31st National Conference

CONDENSED MATTER DAYS

CMDAYS 2023

22 - 24 January 2024

Tezpur University

Abstracts Booklet

IN ASSOCIATION WITH

SERB INDIA

TEZPUR UNIVERSITY ESTD 1994

ORGANISED BY

DEPARTMENT OF PHYSICS

TEZPUR UNIVERSITY

Completion of Glorious 25 Years

Reinventing Physics, Beyond Confines

Department of Physics
Tezpur University

1998-2023

CMDAYS 2023

31st National Conference

CONDENSED MATTER DAYS

22 - 24 JANUARY 2024

CONFERENCE PROCEEDINGS

(abstracts arranged in alphabetical order of the surname of the presenting author)

Organised By

DEPARTMENT OF PHYSICS

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MESSAGE FROM THE VICE CHANCELLOR

Prof. Shambhu Nath Singh
Vice Chancellor
Tezpur Univesity

I am extremely delighted to witness one of the flagship departments of Tezpur University, the Department of Physics, celebrating its silver jubilee year ending with prominent national physics conference, the 31st Condensed Matter Days - CMDAYS 2023. It is noteworthy that many eminent scientists and researchers form reputed institutes all over the country are participating in this event, which serves as a great platform for exchange of scientific ideas apart from being source of inspiration to the researchers and students in different parts of Assam and other North-Eastern states working in the frontiers of condensed matter physics. A boost in the scientific research both in the fundamental and technological aspects, paves the path for the development and prosperity of a nation. Science education and the adoption of scientific approach holds the key to address the current problems ranging from energy crisis, pollution to sustainability goals for the society. The fostering of interdisciplinary and multidisciplinary approach in scientific research has been one of the main objectives under the New Education Policy which the entire country is striving for. Under such scenario, as the Vice Chancellor of Tezpur University, I believe the University has a great role to play and have tried my best effort to promote scientific research and support in every way possible to the departments taking lead in the direction of active research and nurturing scientific ideas in students who are the pillars of our future. It is a commendable effort on the part of the organizers to envision a broader perspectives of physics research and application with the idea of inclusivity through their special sessions on Industry-Academia- Interaction, Atmanirbhar Bharat and Innovation Exhibition. These themes are the real need of the hour, allowing people from different expertise to come together and work towards the common goal of the betterment of all exploiting the scientific knowledge. I wish a great success for the conference and encourage the participants especially the young students to make use of this great opportunity to build upon their scientific aptitude not only in terms of physics research but also to inculcate the idea of innovation and new technology which could thrive the country towards self-reliant and sustainability in future.

MESSAGES FROM EMINENT SCIENTISTS

Prof. Sriram Ramaswamy
Department of Physics
Indian Institute of Science
Bengaluru, 560 012 INDIA
sriram@iisc.ac.in

MY MESSAGE FOR CMDAYS 2023

CMDAYS2023 looks like an exciting event. I'm glad the organisers have taken a broad view of condensed matter, including the physics of soft and living systems. I wish the conference, and especially the young researchers, every success. I'm sorry not to be able to take part, and I hope to have another opportunity to interact with the faculty, students and postdocs at Tezpur, and to visit Assam.

Prof. D. D. Sarma
Solid State and Structural Chemistry Unit
Indian Institute of Science
Bengaluru 560 012 INDIA
sarma@iisc.ac.in

MY MESSAGE FOR CMDAYS 2023

I am delighted that Tezpur University's Department of Physics is organizing the 31st edition of the National Conference, Condensed Matter Days (CMDAYS 2023). Condensed matter science is undeniably a leading field, bridging physics, chemistry, materials science, nanoscience, and technology. As energy, environment, and health challenges, all intricately linked to sustainability, become pressing, scientists, engineers, and inventors increasingly seek the power of condensed matter science to deliver innovative solutions. Therefore, the importance of this field, the very focus of this conference, cannot be overstated.

I have been fortunate to participate in several previous installments of this conference series. I know its crucial role in popularizing science and motivating young researchers to dedicate themselves to condensed matter science. Its emphasis on the northeastern region fulfills the vital purpose of bringing together renowned experts from across the country and beyond, exposing young minds to the most exciting advancements in this multifaceted field.

While I am unable to attend this year, I send heartfelt wishes for the organizers' resounding success and an exciting conference to all participants. I hope to join you all in person next year!

MESSAGE FROM

CHAIRMAN, CMDAYS

Prof. D. Mohanta

Department of Physics
Tezpur University

Began in the form of a small annual meeting at IoP, Bhubaneswar way back in 1993, Condensed matter days, popularly called "CMDAYS" soon became a fullfledged annual event being organized at different parts of Eastern and NE India. Offering fundamental insights, Condensed matter physics lays the foundation to modern technological development and industrial prospects in the fields of optoelectronics, photonics, nanotechnology, quantum technology, sensing and actuation etc.

It is a matter of immense pleasure that Department of Physics, Tezpur University is hosting 31 st edition of cmdays as a part of silver jubilee celebration of the department. The three-day long conference will cover invited talks by leading experts, as well as oral and poster sessions with participation from IISc, IISER, IITs, Universities, Colleges, and Research institutes across the country. I am sure, several innovative sessions including exhibition on ideas and design, industry-academia interaction etc. will make this year's event special! Young researchers and students will certainly benefit themselves from the expert talks and stimulating discussion during the event.

The Convenors, Dr R. Sharma and Dr Diana T deserve a great deal of appreciation for their tireless effort and meticulous planning in organizing the event, cmdays23. I wish the conference- a grand success!

MESSAGE FROM

CHAIRPERSON, CMDAYS 2023

'When we honour the past, and embrace the future; then the present becomes a celebration.'

Prof. P. Deb

Department of Physics
Tezpur University

This Silver Jubilee of Department of Physics, Tezpur University is a milestone/an occasion to be celebrated, to recall the amazing and marvellous ways in which the Department has fulfilled its Vision-Mission. We welcome you to join us at CMDAYS 2023!

Encouraged by the success of the CMDAYS Conference series held since 1992 and the impact it has created among the condensed matter physics and materials science research community both in the region and elsewhere, the Department of Physics, Tezpur University will be organizing the 31st edition of the conference series from 22nd to 24th January 2024 in Tezpur. The first 30 conferences in this annual CMDAYS series attracted a total of more than 3,500 participants including hundreds of distinguished plenary & keynote speakers, in addition to large number of invited speakers. The upcoming conference, with an expected participation of 150 delegates, comprises of 8 technical symposia, plenary and evening lectures, industry-academia session, innovation exhibition as well as keynote, invited, oral and poster presentations.

CMDAYS 2023 is the premier scientific platform to present research to an interdisciplinary and multidisciplinary audience. It provides a window on the future of condensed matter physics and offers an opportunity for researchers—from students and postdocs, to senior scientists—to share expertise, exchange technical information and network with colleagues.

A key to a successful CMDAYS 2023 Conference is the opportunity for conference organizers to define the content and tone of the conference. I urge you to exercise your creativity, technical judgment, and entrepreneurial spirit to ensure effective accomplishment of this year conference. New ideas and emerging concepts in your field should be an important hallmark of this conference. Presentation of a diversity of perspectives is an opportunity and a core value of this conference.

I would like to direct your attention to the content and timeline in this Abstract book. It is designed to provide optimum publicity for the conference, enable timely input to programming, and ensure effective utilization of resources.

PREFACE

Condensed matter physics deals with the physical properties of condensed phases arising from the interaction among the large self-similar entities comprising the system. The fascination lies in their emergent collective behavior through macroscopic properties otherwise not inherited in the individuals making up the system. Condensed matter physicist uses various fundamental laws of physics, such as laws of quantum mechanics, electromagnetism, and statistical mechanics, to understand the collective behavior of these phases. Generally, condensed matter physics brings to mind the world of materials and the studies of their physical properties from electronic band structures, transport, magnetic, optical, electrochemical, mechanical, and dimensionality. However, over the last few decades, the scope and applications of condensed matter physics have widened considerably. The concept has extended from inanimate materials to living systems, such as the dynamics of flocks or herbs of animals, birds, schools of fish, and the collection of cells or micro-organisms in fluids. The dynamics of these condensed living/non-living self-propelled systems categorized as active matter or soft matter, have been the new thrust areas of condensed matter physics. The tools of condensed matter and statistical physics with the hydrodynamics laws have been used to study the dynamics of active matter systems using minimal models and computer simulations. It is fascinating how a simple model constructed using few interactions and time evolution rules within the interplay of relevant external parameters shows the phase transition. On the other hand, there has been immense progress in the frontier of low dimensional and low-temperature systems such as 2D materials/thin films, ultracold atoms, superconductivity, and nanotechnology, where the rich quantum phenomena are realized. Indeed, novel materials development for quantum computation is just at the threshold of a new quantum revolution. The diversity of systems and phenomena available for study makes condensed matter physics the most active field of contemporary physics, theoretically and experimentally.

The organizers have chosen to weave together these two extremes of condensed matter physics with overlapping areas of other branches of science and technology to stimulate young researchers, and postgraduate and undergraduate students to pursue their research in the emerging research areas of condensed matter physics with an Interdisciplinary outlook.
Besides, the organizer has also encouraged the students across the science and engineering disciplines and industry participants to showcase their ideas, designs, and even their science projects in this gathering of renowned scientists and young researchers to interact and receive feedback for further improvement and innovation. The primary goal is to shatter the confined textbook knowledge or laboratory experiments with real-world applications addressing the real challenges of society and contribute to society by employing one's scientific knowledge and innovative ideas. We believe it is high time to break barriers of confined topics/subjects and join hands with the industry and technology sector. Thus, special sessions on industry-academia and Atmanirbhar Bharat are designed solely for this purpose. We have also included a session on women in condensed matter physics to voice the gender gap in science and engineering streams and to promote women scientists to become role models for young female aspirants. Another session, named the doctoral colloquium, will act as a platform for the graduating students to convey the gist of their research works in a general way to the audience.

We believe our humble effort in organizing the conference with the variants of different sessions, talks, and exhibitions, would sow a seed in the mindset of the young students and researchers to utilize their potential to make advances in the broad field of condensed matter through an interdisciplinary approach and reach out to solve the ground problems faced by the society.

The Department of Physics, Tezpur University, takes pride in organizing the 31st national conference CMDAYS 2023 from January 22-24, 2024. The event comprises the keynote and invited talks by experienced and renowned scientists and oral/poster presentations by young researchers working in Condensed Matter Physics.

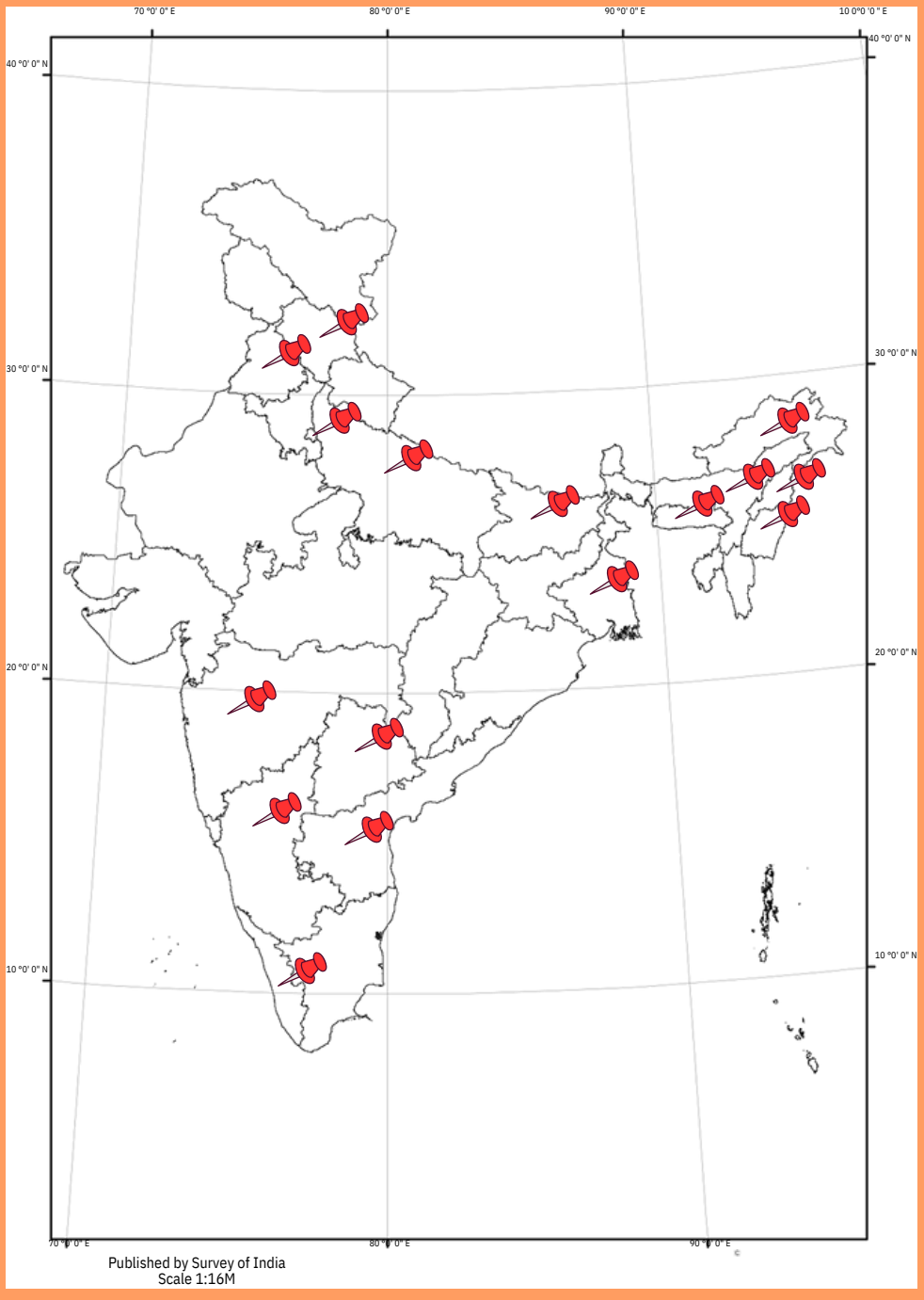
We offer our sincere thanks to Prof. Shambhu Nath Singh, Vice-Chancellor, of Tezpur University, for his unstinted support throughout in organizing this conference. We acknowledge the financial support of SERB and Tezpur University to organize this conference. We express our deep sense of gratitude for the overwhelming response from the scientific community throughout the country. We also thank the department faculties and indispensable student volunteers for preparing this event.

