entities, contributing to various pathological complications. Phenylalanine and tyrosine metabolites can also form similar structures. The precise molecular mechanisms behind these debilitating diseases remain a topic of ongoing

debate. Primary and secondary nucleation play a critical role in protein and metabolite aggregation, as well as their coalescence and cross-catalytic interactions. Aromatic interactions that facilitate optimized intermolecular arrangements also play a vital role in these events.

Sanghamitra Bandyopadhyay (ISI, Kolkata) shed light on the groundbreaking machine learning (ML) applications in biomedical research. As a result of the rapid technological advancements in recent decades, the usage of ML methods in biomedical research has gained immense importance. The talk provided an overview of some ML techniques and molecular biology, followed by brief presentations of some classical as well as recent applications of ML methods to a few problems in computational biology. It also showcased the vast potential of ML in biomedical research and its ability to revolutionize the field in the coming years.

Amiya Kumar Samal (BHU, Varanasi) talked about large igneous provinces (LIPs) of the Indian Shield. The Indian Shield has 16 identified LIPs that offer insights into its geological history and evolution. Most LIPs are identified using precisely dated mafic dyke swarms. These LIPs help understand the tectonic and magmatic processes that have shaped the Indian subcontinent. Many LIPs belong to the DHABASI megacraton and are linked to different mineral systems. They are potential targets for mineralization of various elements. The identified LIP events of the Indian Shield are an integral part of most of the known supercontinents in the Earth's evolution.

The session was followed by a public lecture by Gurmeet Kaur (Panjab University, Chandigarh) on the saga of laterite. This fascinating stone holds a great deal of cultural and historical significance in the Western Ghats, and Kaur's lecture delved into the intricate details of its story. The tale began with the geological formation of laterite, which was first discovered by the people who were living in the region for centuries. The deposits of this stone have played a crucial role in shaping the cultural landscape of the Western Ghats, with the structures built using it serving not only as architectural marvels but also as centres of worship and repositories of history. Some of these sites have even been recognized by UNESCO as World Heritage Sites, highlighting their importance. Even today, the legacy of laterite lives on through these awe-inspiring sites and structures, serving as a reminder of the enduring legacy of human ingenuity that has been etched in stone.

The last day of the meeting began with a lecture by B. Senthilkumaran (University of Hyderabad). He talked about how sex steroid hormones affect brain sex differentiation in bony fishes. This results in gender-specific patterns and distinguishes gender-based mechanisms. Fish exhibit sexual plasticity during gonadal development, which leads to the identification of novel brain-specific biomarkers related to brain-gonadal interaction during sexual development. These biomarkers include tryptophan hydroxylase, tyrosine hydroxylase, cyp19a1, serotonin, catecholamines, glial cell-line derived neurotrophic factor and its receptor, gfra-1. Controlled release of sex steroids through an osmotic pump influences several brain biomarkers, indicating a contributory gonadal influence. The brain serotonergic system directs male sex development, while the catecholaminergic system shows higher activity during female sex development.

In the next talk, Vikash Kumar (NCPOR, Goa) focused on reconstructing the polar climate and exploring teleconnections of the Indian monsoon. Kumar found an inter-hemispheric linkage between the Indian monsoon and surface conditions in the Indian sector of the Southern Ocean over a period of 1000 years. Additionally, he analysed paleoenvironmental changes in the Arctic and found a highly coherent pattern with Indian monsoon variability during the last millennium, likely influenced by meridional thermal gradients over the Indian monsoon domain.

Ishwariya Venkatesh (CCMB, Hyderabad) presented her research on understanding the molecular blueprint of regeneration in mammalian central nervous system neurons, focusing on the regulation of axon growth during development and regeneration. Her team aims to unravel the regulatory mechanisms behind the decline in regenerative capacity in adult neurons by exploring the interplay between transcription factor regulatory networks, epigenetic landscape and 3D genome topology. They are using advanced genomics techniques and mouse models of injury to assess axonal growth to clarify the fundamental molecular mechanisms that govern successful regeneration.

In the next talk, I. N. N. Namboothiri (IIT-Bombay, Mumbai) spoke about using functionalized polycyclic cage compounds as high-energy density materials. These compounds are rigid, compact and thermally stable, making them ideal for situations where space is limited. Adding functional groups like nitro, azido, nitrito or polynitrogen-containing heterocycles can enhance

their energetic properties. He discussed how to synthesize functionalized cage compounds with bis-homocubyl, homocubyl and cubyl skeletons using dicyclopentadiene or cyclopentanone in as few steps as possible.

Haripada Sau (IISER, Pune) discussed the 'constrained Ando dilation problem', which questions whether every toral pair of commuting contractions can be dilated to a toral pair of commuting isometries. The problem arises from Ando's inequality and its advancements for certain matrices and operators. A toral pair is a pair of commuting operators that are annihilated by a toral polynomial, a set of two-variable polynomials with a geometric condition on their zero sets. Sau explained the importance of finding an answer to this question.

In the last talk of the session, B. Eswar Reddy (IIA, Bengaluru) spoke about the evolution of lithium (Li) in the universe, focusing on the high levels found in red giant stars. Li is considered to have originated during the Big Bang. However, its measured abundance in stars is higher than predicted, suggesting Li enrichment over time. Red giants are expected to be sinks rather than producers of Li, making the discovery of abnormally high levels a puzzle. Reddy's research shows that lithium enhancement occurs during the helium (He) flash, resulting in common Li-rich giants in He-core burning stars.

The Annual Meeting concluded with a special lecture by D. Shankar (NIO, Goa), who shared his understanding of the dynamics of the North Indian Ocean. The lecture focused on wind-forced circulation and discussed the theoretical framework that explains its dynamics. Shankar started by providing background information on global ocean circulation and the theories that explain observations. He also talked about the observed seasonal cycle of the circulation of the North Indian Ocean. He then delved into the largely linear theoretical framework used to explain this observed seasonal cycle and also discussed the effects of nonlinearity on the complex physical system of the North Indian Ocean. Shankar contrasted the nonlinear effects of linear processes. Finally, he explained the implications of complexity and linearity for prediction and insights.

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