On behalf of the organizing committee, it gives us immense pleasure to extend the heartiest welcome to all the delegates, participants, and well-wishers of this conference for their valued support and cooperation in organizing this national conference. We do hope the conference will be academically exciting and rewarding one, promote innovation, both for the participants and experts.

We wish you have a comfortable stay at Tezpur University and a fruitful conference.

Convenors
Ritupan Sarmah
Diana Thongjaumayum
CMDAYS 2023

CMDAYS2023 PARTICIPANTS



Distinguished Speakers

Tilings, Tessellations, and Quantum Coding

Komal Kumari, Garima Gajpoot, Sudhir Ranjan Jain
Department of Physics, University of Luxemboug, Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, UM-DAE Centre for Excellence in Basic Sciences, Mumbai 400098

We present a connection between dynamical systems, condensed matter physics, and quantum error correction. Error correction in computation is perhaps the most important aspect. Efficient error-correction is necessary for any computation to succeed. Quantum error correction is more complicated as in addition to bit flip errors, there are continuous errors from dephasing.
We present a quantum error correction code which has the highest encoding rate, i.e. it yields maximum number of logical qubits for given physical qubits. We will explain how it is built from the ideas in the physics and mathematics of quantum billiards, and completely characterize it.

References:

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email: srjain@cbs.ac.in

The story of Supersolid Phase of Matter

Prasanta K. Panigrahi

Department of Physical Sciences, Indian Institute of Science Education and Research Kolkata, Mohanpur-741246, West Bengal, India, &
Center for Quantum Science and Technology (CQST), Siksha 'O' Anusandhan, Khandagiri, Bhubaneswar-751030, Odisha, India.

The augmented nonlinear Schrodinger equation (ANLSE), describing Bose-Einstein condensates (BECs), with the inclusion of Lee-Huang-Yang (LHY) quantum correction [1], has led to the discovery of a fascinating state of matter: the quantum droplet, which has found experimental verification. The appropriately normalized ANLSE is given by

$$i\hbar\frac{\partial\psi}{\partial t} = \frac{-\hbar^2}{2\,m}\frac{\partial^2\psi}{\partial x^2} + \delta g|\psi|^2\psi - \frac{\sqrt{2m}}{\pi\hbar}g^{\frac{3}{2}}|\psi|\psi,$$

the last quadratic nonlinearity originates from LHY correction in one dimensional cigar shaped BEC [2]. Aside from the droplet case, kink-antikink [3] and exact realization of the elusive supersolid phase [4] have recently been identified in a variety of parameter domains. Interestingly, it is found that these solutions are always accompanied by a constant background in contrast to the BEC in quasi-one dimension, where dark, bright and gray solitons have been well investigated both theoretically and experimentally. Here, we trace the historical journey of the supersolid phase from its prediction in 1957 [5], and demonstrate the exact solution in a physically related cold atomic system, with traditional mean-field repulsive and beyond-mean-field attractive correction. The exact solution highlights the way around the no-go theorem of Penrose and Onsager [6], and delineates the parametric domain, where this novel phase of matter can be observed in the same system, possessing quantum droplets.

References:

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*email: pprasanta@iiserkol.ac.in

Noval features of direction reversing active Brownian particle

Sanjib Sabhapandit *

Raman Research Institute, Bangalore 560080, India

Active Brownian motion with intermittent direction reversals is common in a class of bacteria like Myxococcus xanthus and Pseudomonas putida. In the absence of any external potential for such a motion in two dimensions, the presence of the two time scales set by the rotational diffusion constant and the reversal rate gives rise to four dynamical regimes showing distinct behaviors. For a “direction reversing active Brownian particle” in a harmonic potential, due to the interplay between the rotational diffusion constant, the reversal rate, and the trap strength, the steady state distribution shows four different types of shapes. This talk will discuss the novel features that arise in an active particle model due to the interplay
between multiple timescales.

References:

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*email: sanjib@rri.res.in

Invited Speakers

Active-flow coupled dynamics of non-axisymmetric, flexible microswimmers

Tapan C. Adhyapak *

Department of Physics, Indian Institute of Science Education and Research (IISER) Tirupati, Tirupati, Andhra Pradesh, India

Understanding the dynamics of microbes in confined flow channels is sought after for several medical and biotechnological applications. Here, I will present our work based on a simplified microswimmer model capturing a strong coupling of the active flows to the self-propulsion dynamics. We will discuss the fundamental physics behind the swimmers' somewhat surprising dynamics inside a channel and point out a few novel controls predicted by our analyses.

References:

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*email:adhyapak@iisertirupati.ac.in

Semiclassical limit of a measurement-induced phase transition

Sumilan Banerjee [*1] and Sibaram Ruidas [†2]

[1]Centre for Condensed Matter Theory, Department of Physics, Indian Institute of Science, Bangalore 560012, India

[2]International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bengaluru 560089, India.

Chaotic-to-non-chaotic transitions play a prominent role in our understanding of the dynamical phase diagram of both quantum and classical systems. In quantum many-body systems, a certain kind of chaotic-non-chaotic transitions, dubbed 'measurement-induced phase transitions' (MIPT), have led to a new paradigm for dynamical phase transitions in recent years. On the other hand,prominent examples of transition in chaos in classical dynamical systems are the stochastic synchronization transitions (ST). In this case, classical trajectories starting from different initial conditions synchronize when subjected to sufficiently strong common random stochastic noise.

In this talk [1], I will establish a possible link between MIPT and ST by considering models of interacting quantum particles whose positions are measured continuously, albeit weakly. In the semiclassical limit, the dynamics of the system is described by a stochastic Langevin equation where the noise and the dissipation terms are both controlled by the small quantum parameter and measurement strength. I will show the existence of a

chaotic-to-non-chaotic transition in the Langevin evolution as a function of either interaction or noise/dissipation strength.

References:

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Photocatalyst: Eminent Material To Address Waste Water Issue

Riu Riu Wary[1], Mousumi Narzary[1], Bidhu Bhusan Brahma1, Pranjal Kalita[2] ,and Manasi Buzar Baruah *[1]

[1]Department of Physics, Central Institute of Technology Kokrajhar (Deemed to be University, MoE, Govt. of India), Kokrajhar-783370, Assam, India

[2]Department of Chemistry, Central Institute of Technology Kokrajhar (Deemed to be University, MoE, Govt. of India), Kokrajhar-783370, Assam, India

Development of photocatalyst is strongly fascinating the research community in multidisciplinary domain due to its distinctive potential for solar-to-chemical-energy conversion. The development in tailoring the structural, morphological, and optoelectronic properties of suitable material in order to harvest the solar light is the prime concern, which helps in the reduction of photogenerated electron-hole recombination and enhance the quantum efficiency. Sincere efforts have been given to develop efficient photocatalysts that work under solar light.Thus, ZnO nanoparticles are developed using different biomass ash water extracts to study their photocatalytic activity. Since ZnO NPs have some limitations, so composite photocatalysts are also developed to improve the activity performance by increasing the separation between charge carriers. So, we have designed heterojunction and developed the strategy for providing intimate line-to-face contact essential for electronic transition between contacted heterocomponents. Study of structural, optical and morphology of the samples are carried out in details to confirm the formation of desired materials. The designed heterojunction photocatalysts are investigated by the degradation of industrial pollutants under visible and direct solar irradiation. The main reactive species participated dominantly in the reaction are also investigated by radical trapping experiment. From band structure, PL and radical trapping experiment, a charge transfer mechanism is proposed. Thus, discussed studies provide a good foundation for development of promising photocatalyst in order to address the waste water issue.

References:

[1] M. B. Baruah et al. Role of interfacial contact between 2D materials and preselected nanostructures in the degradation of toxic dyes: Multifunctional facets of graphene Environmental Research, 214:113948, 2022.

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*email: mbbaruah@cit.ac.in

Current Trends in Machine Learning: Navigating the Evolving Landscape

Satyabrat Malla Bujar Baruah
LG Software & Electronics, Bengaluru

Beginning with the era of Deep Learning Dominance, the pivotal role of architectures like Convolutional Neural Networks and Recurrent Neural Networks is emphasized, reshaping capabilities in image recognition, natural language processing, and strategic decision-making. The discussion transitions to the critical need for transparency through Explainable AI (XAI), elucidating techniques like LIME and SHAP that provide insights into model predictions, fostering trust in AI systems. Privacy concerns lead to the exploration of Federated Learning, a trend allowing collaborative model training across decentralized devices, reducing data exchange, and enhancing privacy. The democratization of ML takes center stage with AutoML and Hyperparameter Optimization, empowering a broader audience to engage with ML through automated tools and optimization techniques. Versatile strategies such as Transfer Learning and Pre-trained Models expedite model development by leveraging knowledge from one task to another, illustrated by examples from natural language processing applications. The presentation navigates to Edge AI and On-device Learning, showcasing the deployment of lightweight models on edge devices for real-time processing, reduced latency, and enhanced privacy. Ethical considerations, discussed in Ethical AI and Bias Mitigation, provide strategies to identify and mitigate biases, ensuring the fair and responsible deployment of AI technologies, especially in sensitive areas like recruitment. This journey not only examines technological advancements but also serves as a call to action for stakeholders to contribute responsibly and strategically to the future of ML.

email: baruah.satyabrat@gmail.com

Cascaded dynamics of a periodically driven dissipative dipolar system

Saptarshi Saha *and Rangeet Bhattacharyya †
Department of Physical Sciences, Indian Institute of Science Education and Research Kolkata, Mohanpur, 741246, West Bengal, India

Recent experiments show that periodic drives on dipolar systems lead to long-lived prethermal states. These systems are weakly coupled to the environment and reach prethermal states on a timescale much shorter than the timescale for thermalization. Such nearly closed systems have previously been analyzed using Floquet formalism, which shows the emergence of a prethermal plateau. We shall demonstrate that a fluctuation-regulated quantum master equation (FRQME) can adequately describe these systems [1]. In addition to the system-environment coupling, FRQME successfully captures the dissipative effect from the various local interactions in the system. Our investigation reveals a cascaded journey of the system to a final steady state. The cascade involves a set of prethermal or arrested states characterized by a set of quasiconserved quantities. We shall show that these prethermal states emerge in a timescale much shorter than the relaxation timescale. Critical limit beyond which the prethermal plateau ceases to exist will also be shown.

Next, we use the above framework to analyze discrete time-crystalline (DTC) phases in the dissipative dipolar systems subjected to a two-pulse excitation scheme. We find that the effects of driven-dipolar relaxation lend stability to the dynamics and are directly responsible for the robustness [2]. Our results are in good agreement with the recent experimental findings in dipolar systems using nuclear magnetic resonance spectroscopy. Finally, we provide an estimate how the DTC performance degrades with temperature.

References:

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Intensity modulated inexpensive sensing schemes in translational research domain

R. Biswas

Applied Optics and Photonics Research Laboratory, Tezpur University, Napaam-784028, Assam,

Impregnating waveguides with suitable functional elements facilitates copious qualitative as well as quantitative sensing procedures. The majority of cases engage the interaction procedure through non green route. On the contrary, entailing the green route is a promising as well as challenging task. Accordingly, intensity modulated cost-effective sensing routes for determination of volatile organic compounds as well as aquatic pollutants are devised herein. The schemes, entailing a biodegradable functional element, have been proven to be highly functional and cost-effective as compared to other existing approaches. Excellent selectivity as well as specificity of target analytes remain one of the exquisite properties of these sensing routes. others. Based entirely on intensity modulation, these green based routes are found to possess superior sensitivity. They prove to be a good replacement for traditional ones.

email: rajib@tezu.ernet.in

Transition Metal Alloys as Sustainable Alternatives to Rare Earth Permanent Magnets applications

J.P.Borah

Department of Science and Humanities (Physics) , NIT Nagaland

The demand for rare-earth (RE)-free permanent magnets (PMs) is growing due to China's monopoly on RE elements. PMs are increasingly utilized in advanced technologies, including electric motors, magneto-mechanical devices, and biomedical apparatus. Currently, the PMs market is predominantly divided between hard ferrites and Nd-Fe-B/SmCo magnets, with a noticeable performance gap between these two magnet types. Consequently, considerable efforts have been directed towards developing new non-RE based materials and enhancing known magnetic materials to bridge the performance gap between RE PMs and hard ferrite magnets.Various RE-free PMs have been previously developed, such as MnAl, MnBi, Co-rich alloy-based nanocomposites, Co-carbides, Fe-chalcogenides, etc. The essential criteria for evaluating PM suitability include a high Curie temperature, high saturation magnetization, high magnetocrystalline anisotropy constant, and

maximum energy product ((BH)max). Extensive efforts have been made to improve coercivity and magnetocrystalline anisotropy energy by modifying the composition and electronic structure of RE-free PMs to achieve high (BH)max.. In this talk, In this talk, I will first introduce the fundamental criteria for evaluating materials' suitability in permanent magnet applications. Subsequently, I will discuss the enhancement of magnetocrystalline anisotropy, thermal stability, and other magnetic parameters in some Fe and Mn-based alloys through site and interstitial metal substitution.in reference to the recent findings.

References:

[1]. Khoveto Vero, Riyajul Islam, J P Borah, First-principles study on the enhancement of structure stability and magnetocrystalline anisotropy energy of L10-ordered Mn1−xFexAlC compound for permanent magnet application, Journal of Applied Physics, 134, 153902 (2023)
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Supersonic thermal plasma expansion method for synthesis of lithium-based core shell nanoparticles

[1,2]Biswajit Bora
[1]P[2]mc, [2]Comisión Chilena de Energía Nuclear, Santiago, Chile
[2]Universidad Andrés Bello, Departamento de Ciencias Fisicas, , Santiago, Chile.

Different kind of plasma technique had been widely used in material processing industries, starting from coating to nanomaterial production. Out of which, supersonic thermal plasma expansion technique has versatile applications in production of core shell nanoparticles in industrial scale. Plasma torch is generally used to generate directed flow of thermal plasma. The plasma could be exhaust either to open air or to a closed chamber with wide range of pressure range. The thermal plasma torch, where the plasma has very high enthalpy or sustain thermal equilibrium have very high neutral/gas/ion temperature. The high temperature involve in the thermal plasma torch makes it applicable for wide range of application like plasma cutter, waste treatment, melting, material science research, nanoparticle fabrications etc. Once the directed flow of thermal plasma is allowed to accelerate with supersonic velocity through a conversing nozzle by maintaining sufficient pressure difference, the thermal plasma expands towards the low-pressure chamber, and the plasma is cool down rapidly producing supersaturation of the containing vapor, consequently, produce superfine nanoparticles. In this presentation, supersonic thermal plasma expansion method to synthesis different kind of nanoparticles will be discussed. Additionally, preliminary results of core shell lithium-based nanoparticles produced by supersonic thermal plasma expansion method will be presented.

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Survival dynamics of a prey swarm under a predator attack

Rumi De *[1]
[1]Department of Physical Sciences, IISER Kolkata, Mohanpur, Nadia 741246, West Bengal, India

Cohesive group formation has been observed in diverse species, for example, a flock of birds, a school of fishes, a swarm of insects, and an aggregate of cells, to name a few. In nature, swarming behavior has generally been found in search of food, for breeding, to avoid predators, etc. It is quite intriguing how a large number of individuals self-organize to form collective groups and generate complex organized patterns. In this talk, I will discuss how simple computational models, namely self-propelled particle models, help get an insight into the underlying dynamics of a prey swarm under a predator attack. Our study shows that the varying range of interaction strongly influences the trajectory of prey when chased by a predator and affects the survival probability of the prey group [1]. Further, the analysis shows how inertia plays a pivotal role in the survival dynamics of the prey swarm. The prey group survival as a function of predator-to-prey mass ratio shows the existence of three distinct regimes: (i) frequent chase and capture leading to the non-survival of the prey swarm, (ii) an intermediate regime where competition between pursuit and capture occurs, resembling an arms race, and (iii) the survival regime without the capture of prey. Interestingly, our study demonstrates the existence of a favorable predator-prey mass ratio for efficient predation, which corroborates with the field studies [2].

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*email: rumi.de@iiserkol.ac.in

Sillen Aurivillius phases for energy harvesting applications

Ujjal K. Gautam*
Department of Chemical Sciences
Indian Institute of Science Education and Research Mohali
SAN Nagar, Sector 81, Punjab 140306

The layered Sillen-Aurivillius (SA) oxyhalides consist of layers of fluorite [Bi2O2], perovskite [An−1BnO3n+1], and halide [X] (A: Sr2+, Bi3+, etc.; B: Nb5+, Ta5+, etc.; n = 1,2,3, etc.). Their many advantages include, besides immense structural flexibility, a high photostability and a narrow band gap (~2.5 eV). Using these materials, in this talk, I will counter two common notions: (i) that all photocatalysts degrade upon use by taking two reactions: H2O2 photo-production and rhodamine-B (RhB) photo-degradation; (ii) that the RhB-degradation lacks any commercial prospects even after 54 years of research by showing that SA phases convert RhB to Rhodamine-110 (Rh110), a highly expensive and important fluorophore and while doing so, it continue to improve its activity for ~300 h due to a leaching induced 'self-activation' process. The commercial production of Rh110 is challenging due to the formation of various side-products originating from the presence of the two labile amino side groups, leading to purification difficulties, low yield, and high costs. We have been able to produce Rh110 from RhB using Bi4TaO8Br as a photocatalyst. The catalyst is not just stable over 30 catalytic cycles but also gets activated continuously in successive cycles to produce a reaction yield up to 88%.

Similarly, we have used them for the conversion of O2 from air to H2O2 with a high production rate of ~3 mmol/h/g (17.5% photon conversion). Here too, the catalyst gets consistently activated continuously to increase the H2O2 yield by >200% to 6.5 mmol/h/g, unlike other catalysts for H2O2 production.

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e-mail*: ujjalgautam@iisermohali.ac.in

Engineering Multifunctional Molecular Magnetic Materials

N. Gogoi
Department of Chemical Sciences, Tezpur University, Napaam-784028, Sonitpur, Assam, INDIA.

Since the discovery of room temperature magnetism in Prussian blue analogues, cyano bridged extended solids as well as molecular aggregates have gained particular importance in construction of multifunctional molecular magnetic materials [1-2]. Our research group adopts a two-pronged approach to infuse multifunctionality in cyano bridged heterometallic architectures. The first strategy focus on enhancing uniaxial magnetic anisotropy of the transition metal ions involved in cyano bridged assemblies via subtle tuning of local coordination geometry [3]. Experimental as well as computational studies are carried out to understand key factors which govern the magnitude of uniaxial magnetic anisotropy and thereby possible approaches to enhance this important characteristic are conceived [4-5]. The second and more diversified approach to design multifunctional molecular magnetic material involve functionalization of the organic capping ligands typically employed to control the dimensionality of cyano bridged architectures. We have successfully employed both of these two approaches to fabricate cyano bridged architectures with multifunctional characteristics and the results will be elaborated in this lecture [6-7].

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e-mail: ngogoi@tezu.ernet.in

Colloidal Metal Halide Perovskites Nanocrystals: Post-synthetic Alloying for Composition Tuning beyond Thin Film Perovskites

Abhijit Hazarika

Department of Polymers & Functional Materials,

CSIR-Indian Institute of Chemical Technology, Hyderabad-500007

Within the realm of emerging inorganic semiconducting materials, metal halide perovskites (MHPs) stand out as a highly promising system, particularly in the domain of photovoltaic (PV) technologies. MHPs, with general chemical formula ABX3, have emerged as an exceptionally compelling category of solution-processable semiconductors over the past decade. They inherently possess a myriad of desirable characteristics, including high light absorption coefficient, extensive charge carrier diffusion, and low exciton binding energy, making them an ideal candidate for solar absorber materials. In confined dimensions, the 3D colloidal Quantum Dots (QDs) of MHP materials present additional advantages not achievable in their bulk or thin-film counterparts. For instance, although geometrical factors like Goldschmidt Tolerance Factor (GTF) do not favor formation of 3D structure of CsPbI3 with corner-shared [PbI6]4- octahedra in ambient conditions, such structure can be stabilized in colloidal nanocrystalline form. Similarly, alloy compositions like Cs1-xFAxPbI3 or Cs1-xFAxPb(Br1-xIx)3 can be synthesized in colloidal nanocrystalline form for any arbitrary value of "x". Such flexibility is often absent in the corresponding bulk/thin-film materials. The ability to exert synthetic control and manipulate compositions at will not only facilitates the tuning of optoelectronic properties by expanding the compositional space of MHPs but also opens up unique opportunities for designing Quantum Dot Solar Cells (QDSCs) that can complement thin-film Photovoltaic Solar Cells (PSCs). In this presentation, we will delve into the intricacies of post-synthetic alloying, showcasing how it enables the arbitrary manipulation of compositions in MHP quantum dots through the interparticle cross-exchange of A and X-site cations. This manipulation, in turn, allows us to fine-tune photoluminescence emission across the visible and near-infrared (NIR) range of the electromagnetic spectrum.

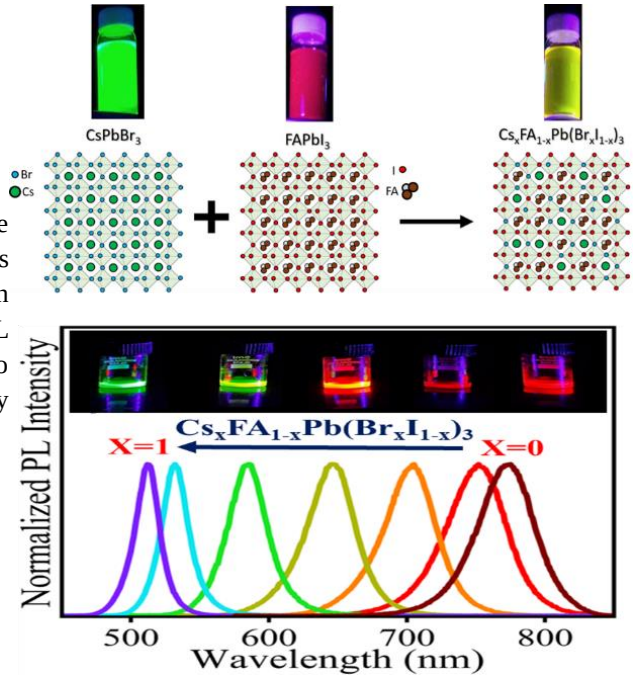

Figure 1: (Top panel) Schematic diagram showing the formation of phase stable CsxFA1-xPb(BrxI1-x)3 NCs via A & X site cross ion exchange reaction between CsPbBr3 & FAPbI3 NCs. (Bottom panel) Steady state PL emission spectra showing the tunability over green to NIR, the inset showing digital photograph of alloy compositions under UV illumination.

*email: abhijit@iict.res.in

Ergotropy of incoherent quantronic energy transferers

Manash Jyoti Sarmah, Javed Akhtar, Himangshu Prabal Goswami*

Department of Chemistry, Gauhati University

Quantronic or quantum electronic systems are nonequilibrium quantum systems where energy is exchanged in the form of antibunched photons between a system and multiple environments in the presence of electronic systems states. The environment is usually unstructured (resembling a heat or electronic reservoir) with little or no coherences between the reservoir states. A classic example is the entire photosynthetic reaction center either I or II. Energy exchange processes between the system and the environments are not only of the Frank-Condon like vertical excitations, but are also accompanied by nonvertical transitions or transitions due to incoherent energy transfer or presence or oriental disorder [1]. Most of such transitions are usually averaged out owing to randomness, but a few of these transitions survive especially due to some specific nature of coupling between system and reservoir states.

There is no lively theory which majestically captures such extreme events and allows the structuring of an analytical understanding of energy or particle exchanges. In the presence of degeneracy, the nonequilibrium nature of the entire quantronic system is responsible for creating quite an exotic effect due to an asymmetrical nature of coupling between system and reservoir, i.e coupling the populations and coherences. These coherences are sometimes short-lived or may be long-lived. Long lived coherences usually dominate when competing internal processes slow down the fast dephasing processes, eg. secondary vibronic coupling or coupling of a few system modes to specific modes of vibration. This introduces a fictitious structure around those states involved directly in the system-reservoir exchange channels. This introduced reservoir structuring is an artefact of designing a controllable quantronic system to meet a specific purpose, eg. acting to be an engine or thermoelectric device or a point contact junction etc. The external control generates an internal degree of freedom which goes beyond control: the birth of nonvertical transitions and these affect the controllable observables like flux, efficiency, power, noise etc in an unknown manner, i.e a trade-off.

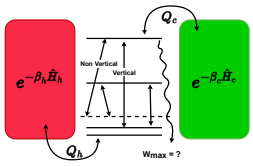

Figure 1: A nonequilibrium coherent quantum system coupled to two unstructured environments. The nonvertical transitions are energy exchange processes in the system that happen through populations getting coupled to coherences.

Since external control introduces a lack of internal control, the usability of a quantronic device is rather limited to how much Helmholtz free energy (the usable work) is available when energy transfers take place within and beyond the Frank-Condon like transitions. If a particular initial state of the quantronic system doesn't allow efficient energy transfer, i.e no work can be done, it is rendered passive while if work can be done, the state is active. Ergotropy is the maximum work that can done by an active state of the quantronic system. The role of incoherent transitions on ergotropy becomes the primary point of investigation and is the subject behind the talk [2]. The way we can visualize the role of nonvertical transitions on the maximum possible work that can be attained in quantronic energy transferers within the framework of a simplistic (not holistic) picturesque shall be discussed in this work.

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*email: hpg@gauhati.ac.in

Microwave Carbonization of Samanea Saman Biomass for the Development of Zinc-ion Supercapacitor Electrode

Saswati Sarmah, Biraj Kumar Kakati*

Department of Energy, Tezpur University, Tezpur – 784 028, India

Biomass derived activated carbon is a promising electrode material for supercapacitor owing to its superior properties such as high surface area, good conductivity, and porous morphology. The present study utilizes Samanea saman biomass as the source for the synthesis of N, S co-doped activated carbon (NSMAC) via combined hydrothermal and microwave carbonization method. The morphological and BET analyses of the NSMAC reveal a high surface area, porous structure which aids in ion transport leading to a high specific capacitance of 495 Fg−1 at 1 Ag−1 in Na2SO4 electrolyte. A NSMAC/MnO2 composite cathode was later developed using microwave heating for the fabrication of a Zn-ion supercapacitor. The physico-chemical properties of the developed NSMAC/MnO2 composite were analyzed with the help of FESEM, XRD, Raman spectroscopy, EDX and XPS.

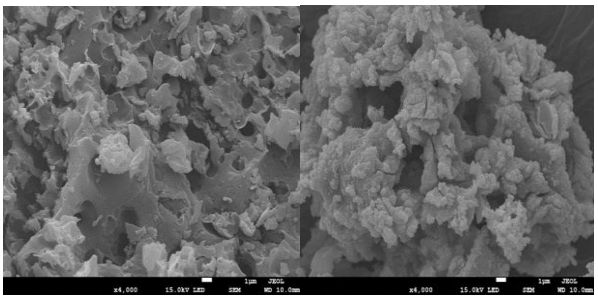

Figure 1: The FESEM micrographs of synthesized (a) NSMAC and (b) NSMAC/MnO2 composite

The FESEM micrographs of synthesized NSMAC and its composite are shown in fig. 1. The hierarchically porous structure of the synthesized NSMAC and its composite is evident in the micrographs. This kind of structure helps in good capacitance retention. The cyclic voltammograms of the synthesized NSMAC and NSMAC/MnO2 composite electrodes in Na2SO4 electrolyte are shown in fig. 2. The developed NSMAC/MnO2 composite cathode exhibited a specific capacitance of 574 Fg−1 (@1 Ag−1) with 143.5 Whkg−1 energy density at 900 Wkg−1 power density in Na2SO4 electrolyte along with high capacitance retention as compared to neat NSMAC electrode (fig. 3). The specific capacitances of both the electrodes in ZnSO4 electrolyte were found to be 117 and 290 Fg−1 (@1 Ag−1), for the neat NSMAC and NSMAC/MnO2 composite, respectively. The specific capacitance of the composite electrode is found to be better than those reported Qui et al. (2022) [1].

Finally, a two-electrode prototype Zn-ion supercapacitor was fabricated using Zn foil as the anode and developed NSMAC/MnO2 composite as the cathode showing energy density of around 90 Whkg−1 at 0.5 Ag−1.

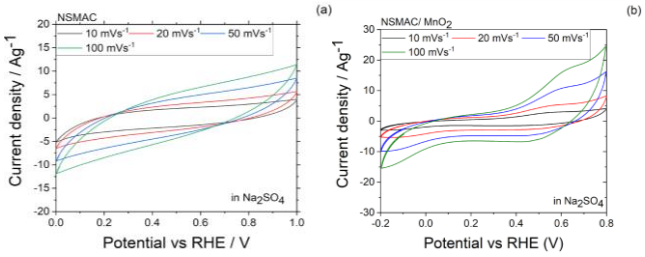

Figure 2: Cyclic voltammograms of synthesized (a) NSMAC and (b) NSMAC/MnO2 composite electrodes in a three-electrode electrochemical test

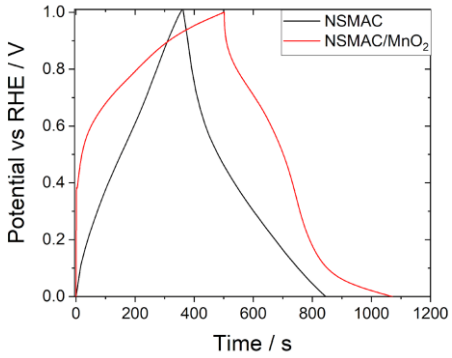

Figure 3: Galvanic charge-discharge of NSMAC and NSMAC/MnO2 composite electrodes in Na2SO4 electrolyte

Therefore, microwave assisted synthesis of activated carbon and its composite may be an efficient alternative to develop electrodes for Zn-ion supercapacitor. The electrochemical study of the developed composite electrode showed an impressive power density of 900 Wkg−1 in a controlled discharge current of 1 Ag−1. Therefore, there is a scope of using this electrode for the development of a high-performance Na-ion supercapacitor.

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* email: bkakati@tezu.ernet.in, biraj@outlook.com

Prosthetic Hand: Commercial versions vis-à-vis TU Bionic Hand

Nayan M. Kakoty
Department of Electronics & Communication Engineering, Tezpur University

This session will focus on the journey starting with the aim for development of a low-cost electromyogram (EMG) controlled prosthetic hand at Tezpur University leading to the completion of its clinical testing and undergoing pilot testing. It will sight indigenous prosthetic hands vis-à-vis commercial versions in international scenario. Emphasizing the contribution to the service for the individuals with limb amputations in India, this talk will also include a glimpse of a recently started work on brain computer interface-based control of prosthetic hand.

email: nkakoty@tezu.ernet.in

Modification of Electronic Properties of MgO Monolayers for Desired Applications

Rituparna Hazarika and Bulumoni Kalita
Department of Physics, Dibrugarh University, Assam 786004, India

Two-dimensional (2D) hexagonal graphene-like materials mark great potential in various areas of modern nanotechnology. One of the latest research interests is the band gap engineering in atomically thin monolayer monoxides to satisfy the requirements of different applications of modern nanotechnology []. Based on DFT calculations, we propose oxygen vacancies; substitution of non-metallic elements and increment in number of layers as effective ways for alteration of the electronic band structure in MgO monolayers (ML) to become suitable for optoelectronics and spintronics [-]. It has been observed that concentrations as well as position of oxygen vacancy defects significantly alter the electronic energy band structure of MgO MLs [2]. Substitutional doping and co-doping of 2p elements such as B, C, N in both Mg and O sites is also effective in introducing huge alteration in the electronic structure of ML systems [3,4]. Doping introduces magnetism in the non-magnetic pristine MgO monolayers even converting its semiconducting nature to metallic in some of the doped systems. Further, bi- and tri-layered MgO undergo reduction in electronic band gap compared to the MgO ML. The modified electronic structure renders MgO monolayer effective in optoelectronics covering IR to visible range of the electromagnetic spectrum and also in spintronics.

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*email: rituparnahazarika277@gmail.com, bulumoni@dibru.ac.in

Probing magnetism in novel materials through neutron diffraction

S. D. Kaushik
UGC-DAE Consortium for Scientific Research, Mumbai Centre, BARC, Mumbai – 400085 INDIA

Research in identifying microscopic cause of magnetism in various compounds have always fascinated research group across the world. These days Multiferroic materials are being seen as savior in quest of achieving high capacity data storage with less space, among various other technological applications, due to their unique property, where electric and magnetic properties may be coupled which provide opportunities to induce and control multiferroic behavior.
Perovskite based materials have shown quite promising results. In this lecture I will talk about some of the recent results on perovskite and some novel materials which have been characterized through neutron diffraction, which itself is a unique probe to study the magnetism in the material. Through temperature and magnetic field dependent neutron diffraction, the correlation in physical and structural (crystal as well as magnetic) properties have been identified. In addition to this the basics of neutron diffraction technique along with some other recent results will be discussed in which magnetic structure study has been reported by us.
The knowledge of temperature dependent evolution of microscopic parameters determined form the analysis of temperature dependent neutron diffraction enable us to understand the physical property more comprehensively.

email: sdkaushik@csr.res.in

Curvature-induced waves in polar flocks

Siddharth Jha *[1,2], S J Kole †[1], Sriram Ramaswamy ‡[1], and K Vijay Kumar §[3]
[1]Dept of Physics, Indian Institute of Science, Bengaluru 560012, India
[2]Dept of Physics & Astronomy, University of California Los Angeles, CA 90095-1547, USA
[3]International Centre for Theoretical Sciences, Bengaluru 560089, India

Polar ordering is ubiquitously seen across soft-condensed matter. Phases of living materials such as bird flocks, collections of motile cells, or tissues with planar-cell-polarity are archetypal examples of polar active matter. The source of activity in such systems can, typically, be traced to non-reciprocal interactions. Recent work in developing embryos has highlighted the tight couplings that exist between orientational ordering and the geometry of the underlying surface. Motivated by these phenomenon, we study a minimal model of a polar flock on a curved surface. We show, by a combination of analytical and numerical techniques, that the interplay of curvature and non-reciprocality leads to striking effects including vortex-aster transitions and self-sustained wavelike oscillatory states. By providing a geometrical interpretation for the active self-advection effects, we develop a physical understanding that intuitively explains these dynamical states of the polarity field.

email: *siddharth@physics.ucla.edu,†swapnilkole@iisc.ac.in, ‡sriram@iisc.ac.in, §vijaykumar@icts.res.in

Ultrafast THz pulses from transient currents in metallic heterostructures

Sunil Kumar
Femtosecond Spectroscopy and Nonlinear Photonics Group
Department of Physics, Indian Institute of Technology Delhi, India

Terahertz (THz) time-domain spectroscopy using efficient sources and detectors of THz radiation has become a powerful experimental tool for non-destructive testing of materials and can be used to probe various fundamental linear/nonlinear physical processes. In modern applications, compact and efficient THz sources and detectors are in demand which are cost-effective and can be applied in a broad frequency range. Femtosecond laser excited spintronic heterostructures have emerged as a potential candidate for powerful and broadband THz radiation sources. Increasingly popular systems in this regard are the bi- and tri-layer combinations of thin films of ferromagnetic (FM) metal and nonmagnetic (NM) heavy metal.

Inverse spin Hall effect (ISHE) in the NM layer is majorly considered as the main mechanism to develop a transient current source which emits THz radiation. We have used THz emission spectroscopy to study the evolution of the THz emission from modified heterojunction in such heterostructures. In this talk, I will discuss some of the recent results from our laboratory [1-5].

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*email: kumarsunil@physics.iitd.ac.in

Magnetic helix – A new possibility to explore

Santanu K. Maiti*

Physics and Applied Mathematics Unit, Indian Statistical Institute, 203 Barrackpore Trunk Road, Kolkata-700 108, India

Magnetic helix (MH) structure can be a role model for future spintronic devices. Utilizing the advantage of constructing possible magnetic configurations, we investigate, for the first time, spintronic behavior in a helical geometry with finite magnetic ordering.The interplay between short- and long-range hopping of electrons yields many nontrivial features which are thoroughly studied. Quite interestingly, we see that the MH exhibits the strong chiral-induced spin-selectivity effect, like what is observed in chiral molecules. Finally, to make the model more realistic, we also examine the effect of helical dynamics. All the results are valid for a wide range of physical parameters, which proves the robustness of our analysis.

*e-mail:santanu.maiti@isical.ac.in

Polarization Resolved Second Harmonic Generation (SHG) Microscopy for investigating macromolecules

Indira Govindaraju[1], Ishita Chakraborty[1], Sindhoora Kaniyala Melanthota[1], Guan-Yu Zhuo[2,3], Sib Sankar Mal[4], Bhaswati Sarmah[5], Vishwa Jyoti Baruah6, Krishna Kishore Mahato1, Nirmal Mazumder[1],*

[1]Department of Biophysics, Manipal School of Life Sciences, Manipal Academy of Higher Education, Manipal-576104, India

[2]Institute of New Drug Development, China Medical University, No. 91, Hsueh-Shih Road, Taichung 40402, Taiwan

[3]Integrative Stem Cell Center, China Medical University Hospital, No. 2, Yude Road, Taichung 40447, Taiwan

[4]Materials and Catalysis Lab, Department of Chemistry, National Institute of Technology Karnataka, Surathkal, Karnataka, India-575025

[5]Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat, Assam, 785001, India

[6]Centre for Biotechnology & Bioinformatics, Dibrugarh University, Assam-786004, India

We developed a four-channel photon counting based Stokes polarimeter for spatial characterization of polarization properties of Second Harmonic (SH) light. In this way, the critical polarization parameters can be obtained concurrently without the need of repeated image acquisition. Various polarization parameters, including the degree of polarization (DOP), the degree of linear polarization (DOLP), and the degree of circular polarization (DOCP), are extracted from the reconstructed 2D Stokes vector based SH images in a pixel-by-pixel manner. The Stokes vector measurements are further extended by varying the polarization states of the incident light and recording the resulting Stokes parameters of the SH signal. In turn this allows the molecular structure and orientation of the samples including collagen fibers, skeletal muscle fiber, and starch granules. The combination of SHG microscopy and Stokes polarimeter hence makes a powerful tool to investigate the structural order of targeted specimens.

*email ID: nirmal.mazumder@manipal.edu

Neural-network quantum state (NQS) based variational wavefunction for strongly correlated electron systems

Amal Medhi
Indian Institute of Science Education and Research
Thiruvananthapuram, Kerala 695551, India

The variational Monte Carlo (VMC) is a powerful numerical technique to study the ground state of quantum many-body Hamiltonian such as the Hubbard model. It is applicable for a wide range of parameters and has no fermionic sign problem that restricts some other numerical techniques. However, the disadvantage of VMC is that the results are biased by the choice of the variational wave function. Recently, there has been intense research interests in using the machine learning (ML) technique to study condensed matter systems. In particular, it has been shown that artificial neural-network (ANN) can be used to represent the wave function of quantum many-body systems efficiently. An important advantage of using neural-network quantum state (NQS) as a variational wave function is the possibility to construct an wave function which is unbiased and potentially accurate representation of the true ground state. Though NQS wave functions for bosonic systems have been studied in numerous works, the same is not the case for fermionic systems. This is because there is a key limitation in the NQS representation in the sense that, though neural networks can represent complicated non-linear functions, it fails to correctly reproduce the sign structure of a quantum many-body wave function in general. The problem is more severe for fermionic systems. In this talk, we will discuss our recent works on application of various artificial neural-network based wave functions to represent the ground state of the fermionic Hubbard model on one and two dimensional lattice.

Chemiresistive Gas Sensor: Prospects and challenges

Biplob Mondal
Department of ECE, Tezpur University

Rapid growth in industrialization, advancement in manufacturing technology and transportation, improper waste management, uncontrolled urbanization has caused in severe increase in the concentration of hazardous and toxic chemicals/gases into the atmosphere. This has negatively impacted the environment and has detrimental effects on human health, plants, and other animals. Accurate and timely detection of such harmful substances is important for creating healthy and safe household/industrial environments, product control in manufacturing plants, and agricultural and food quality control. Over the past few decades, semiconductor chemiresistive gas sensor could witness a great technological development and dominated the market in recent times. Nevertheless, chemiresistive gas sensor still faces a lot of challenges to meet the recent times demands of being lightweight and flexible for wearable applications, mechanically robust, amenable to wide environmental variation, humidity tolerant, low powered or self-powered and self-cleaned, In this talk limitations and technological challenges in sensor fabrication, emerging material and scope for practical integration as well as the futuristic strategy for material design delivering unique properties, and innovative growth techniques will be highlighted. The factors affecting performance and technique and mechanism for enhanced performance will also be discussed.

Turbulence in a dense suspension of polar, active swimmers

Prasad Perleker

TIFR Hyderabad

We study the effects of inertia in dense suspensions of polar swimmers. The hydrodynamic velocity field and the polar order parameter field describe the dynamics of the suspension. We show that a dimensionless parameter R (ratio of the swimmer self-advection speed to the active stress invasion speed) controls the stability of an ordered swimmer suspension. For R smaller than a threshold R1, perturbations grow at a rate proportional to their wave number q. Beyond R1, we show that the growth rate is O(q2) until a second threshold R=R2 is reached. The suspension is stable for R>R2. We perform direct numerical simulations to investigate the steady state properties and observe defect turbulence for R<R2.

*email: perlekar@tifrh.res.in

Quantum Simulation of Localized Matter Waves and Applications

Utpal Roy

Department of Physics, Indian Institute of Technology Patna, Bihta-801106, India

Bose-Einstein condensate (BEC) is a highly tunable and coherent matter wave, which opens up a huge possibility towards numerous emerging areas, including quantum simulation and quantum sensing. Applications of BEC as quantum simulator mostly rely on the optical lattices which can efficiently be engineered due to the unprecedented progress in the experimental front. External confinement also plays a vital role for unraveling the formation mechanism of various localized and nonlinear excitations in this system. However, investigating the formation and dynamics of such system through exact theoretical approach becomes quite nontrivial due to its nonlinear nature. Various experimentally tested trap profiles will be considered to generate localized and stable excitations, which are useful in advanced applications in quantum information sciences. In this talk, I will emphasize on the formation, control and trap engineering of solitons, rogue waves, Anderson localized ultracold clouds, their quantum simulation and technological implications.

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email: uroy@iitp.ac.in

Medical Robotics: The Next Generation Health Care

Abhijit Chandra Roy
Research and Management Lead
Q-Line Biotech Private Limited
Technopark IIT Kanpur

In the realm of advanced healthcare, it is foreseen that humanoid robots will play pivotal roles, not solely during health crises such as COVID-19 but also as fundamental components integrated into hospital and healthcare systems as a standard practice. Despite their potential in healthcare applications, these robots currently lack essential medical capabilities, notably the absence of a large-area soft sensory organ akin to human skin. As a result, they can't sense a gentle touch, nor can they gauge wherefrom of the touch. Imagine deploying one of these mechanical beings in a hospital or healthcare setting. The risk of unintentional harm to patients, doctors, nurses, and anyone in close proximity is simply irrefutable.

To address this impending issue, during the COVID-19 pandemic, we proposed a solution: the development of a soft artificial skin using a soft, flexible and transparent material, achieved through collaboration between field of contact mechanics, optics, electronics, and computer science. Our research encompasses a robust 3D-printable large-area electronic skin constructed from a soft and resilient polymer. This electronic skin exhibits exceptional sensitivity to touch, load, and bending, with sensitivity levels reaching up to 150 kPa^(-1) for touch and load detection—750 times greater than previous reports. Furthermore, our soft electronic skin demonstrates remarkable long-term stability, maintaining consistent performance for nearly a year. Importantly, we have devised a cost-effective fabrication process capable of producing significant quantities of large-area electronic skin.

The soft electronic skin is comprised of a specially designed optical waveguide combined with a layer of a flexible membrane housing an array of soft structures, which function as passive sensing nodes. The use of soft structures allows the electronic skin to stretch without causing disconnections among the sensing nodes. We have conducted comprehensive tests and validations to demonstrate the functionality of this soft electronic skin across various scenarios.

*email: abhijit.ch.roy1@gmail.com

Helium clustering and role of vacancy in CuZr alloy

Dhrubanka Sarma [a,b] , Ujjal Saikia[c] , Munima B. Sahariaha,[b],*

[a]Institute of Advanced Study in Science and Technology, Guwahati, Assam-781035, India

[b]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh 201002, India

[c]Max-Planck-Institut für Eisenforschung, Max-Planck-Straße 1, 40237, Düsseldorf, Germany

Helium induced degradation of structural materials is a major concern for materials operating for a long time under extreme radiation environments. In order to prevent such degradation, it is important to understand how He interacts with the host atoms and with itself inside the host environment. The presence of defects such as vacancies and their interaction with He is also important here as these defects may act as a source of nucleation for the clustering of He. Ab initio calculations have been used to understand the behaviour of He inside CuZr crystalline alloy in the B2 phase with equal atomic ratio. The formation of metallic vacancy, He interstitial, and vacancy-He complex have been investigated systematically to understand the trapping and binding behaviour of He. The obtained results reveal that the interstitials play a significant role in the formation of Cu and Zr vacancy and the presence of vacancy in turn effects the clustering.

Participants

Study of Pseudo-Hermitian Hamiltonians for 2-Level Systems

Stalin Abraham*[1] and A. Bhagwat†[2]

[1,2]School of Physical Sciences, UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, Mumbai 400098, India

Non-Hermitian quantum mechanics has a long history, with applications in several areas of physics, including Nuclear Physics, Atomic Physics, Condensed Matter Physics and Quantum Computing. One of the key ideas behind the non-Hermitian quantum mechanics is to study dissipative systems through the Hamiltonian operators that are not Hermitian. In the late 90's, Karl Bender (Ref. [1]) studied in detail a class of the non-Hermitian operators having real eigenvalues, by weakening the requirement of Hermiticity to being PT-symmetric where P and T are parity and time reversal operators respectively . This led to development of PT-symmetric Quantum Mechanics (PTQM). Later more studies on PT-symmetry has been carried out by many including Mostafazadeh (Ref. [2]).

One of the interesting features of the PTQM is that spectrum of the un-broken PT-symmetric non-Hermitian Hamiltonian is real. Under the condition of broken PT-symmetry, some of the eigenvalues become complex, thereby allowing one to describe systems with dissipation. The present study focuses on such operators defined on finite dimensional vector spaces over the field $\mathbb{C}$. The PT-symmetric operators belong to a broader class of operators, called pseudo-Hermitian operators. The set of all pseudo-Hermitian matrices belonging to $\mathbb{M}_2(\mathbb{C})$ is being investigated in detail. A few results that we obtained are summarised below. Pseudo- Hermitian matrices are defined as follows:

Definition: Let $G \in \mathbb{M}_n(\mathbb{C})$ such that $G^\dagger = G$ and $\det(G) \neq 0$.Then a $H \in \mathbb{M}_n(\mathbb{C})$ is said to be G-pseudo Hermitian if

$$H^\dagger = GHG^{-1} \tag{1}$$

Note that for a given G, the matrix H satisfying the above equation and for a given H, the matrix G satisfying the same equation are not unique, i.e, there could exists more than one H, for a given G and more than one G for a given H satisfying the equation. It follows from the above equation that the set of all the matrices H satisfying the above equation for a given G forms a real vector space. But the dimension and other structures of the vector space are not obvious. We therefore investigate the question that for a given G what all the matrices H satisfy the above equation.

It has been known in the literature that all the PT-symmetric matrices are pseudo-Hermitian for some G matrix (as defined in Eq.1). The converse does not hold in general but in the case of matrices from $\mathbb{M}_2(\mathbb{C})$, it has been argued in the literature (Ref. [3]) that a matrix is PT-symmetric if and only if it is G-pseudo-Hermitian. In the present work, we developed an alternative proof of the same result, which enabled us to view all the G-pseudo-Hermitian matrices for a given G as a linear variety of dimension 3. This observation paves the way of studying the G-pseudo-Hermitian matrices more systematically. To begin with, the set of all PT-symmetric matrices in $\mathbb{M}_2(\mathbb{C})$ is partitioned into four cells, S_1, S_2, S_3 and S_4 (see Table (1) for details). For a given $G \in \mathbb{M}_2(\mathbb{C})$, the set of all matrices $H \in \mathbb{M}_2(\mathbb{C})$ satisfying Eq.(1) forms a three-dimensional real vector space, with basis from the cells S_j, such that when $\mathrm{Tr}(G) = 0$, one basis vector is from S_1 whereas the other two are from S_2. On the other hand, when $\mathrm{Tr}(G) \neq 0$, one basis vector is from S_1 and the other two are from S_4.

It is further found that for any two $G_i, G_j \in \mathbb{M}_2(\mathbb{C})$ such that $G_i \neq G_j$, there always exists exactly one trace less $H \in \mathbb{M}_2(\mathbb{C})$ (up to scaling by a constant) which is pseudo-Hermitian with respect to both these G matrices. Set of all the matrices $G \in \mathbb{M}_2(\mathbb{C})$, satisfying Eq.(1), given a specific $H \in \mathbb{M}_2(\mathbb{C})$, turns out to be describable in terms of quadratic varieties.

Table 1: Properties of matrices belonging to the classes S_1, S_2, S_3 and S_4.

Set	Nature of Spectrum	Normal	Diagonalisable
S_1	Real, non-degenerate	Yes	Yes
S_2	Complex conjugate	Yes	Yes
S_3	Real, degenerate	Yes	Yes
S_4	Real, non-degenerate	No	Yes
S_4	Complex conjugate	No	Yes
S_4	Real, degenerate	No	No

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*email: stalin.abraham@cbs.ac.in

†email: ameeya@cbs.ac.in

Structural disordering induced Raman signal signature of room temperature partial zircon to scheelite-type phase conversion in $GdVO_4$ nanosystems upon Eu^{3+} incorporation

Aftab Ansari and Dambarudhar Mohanta

University of Science and Technology Meghalaya, Tezpur University

This work reports on detailed Raman analysis of *zircon*-to-*scheelite* partial phase conversion encountered in $GdVO_4$ nanosystem with Eu^{3+} around permissible substitutional doping. In the low frequency regime temperature dependent inhomogeneous splitting of the low frequency ν_2 vibrational lines has previously been assigned to localized structural disordering caused in the crystal lattice [1]. Interestingly, the line shape is quite asymmetrical and comprises of two modes with one being that of the tetragonal *scheelite*-type structure with space group of $I4_{1/a}$ [2].

At room temperature Raman studies of $GdVO_4$ nanosystem, the overlap of two Raman active modes namely, A_{1g} (scissoring) and B_{2g} (twisting) characterize *scheelite*-type characteristics in the nanosystem under study. Incorporation of Eu^{3+} in the system resulted in enhancing the intensity of the *scheelite*-type characteristics due to possible localized phase transition around Eu^{3+} sites in the matrix. The observed *scheelite*-type signal enhancement and consequently partial *zircon* lattice to *scheelite* lattice conversion due to inclusion of Eu^{3+} doping (1-7 %) has been highlighted and analyzed emphasizing manifested modes in detail.

Table 1. Raman signals observed

Raman shift (cm^{-1})		**Modes assigned**
Internal Vibrations	**ν_2 ~380**	Symmetric V-O stretching or O-V-O bending model
	ν_3 modes ~800-820	Overlap of two E_g and B_{1g} modes.
	ν_2 mode ~880	Vibrational structure (stretching internal vibration in $[VO_4]^{3-}$ anionic group)

To be specific, among the Raman modes featured, the A_{1g} mode is attributed to O-V-O vibration while B_{2g} represents the translatory vibrational mode (~258 cm^{-1}) attributed to the Eu–O stretching.The intense high-frequency mode, ν_2 = 880 cm^{-1} would describe stretching internal vibration in the tetrahedral $[VO_4]^{3-}$ anionic group for an ideal *zircon*-type conformation with tetragonal symmetry. The important Raman modes are enlisted in Table 1.

So far, we have not come across any report that deals with the relative information on the effect of dopant inclusion in the ν_2 Raman mode. While complete conversion is unlikely, partial phase conversion is admissible locally upon Eu^{3+} doping in the host lattice. Thus one must take into consideration the processes of structural disordering while interpreting physical and optical properties of doped $GdVO_4$ nanosystems. A schematic illustration has been included in Figure 1 for better understanding of the conversion detail. The study can be extended with evaluation of temperature and pressure dependency on partial phase transition and its correlation with dopant kind and level. Incorporation and understanding of intentionally introduced partial phase conversion would help modulate decay life times of nanophosphors and also for preparing diagnostic agents.

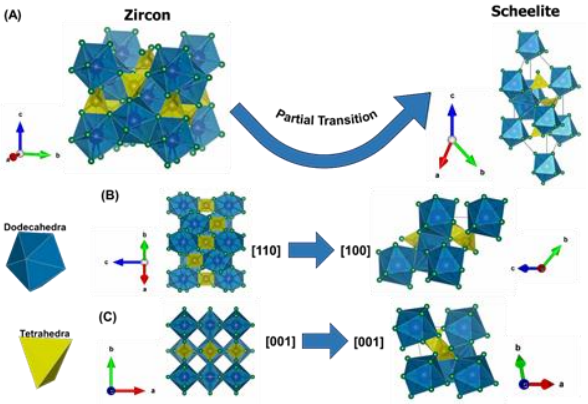

Figure 1: Unit cells are prepared using Vesta® demonstrating (A) transition from zircon to scheelite. The display of change in orientations for projections along the hkl planes [110] to [100] and [001] sharing by the two lattice types shown in (B) and (C); respectively.

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*email:aftyfi9@gmail.com

Ratchet effect in an inhomogeneous Periodic Bistable potential

Shesstarwell k. Bani[1], D. Kharkongor[2] and S. S. Pohlong[1]

[1]Department of Physics Nort-Eastern Hill University, Shillong-793022 [2]Department of Physics St. Anthony's College, Shillong-793001

Ratchet Effect (RE) in a periodic potential with sinusoidal driven force and friction coefficient with phase difference [1-2] . A weak friction coefficient is unlike temperature variation is not expected the yield of RE, to yield RE a Zero-mean applied force is need to apply [3]. previously the current resurgence of investigations, RE was put as an important model to explain material transport in biological systems. In a periodic bistable potential we brought the RE to renewed attention for further studies in material transport [4]. Ratchet Transport is involved when we interplay of symmetry breaking and quenched temporal disorder [5-6]. With respect to phase difference (ϕ) (symmetry breaking) ratchet current is concerned.

Here our system we consider:

Periodic bistable potential
$V(x) = 2/3 \{cos\ (x) + cos\ (2x)\}$

a friction coefficient,
$\gamma(x) = \gamma 0\ [1 - \lambda\ cos\ (x + \phi)]$

and a small applied force
$F(t) = F_0\ cos\ (\omega t)$

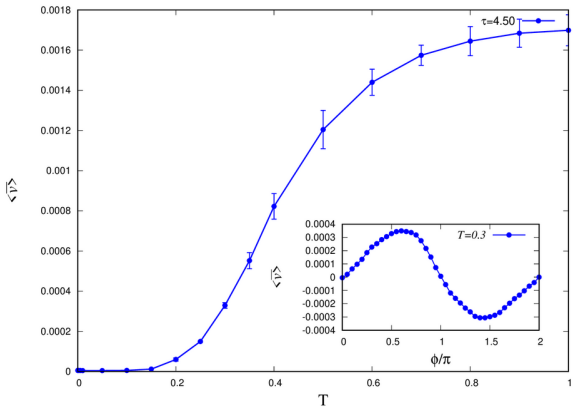

Figure 1: Ratchet effect the change of <v> vs T, the inset is the change of <v> with ϕ

Numerically the investigation of Ratchet Current is defined by the generalized Langevin Equation [7].

$m\acute{v} = F(t) - \gamma(x)\upsilon - \partial v(x)/\partial x + \sqrt{(\gamma(x)T\xi(t))}$

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*email: shesstarwellkharbani@gmail.com

Investigation of electrochemical properties of PEDOT-PSS based composite electrode towards electrochemical sensing

Susmita Baruah*[1], D. Mohanta[1] and C.A. Betty[2,3]
[1]Department of Physics, Tezpur University, Tezpur-784028, Assam, India
[2]Chemistry Division, Bhabha Atomic Research Centre, Mumbai-400085, Maharashtra, India
[3]Homi Bhabha National Institute, Mumbai-400094, Maharashtra, India

Simple electrochemical deposition technique has been employed to synthesize Poly (3,4-ethylenedioxythiophene): polystyrene sulphonic acid (PEDOT-PSS) over ITO electrode by taking graphene oxide (GO) as dopant. Spherical gold nanoparticles (AuNPs) were uniformly decorated on the surface of the GO/PEDOT-PSS/ITO electrode by employing electrochemical layer by layer deposition method [1]. Structural, vibrational and morphological studies of all the prepared electrodes have been carried out by XRD, FTIR, FESEM respectively. The XRD data of pure PEDOT-PSS reveals broad peak located at 25^0 corresponding to (010) plane, peak at 13.36^0 was observed for GO (002) in GO/PEDOT-PSS and the intense peak at 38.29^0 corresponding to (111) was observed for Au in AuNP/GO/PEDOT-PSS/ITO [1,2,3]. The electrochemical studies have been performed by employing a three-electrode system comprising of synthesized electrode as working electrode, platinum as counter electrode and Ag/AgCl as reference electrode. To understand the charge transfer kinetics between the electrode and electrolyte interface the prepared electrodes have been characterized by cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) in a three-electrode setup. Our results indicate that the gold nanoparticles decorated GO functionalized PEDOT-PSS based electrodes provide better charge transfer kinetics as compared with the pristine and binary. Presence of the oxidizing functional groups on the surface of GO makes it suitable for the efficient immobilization of the biomolecules by covalent linkage.

Moreover, deposition of AuNPs over the electrode can enhance the conductivity and charge transport mechanism and may offer better sensitivity and linearity. This study explores AuNP/GO/PEDOT-PSS composite electrodes as an excellent candidate for electrochemical sensing application.

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*[1]email: susmita1@tezu.ernet.in

[1]email: best@tezu.ernet.in

[2,3]email: bettyca@barc.gov.in

Emerging advanced materials for aluminium and potassium based energy storage devices - A review

Ritupurna Baishya[a*]

[a] Department of Physics, Tezpur University, Assam 784028, India.

The insurgence of lithium-ion batteries revolutionized the clean energy transition making the lithium ion-based batteries a household name since 1991 after SONY commercialize it. With the rapid growth of Lithium batteries, they are becoming the leading market share holder to sustain the need for the energy supply as well as storage due to its portability and highly efficient performance. But in the present-day scenario despite the widespread popularity of the lithium-based energy systems, the longevity of the lithium-ion system is encumbered by its availability and supply chain. That is why the modern-day research on energy storage demand diversity and high scalable new battery technologies to mitigate the challenges.

Considering the abundancy, low flammability and its three electron per cation redox electrochemistry leading to its high theoretical capacity, aluminium is gaining popularity in the present-day battery research. Also due to its reduced cost per kWh of aluminium, the viability of the aluminium system is high in comparison to the costly lithium. The aluminium battery research primarily focuses on positive aluminium hosting electrode materials and the electrolyte system. But due to the lack of library of proper host material owing to low standard potential of aluminium the progress in the field of aluminium batteries is somehow halted.

Another field in focus for beyond lithium-ion batteries is potassium ion batteries (PIBs). Potassium possesses some great benefits like high abundance, low cost and most importantly it has a low reduction potential (-2.93 V) compared to sodium (-2.71 V) and this is close to lithium (-3.93 V). But the ionic size of the potassium (1.38 Å) is comparatively larger than the lithium (0.76 Å) and sodium (0.97 Å) ions which results more distinct structural damage during potassiation / depotassiation leading to material dissolution, low cycling stability and capacity fading. Therefore, the main challenge lies ahead for the growth of potassium ion system is to figure out suitable, dissolution free electrode materials.

Herein a brief review on various most promising advanced electrode materials for aluminium and potassium ion batteries have been demonstrated. Along with that various strategies for capacity improvement are also illustrated here.

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*email: ritzraj116@gmail.com

Synthesis of α-NiS decorated Fe_3S_4 nano hybrids and its application towards heterogeneous Fenton catalysis in dye degradation

Priyanga Manjuri Bhuyan [a, b] and Parikshit Gogoi [a]

[a] Department of Chemistry, Nowgong College (Autonomous), Nagaon, Assam, India

[b] Department of Chemistry, Gauhati University, Guwahati, Assam, India

Greigite (Fe_3S_4) and α-millerite (α-NiS) are important transition metal sulfides in Fenton Chemistry [1]-[2]. These sulfides are effective for Fenton reactions when exposed to light, as light acts as a source of electrons to convert Fe^{3+} to Fe^{2+} and Ni^{3+} to Ni^{2+} [1]-[2].

In our study, we prepared a catalyst by combining these two metal sulfides that can effectively be used as a Fenton catalyst even without light exposure. Fe_3S_4 has good Fenton activity but is more suitable for acidic pH conditions and is less stable in solution. We found that Greigite could degrade 55% of Fast Green dye at the reaction conditions of natural pH = 5, catalyst quantity = 0.5 g/L, and H_2O_2 concentration = 0.048M. Similarly, millerite is stable in alkaline pH only but shows good Fenton activity in acidic environments. Millerite could degrade only 49% of the dye under the same reaction conditions as Greigite. However, when we combined these two sulfides into a composite catalyst, we observed that it easily degraded 93% of 30 ppm Fast Green dye at pH 4 with 0.048 M H_2O_2 within 25 minutes of reaction time, and 98.11% of 270 ppm EBT within 6 minutes of reaction time. The composite catalyst involved two redox cycles, converting the ions from higher to lower oxidation states and vice versa. The reduced state of sulfur (S^{2-}) plays an effective role by transferring electrons to the higher oxidation states of the metal sulfides and converting itself to SO_4^{2-}. The incorporation of NiS in the composite catalyst increased its activity, reactivity, stability, and reusability, with minimal leaching. The catalyst could be used for five catalytic runs by extracting it from the solution using an external magnet.

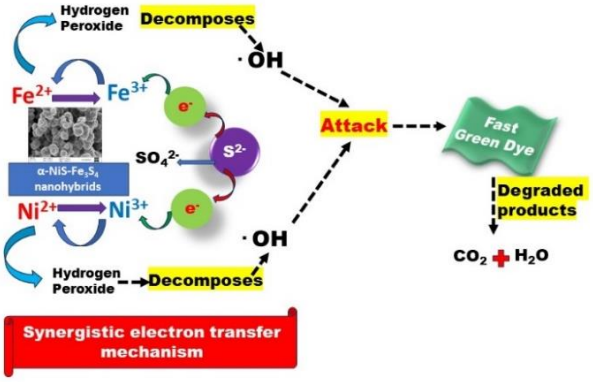

Figure 1: Degradation of Fast Green dye by α-NiS decorated Fe_3S_4 nano hybrids by heterogeneous Fenton-like reaction

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*email: priyangamanjurib@gmail.com

email: parikk100@gmail.com

Exploration of Microstructural, Optical, and Electrical Properties of Semiconducting Vanadium Oxide Thin Films

Jnanraj Borah[a*], Joydeep Das[a], Bablu Basumatary[b], Arup R. Pal[b], Bimal K. Sarma[a#]

[a]Nanophysics Laboratory, Department of Physics, Gauhati University, Guwahati 781014, Assam, India

[b]Plasma Nanotechnology Laboratory, Physical Sciences Division, Institute of Advanced Study in Science and Technology, Paschim Boragaon, Guwahati 781035, Assam, India

Vanadium oxides are well-known for their multiple oxidation states and numerous polymorphs, including VO_2, V_2O_5, V_2O_3, Magnéli phases (V_nO_{2n-1}), and Wadsley phases (V_nO_{2n+1}) [1-3]. Their distinctive chemical, electrical, and optical properties make them versatile for various applications. Certain phases, such as VO_2 and V_2O_3, experience transitions between metal and insulator phases, known as metal-to-insulator transition (MIT) [2, 4, 5]. The oxide phases of Vanadium in thin film form are deposited by direct current magnetron sputtering of Vanadium in Ar environment followed by post-deposition heat treatment. The investigation encompasses variations in Vanadium deposition and post-deposition oxidation conditions. The Vanadium thin films are subjected to annealing in air and controlled O_2 environment in vacuum. Morphological analyses using Field Emission Scanning Electron Microscopy (FESEM) reveal the capsule like structure of the thin films with thickness below 100 nm in most cases. The films are semitransparent and optical band gaps (1.81-3.39 eV) show dependence of the post-deposition oxidation conditions. The temperature dependent electrical resistivity measurements indicate the semiconducting behaviour of the films. Specifically, the vanadium thin film deposited for 15 min and annealed at 500 °C for 1 h under vacuum in controlled O_2 gas flow (2 sccm) exhibits a notable decrease in the resistivity within the temperature range of 60-65 °C. XRD analyses point towards V_2O_5 as the predominant phase formed under annealing in air. Raman spectra confirm the presence of a highly crystalline V_2O_5 phase under the identical condition. Under annealing in vacuum with O_2 gas flow, the VO_2 and V_2O_5 phases coexist as confirmed from the Raman spectra, which also indicates V_2O_5 as the dominant phase. The sudden fall of the resisitivity of this thin film at 63 °C suggests a weak MIT primarily attributed to the minority phase present in a mixed vanadium oxide.

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*Presenting author's email: jnanrajborah@gauhati.ac.in

#Corresponding author's email: bimal@gauhati.ac.in

Synthesis and Magnetic Properties of Geometrically Frustrated Pyrochlore Nanoparticles

Kulendra Borah[a], P.D. Babu and[b], Y. Sundarayya[a]*
[a]Department of Physics, Nagaland University, Lumami – 798627, Nagaland, India
[b]UGC-DAE Consortium for Scientific Research, Mumbai Centre, BARC, Mumbai – 400085, India

Single phase monodisperse cubic $R_2Sn_2O_7$ (R = Y, Nd, & Er) nanoparticles with particle size ~ 20 nm have been synthesized through hydrothermal method. Analysis of X-ray data results an average crystallite size ~ 10 nm of $R_2Sn_2O_7$ nanoparticles with the structural parameters follow the rare-earth contraction. The elemental analysis displays the presence of R in R^{3+} and tin in Sn^{4+} states. The bifurcation of zero-field cooled (ZFC) and field cooled (FC) magnetization at room temperature indicates the ferromagnetic (FM) interactions due to the oxygen vacancies on the surface of $R_2Sn_2O_7$ nanoparticles with a non-negligible coercivity.

Pyrochlores are one important class of oxide materials that exhibit magnetic frustration leading to interesting spin structures. They exhibit a combination of d-f orbital coupling, strong electronic correlations, small magnetic moments, geometric frustration, and large spin-orbit coupling effects. These features may give rise to a novel metallic spin liquid ground state, new topological phases, and an anomalous Hall effect [1, 2]. The pyrochlore family of oxides crystallizes into cubic structure with space group $Fd\bar{3}m$ [3-4]. These compounds develop a novel two-in/two-out spin ice structure due to competing exchange dipole-dipole interactions [5, 6].

Single phase monodisperse $R_2Sn_2O_7$ (R = Y, Nd, and Er) nanoparticles have been synthesized through hydrothermal method using acetate of R and Sn.

The analysis of powder X-ray date reveals that the as-prepared samples crystallize into cubic phase of $R_2Sn_2O_7$ with Space group: $Fd\bar{3}m$, No.227 symmetry, as shown in Figure 1. The lattice parameter values of $Y_2Sn_2O_7$, $Nd_2Sn_2O_7$ and $Er_2Sn_2O_7$ obtained through Rietveld refinement are 10.41 Å, 10.63 Å, and 10.36 Å respectively. The values of bond length and bond angles are found to vary in accordance with the rare-earth contraction effect. The average crystallite size of $R_2Sn_2O_7$ estimated to be ~ 10 nm. The FESEM images show uniformly distributed $R_2Sn_2O_7$ nanoparticles with size ~ 20 nm. The elemental analysis discloses the presence of Sn in Sn^{4+} ($5s^05p^0$), Y in Y^{3+} ($4d^05s^0$), Nd in Nd^{3+} ($4f^35d^06s^0$) and Er in Er^{3+} ($4f^{11}5d^06s^0$) states.

ZFC and FC magnetization measurements have been performed in an external field of H = 100 Oe. The FC magnetization of $R_2Sn_2O_7$ nanoparticles is nearly zero at 300 K and indicates the paramagnetic nature of the $R_2Sn_2O_7$. The magnetization is found to increase with decrease of temperature to 3 K, attains a maximum value of 0.11 emu/g and 0.10 emu/g respectively for $Nd_2Sn_2O_7$ and $Er_2Sn_2O_7$. A reduction of three-orders of magnetization has been observed for $Y_2Sn_2O_7$ in comparison with the other samples, indicating the Nd and Er play an important role in deciding the FM ground state. However, the magnetization of $Y_2Sn_2O_7$ show a bifurcation of ZFC and FC magnetization that reflects the presence of magnetic interactions at room temperature. In the absence of magnetic contribution from any of the constituent ions as expected, the M-H curve displays a ferromagnetic loop with a coercive field, H_c ~ 240 Oe, indicating the surface FM behaviour of $Y_2Sn_2O_7$ nanoparticles, due to the oxygen vacancies on the surface.

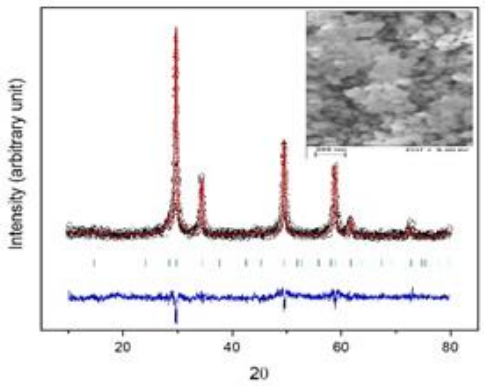

Figure 1: Powder X-ray diffractogram of $Y_2Sn_2O_7$ with the respective FESEM image shown in the inset.

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email: kulendra_rs2019@nagalanduniversity.ac.in
*Corresponding author: ysundar@nagalanduniversity.ac.in

Effective machine compliance and the nature of the Portevin-Le Chatelier bands

Prankrishna Borgohain *[1] and Ritupan Sarmah †[2]

[1]Department of Physics, Tezpur University, Napaam, Tezpur- 784028, India

Plastic deformation is intrinsically a highly dissipative, nonlinear, irreversible, far from equilibrium phenomenon. In metals and metallic alloys, dislocations are the carriers of plasticity. Generally, plastic deformation is homogeneous at the macroscopic level even when the dislocation motion is intermittent at the microscopic level [1, 2]. The stress-time curve is smooth and deviates from the linear behavior beyond the elastic limit. Under suitable driving conditions, a uniform deformation mode becomes unstable, leading to a spatially and temporally inhomogeneous state and the associated stress time showing irregular behavior [1]. The intermittent plastic deformation is called serrations, and the phenomenon is known as the Portevin Le-Chatelier (PLC) effect or jerky flow [1] . The intermittent plastic flow accompanied by dislocation patterns prominent as band like structures at the surface of the sample [3]. These spatio-temporal bands are further classified into three distinctly different category namely the randomly nucleated type C band with large amplitude regular serration, partially propagating type B band with a bit irregular serration and fully propagating type A band with very small amplitude stress drops. At constant temperature, it has been observed that conventionally the band types change their nature from type C to type A as the strain rate is increased. One finds the intermittent plastic flow below the room temperature as well as at very high temperature also. Recently, Lee et al has reported that at high temperature and constant strain rate condition, the band types dynamically change from a mixture of A and B (A+B) to (B+C) and then to type C [4].

The PLC effect is explained on the basis of the theory of dynamic strain ageing. Out of numerous studies, however there is only one dynamical model which captures most of the features of the PLC effect is the Ananthakrishna model (AK model) [1]. The existence of the window of strain rate and temperature, negative strain rate sensitivity etc are some of the example features captured by the model.

We investigate the role of effective machine stiffness on the Portevin-Le Chatelier bands within the Ananthakrishna (AK) model. We show that not only does the nature of the band change as a function of applied strain rate, but it also changes continuously with effective machine stiffness for a fixed strain rate, implicitly capturing the dynamic transition of dislocation band types at elevated temperatures. The dynamic change of band types to effective machine stiffness attributes to a temperature rise in the system. The increase in the temperature efficiently alters the elastic moduli of both the sample and the machine and thus induces changes in the effective modulus. The effective modulus of the coupled system decreases as temperature increases, leading to a dynamic continuous transition in band types and the nature of stress fluctuations. Thus, we show that the AK model implicitly captures the dynamical change of dislocation band types subjected to constant strain rate deformation and temperatures. Our analysis explains the intermittent stress-strain curve observed at low and high temperatures and suggests that the AK model captures the PLC instability domain.

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*email: prankrishna@tezu.ernet.in
†email: ritupan@tezu.ernet.in

Comparative assessment of photocatalytic activity in PVDF and PVDF/ZIF-8 membranes

Mangkorepla Changkija*[1], Debarun Dhar Purkayastha*[1]

[1] Department of Physics, National Institute of Technology Nagaland, Chumoukedima PO: Dimapur-797103, Nagaland, India

Addressing the nullification of toxic organic contaminants in wastewater, particularly from textile and dyeing industries, is a crucial focus in environmental and material science research. Extensive research has been dedicated to developing efficient technologies for the rapid breakdown of harmful contaminants. Photocatalytic processes are gaining widespread attention as a green technology to address environmental contamination issues. Among various materials, the use of metal organic frameworks (MOFs), such as Zeolite Imidazolate framework-8 (ZIF-8), in photocatalytic degradation has emerged as a promising approach for pollutant removal. In this study, we conduct a comparative analysis of the photocatalytic applications of nanofibrous PVDF membranes in presence and absence of a ZIF-8 layer. The PVDF/ZIF-8 membrane exhibited a superior photocatalytic performance in degrading an aqueous solution of methylene blue (MB) compared to the pristine PVDF membrane under UV light irradiation. The enhanced catalytic response of ZIF-8 is attributed to its improved crystallinity. The findings indicate that the PVDF/ZIF-8 membrane is a promising candidate for the photocatalytic degradation of methylene blue (MB).

Its use in practical field scenarios provides a practical and scalable solution for industries in search of environmentally friendly methods to manage wastewater and address critical ecological concerns.

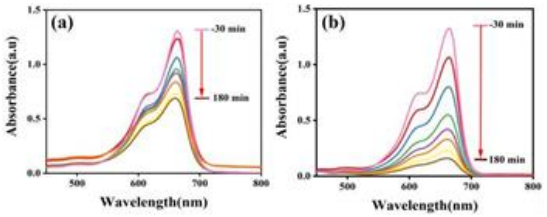

Figure 1. Absorbance spectra of MB by (a) PVDF membrane and (b) PVDF/ZIF-8 membrane.

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*email:kuku.changkija2511@gmail.com
debarun@nitnagaland.ac.in

Driven dynamics of a coupled order smart materials

Sita Chettri *[1] and Ritupan Sarmah †[2]

[1,2]Department of Physics, Tezpur University, Napaam-784028, Assam

The utilization of metals and materials, along with the manipulation of their properties for societal benefit, has been essential since ancient times. In contemporary society, these materials are critical components in infrastructure, electronics, and consumer goods. Smart materials, including ferromagnetic martensites and magnetostrictive materials, exhibit high responsiveness to external conditions and can be influenced by external fields [1]. Their distinct properties render smart materials ideal for a wide range of applications, including robotics, medical devices, self-healing materials, and adaptive structures in aerospace and civil engineering. However, comprehending the intricate dynamics of these materials in response to external stimuli is challenging, given the presence of multiple order parameters(OPs).

For instance, smart materials like magnetostrictive and ferromagnetic martensites showcase strain and magnetization as OPs, leading to significant mechanical deformation in the presence of external magnetic fields due to magneto-elastic coupling. In contrast, ferroelectric materials like $BaTiO_3$ have strain and polarization as their OPs. The lack of knowledge regarding the coupling mechanisms between these existing OPs has hindered progress in designing such materials. To understand the driven dynamics of a magnetostrictive ribbon, a nonlinear coupled order parameter model has recently been introduced [2]-[3]. The model has successfully demonstrated the experimental reported dynamics, including the period-doubling (PD) route to chaos as a function of the amplitude of the dc field, the quasi-periodic (QP) route to chaos as a function of the amplitude of the oscillating field, and suppressed and induced chaos as a function of perturbating fields. When the model is applied to ferromagnetic martensite, it predicts interesting dynamics such as mixed-mode oscillations [4], and suggests that the model can be used as a frequency multiplier. However, a comprehensive analysis of the model is lacking, and such an analysis holds the potential to pave the way for designing efficient materials tailored for specific applications.

The model equations in the dominant mode of vibration correspond to magnetostrictive ribbons are given by,

$$\ddot{A}(\tau) = -\Big[\tau_\epsilon A(\tau) + 3\beta A^3(\tau) - \frac{5\Delta}{8}A^5(\tau) + k^2 A(\tau) + \gamma k \dot{A}(\tau) + \frac{\zeta}{2}(3pA(\tau)B^2(\tau) - (1-p)B(\tau))\Big], \tag{1}$$

$$\dot{B}(\tau) = -\Gamma'\Big[\tau_c B(\tau) + \frac{B^3(\tau)}{2} + k^2 B(\tau) - \frac{\zeta}{2}((1-p)A(\tau) + pA^2(\tau)B(\tau)) - h_{ac}\,\sin\Omega\tau - h_{dc}\Big], \tag{2}$$

where A and B are physical observable strain and magnetization, the over-dot represents time derivatives, and other symbols represent physical material parameters.

In this work, we present a detailed investigation of the dynamics of nonlinear coupled OP model focusing on the interactions between the individual OP and their effects on the overall behaviour of the system. Specifically, we explore the dynamics of the model with the variation of the physically significant parameters. Our main focus is to look for the hidden dynamics exhibited by the model. Our findings have significant implications for an application where coupled OP smart systems are used and can be used as a basis for further research into other coupled OP smart systems as well, which are present in nature.

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*email: sitaphd@tezu.ernet.in

†email: ritupan@tezu.ernet.in

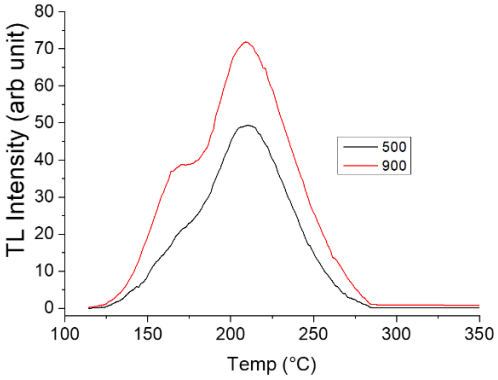
Preparation and luminescence studies of highly luminescent $Ba_{1-x}Y_xSO_4$: Eu nanoparticles: determination of trapping parameters

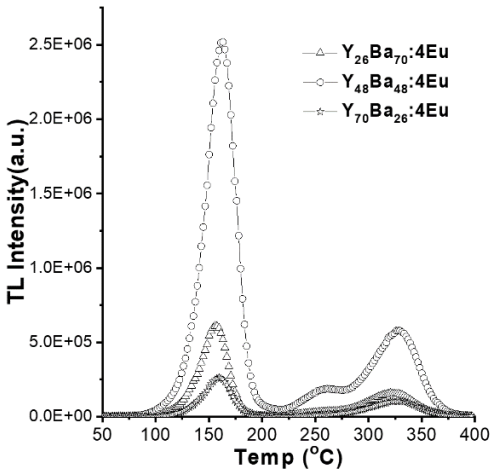
L. Robindro Singh[1], Ishorjit Chongtham[2], James Oinam[1] and U.C. Srivastava[2]

[1]Department of Nanotechnology, North-Eastern Hill University, Shillong-22, Meghalaya, India.
[2]Amity Institute of Applied Science, Amity University, Noida-201301, UP, India.

Small crystalline sizes of $Ba_{1-x}Y_xSO_4$ (x=0.26, 0.48, 0.70) nanoparticles doped with 4 at. % Eu^{3+} were prepared by wet chemical technique at low temperature. Characterizations of the prepared nanoparticles show that the nanoparticles are pure. Photoluminescence emission intensity depends on the ratio of Y^{3+} in Ba^{2+} showing strong luminescence emission due to $^5D_0 \rightarrow {}^7F_1$ and $^5D_0 \rightarrow {}^7F_2$ transitions. But at higher heated samples the electric transition dominates over the magnetic transition Thermoluminesence glow curves show that the glow peak 170 °C dominates over 350°C peak but the condition is contrary with decrease concentration of Ba^{2+}, this pattern follows for all the systems. The activation energies both the lower and higher heated samples are 1.2 to 1.54 eV.

Key words: Glow curves, iconicity, activation energy, order of kinetics.





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*Email: lrsingh@nehu.ac.in

email: ishorjit12345@gmail.com

Optical Properties of ZnO Nanostructure and its Antimicrobial Activity Against *Staphylococcus aureus* and *Klebsiella pneumoniae* Bacteria

Munmun Midya Chowdhury[#], and Pijus Kanti Samanta[*]

Department of Physics, Prabhat Kumar College, Contai-721404, West Bengal, India

ZnO is a multifunctional material that is being studied because of its distinct antibacterial and optoelectronic properties [1-3]. ZnO nanostructures have been successfully synthesized using a straightforward wet chemical process. Well-crystalline material was formed, as shown by X-ray diffraction data. The creation of a hexagonal unit cell structure is suggested by the diffraction data. There was no peak for impurities, suggesting that pure material was formed. The materials' remarkable transparency in the visible range was shown by the UV-visible spectrum. The observation of band gap enhancement suggests the presence of the quantum confinement effect. Excellent antibacterial activity of ZnO nanoparticles is demonstrated against Klebsiella pneumoniae and Staphylococcus aureus germs. As a result, optoelectronics and biological applications may benefit from the synthesized ZnO.

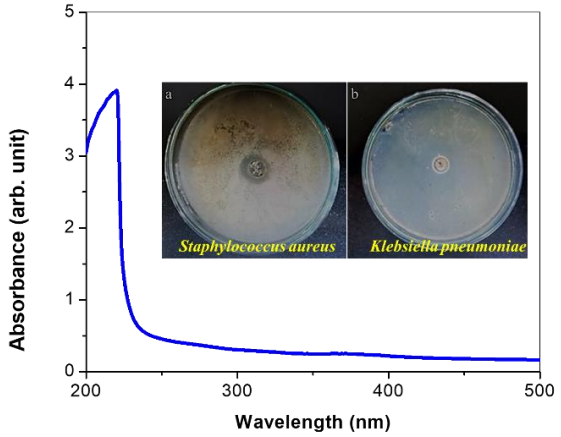

Figure 1: UV-vis absorption spectrum of ZnO nanoparticles. Inset shows the zone of inhibition for the antimicrobial activity against *Staphylococcus aureus* and *Klebsiella pneumoniae* bacteria.

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#email: munmun.phys@gmail.com
*email: pks.pkcphy@gmail.com

Liquid Crystal as a Versatile Template For Growth and Organization of Ag Nanostructures

Kaustabh Dan
Government General Degree College, Gopiballavpur-II, Beliaberah, Jhargram,
West Bengal-721517

In recent years, significant research effort has been devoted towards understanding the templating effect on the growth of nanostructures in multiple dimensions. Liquid crystals (LCs), the fourth state of matter, in this context plays a prevalent role in organization of various nano-structures owing to its fascinating properties of self-assembly, possessing order and mobility at various length scales, extreme sensitivity to the external perturbation, existence of all kinds of supra-molecular interactions and its shape anisotropy which provides good support for the nano-materials to organize themselves in multiple dimensions [1]. Nonetheless, research in this direction widely contemplating on dispersion of synthesized nanoparticles externally in LC medium and its effect on organizing them into various structures. LCs in all these instances played only the role of dispersed medium for adhering nano particles to form novel structures. However, a less attention had been given for such cases where the LC medium acts both as reductant and stabilizer for the growth and assembly nano structures [2]. Only a handful of studies where this dual role of LCs is explored also do not exhibit any versatility in shape or assembly of nano structures [3].

In this present study, we report robust method for facile one-step synthesis and assembly of Ag nanostructures with versatile shape or size inside a well-known liquid crystalline solvent exhibiting nematic phase in room temperature, MBBA [N-(4-methoxybenzylidene)-4-butylaniline] with $AgNO_3$ as precursor in a single step without using any external reducing or stabilizing unit other than MBBA. The evolution of Ag nanostructures as a function of precursor concentration, effect of heating and ageing of samples are extensively studied by Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM) and UV-Visible (UV-Vis) Absorption Spectroscopy. A detailed analysis based on SEM and TEM gives valuable insight on the morphological evolution of Ag nanostructures in relatively smaller and larger length scales, respectively. While lower Ag concentration of 3 to 20 mol %, AgNPs with mostly spherical morphologies of size mostly 3-10 nm are observed. Higher concentration of Ag^+ ion (40, 50 and 80 mol%) with heating treatment not only alters the size distribution but also significantly modifies the shape of the Ag nanostructures.

While in relatively smaller length scales and higher magnification, we observe growth of Ag nano cubes with slight rounding at the corners (Fig. 1(b)), at larger length scale we observe that Ag nanostructures assembles themselves into ribbon like morphologies extending upto few micrometers and they consist of rich shape anisotropic nanostructures such as triangles, hexagons, rods, trapezium and faceted structures (Fig. 1(a)). The optical properties of these Ag nanostructures are manifested by the characteristic surface plasmon resonance peak through UV-Visible Spectroscopy which indicates growth condition, effect of ageing and precursor concentration alters the SPR peak position and intensity considerably. We envisage that our present study will find its scope with liquid crystal as soft, tunable template for the in-situ growth and assembly of various metal nano structures.

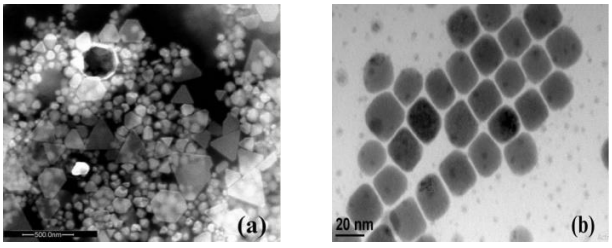

Figure 1: (a) SEM image of anisotropic Ag nanostructures; mostly triangular and faceted morphologies synthesized inside MBBA (b) TEM image of Ag nanocubes with slight rounding at corners.

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*email: kaustabhdan@gmail.com

Flexible Meta-Structure Absorbers for Enhancing Microwave Absorption for Wideband Applications in Modern Communication and Radar Systems

Debasish Das and Prof. Nidhi S Bhattacharyya

Department of Physics, Tezpur University

Microwave absorbers play a pivotal role in modern communication, radar, stealth application and sensing systems, providing a crucial solution to managing electromagnetic interference and improving overall system performance. In recent years, significant advancements have been made in the development of microwave absorbers, with a particular focus on achieving wideband absorption, thin, light weight and flexible. Recently, meta-structure shields (MSS) have evolved as hybrid absorber designs that leverage the structural properties of metamaterials, combined with the dielectric or magnetic properties of the constituent material, to achieve a broadband absorber [1]. The arrayed subwavelength structure, in conjunction with the matrix, functions similar to a homogeneous material, and its absorption frequency range can be adjusted by modifying the size and shape of the structure [2].

Effective absorption hinges on two key conditions. First, there must be impedance matching at the interface between air and the absorber. Impedance mismatch can result in significant reflection loss, as indicated by the equation [2]:

$$RL = 20\,log\left|\frac{Z_{in} - Z_0}{Z_{in} + Z_0}\right|$$

Here, Z_0 is free space impedance and Z_{in} impedance of the absorber. Perfect matching condition will be when Z_{in}=Z_0 where the incident EM wave will enter the absorber without undergoing any reflection. Second, the absorber material should be able to attenuate the impinged electromagnetic wave rapidly. The power of the electromagnetic wave decays exponentially with distance, x, by the factor $e^{-\alpha x}$, where α is the attenuation constant of the material. The reflection loss of the absorber depends upon the intrinsic material parameter: complex permittivity (ε_r) and complex permeability (μ_r) [2].

In this investigation, the focus is directed to a microwave resonating-type absorber designed for wideband applications, particularly highlighting a meta-structure absorber (MSA) with a metal backing. The periodic unit cell of the MSA is methodically crafted by encapsulating an expanded graphite-silicone (EG-Si) composite within a flexible silicone rubber matrix. Microwave material characterization is conducted on EG-Si composites with varying weight percentages (2, 4, 5, 6, 9, and 13 wt. %) across the X-band frequency range. Utilizing CST simulation, the unit cell parameters are adjusted to achieve a broad spectrum of −10 dB absorption with bandwidth throughout the X-band. The simulation also scrutinizes the absorber's absorption performance in terms of polarization and incident angle dependence. The resonance and absorption mechanism are explored through a detailed analysis of the simulated electric field and magnetic field within the unit cell. Experimental measurements of absorption for the prototype absorbers are carried out using the waveguide measurement technique.

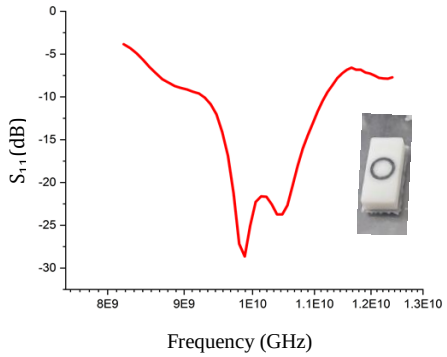

Figure 1: Experimental S_{11} Curve for MSA

Figure 1 illustrates that the designed MSA provides a −10 dB bandwidth of 2.05 GHz, accompanied by a maximum reflection loss (RL) value of −28.75 dB. Simulation results further demonstrate that the developed absorber exhibits an absorption efficiency exceeding 85%, accommodating incident angles up to 50 degrees for TE-polarized waves and 40 degrees for TM-polarized waves.

A summary of the work is provided in Table1.

Table 1: Summary of the work

Absorber Type	flexibility	Thickness (mm)	Resonance (GHz)	S_{11} (dB)	-10 dB BW (GHz)	Polarization sensitive
Single ring MSA	Yes	8	9.9	-28.75	2.05	No

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*Email: dasdebasish278@gmail.com Email: nidhisbhatta@gmail.com

Development of 2D Nanocomposite for Soil Health Enhancement

Antara Deb *[1] and Pritam Deb †[1]

[1]Department of Physics, Tezpur University, Napaam, Tezpur, Assam, India-784028

Excessive use of chemical fertilizer has become a cause of concern for its detrimental impact on the environment [1]. Recognizing the urgent need for an eco-friendly alternative, the spotlight has shifted to 2D nanocomposites as a revolutionary solution in soil conditioning.Nanoscale based soil conditioners are the materials that are characterized by their large surface area to volume ratio, along with the capability for gradual nutrient release, hold great potential as viable solutions in the realm of agriculture[2].

The 2D nanocomposite of Graphitic Carbon Nitride/Iron Oxide (FeOGCN) soil conditioner has been synthesized using single step pyrolysis method [3], and successively the optimum time for sonication is studied. To confirm the phase and orientation of the prepared sample Raman Spectra is analyzed.

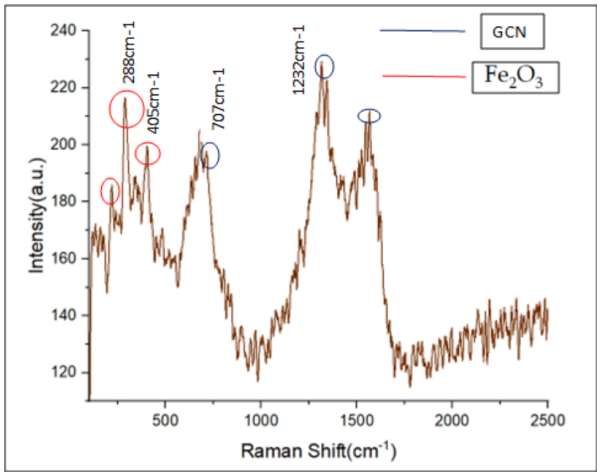

Figure 1: Raman Spectra Analysis of FeOGCN.

The effects of FeOGCN are also examined on the growth of microbes found in soil, particularly for alluvial soil due to the geometrical location of the research site. It is found that the limited use of FeOGCN in the soil has no negative impact on the soil microbes present. The microbial population in the treated soil exhibited greater viability compared to the bare alluvial soil. Furthermore, the analysis

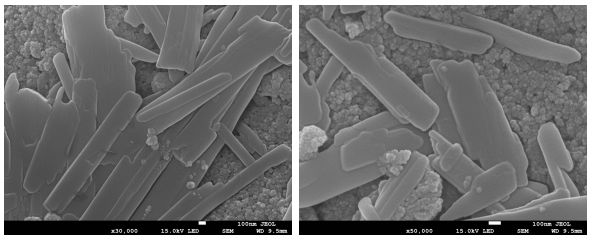

Figure 2: FESEM micrographs of FeOGCN.

of the available carbon and nitrogen content demonstrates an increase in available carbon content in the treated soil in contrast to the bare alluvial soil.

Table 1: Availability of Total Carbon and Nitrogen in Soil

Soil Type	Available Carbon (wt%)	Available Nitrogen (wt%)
Bare Alluvial Soil	1.27%	0.53%
Soil Treated with 1mg/ml FeOGCN	1.46%	0.40%

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*email: phm22001@tezu.ac.in
†email: pdeb@tezu.ernet.in

Quantum enhanced relaxivity in MR imaging probe application

Snehasish Deb and Pritam Deb*
Advanced Functional Material Laboratory (AFML), Department of Physics, Tezpur University, Tezpur 784028, India

To address the challenges in advanced magnetic resonance imaging (MRI), several methods and techniques have been developed. One of the methods is introducing new contrast agents. In the quest for enhanced MRI contrast agents (CAs), nanoparticles have been engineered with meticulous precision. In recent years, significant advancements have been achieved precisely to modulate the structures of magnetic nanoparticles for studying structure-relaxivity correlations [1]. In this study, a flexible mechanism has been explored to improve MRI sensitivity by adjusting the anisotropy of the ensemble, offering significant insights into the design principles for next-generation contrast agents [2]. This will advance our basic knowledge of magnetic relaxation phenomena and open the door to the development of tailored contrast agents with exceptional performance.

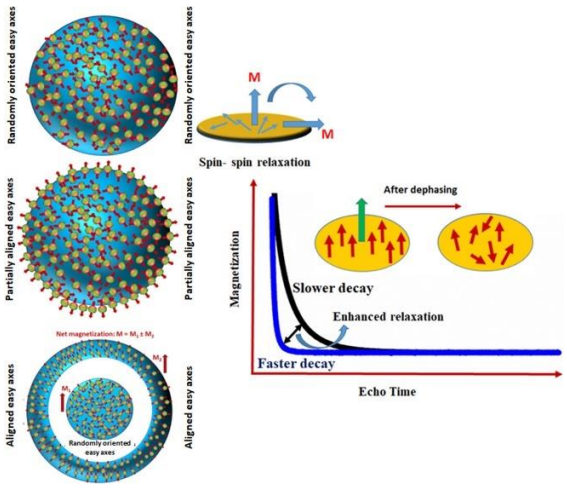

Figure 1: Schematic showing various ensembles with varied easy axes alignment and relaxation curve. This figure has been adapted with permission[2].Copyright © 2022, American Chemical Society.

The customized $Ni_{1-x}Zn_xFe_2O_4$@CoO nanoparticles created by octahedral site substitution demonstrate the possibility of adjusting composition for the best contrast, and the study of structure-correlated transverse relaxivity enhancement provides opportunities for the development of very effective contrast agents [3]. These developments have enormous potential to transform medical imaging, provide better diagnostic tools, and eventually enhance patient care. Herein, recent advancements related to the CAs have been addressed, focusing on potential avenues and challenges for further research.

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*email: pdeb@tezu.ernet.in

Enhanced luminescence response in microwave-assisted synthesis of WS_2/WSe_2 nanohybrid structure

Bhupali Deka*, Bharlina Rabha, and D. Mohanta
Nanoscience and Soft-Matter Laboratory, Department of Physics, Tezpur University, Napaam,
Tezpur-784 028, Assam, India

Since the groundbreaking discovery of graphene, there has been a surge of interest in two-dimensional (2D) transition metal dichalcogenide (TMD) nanomaterials, owing to their exceptional properties [1]. Recently, a growing fascination has emerged around two-dimensional layered van der Waals nanostructures and their hybrid systems, which showcase extraordinary interlayer interactions, potentially resulting in intriguing synergistic effects [2]. Moreover, their layered structure imparts outstanding optical and electrical properties [3].

In this study, nanohybrid materials of WS_2/WSe_2 were synthesized using a rapid microwave-assisted approach in different pH environments (pH 1, pH 7, and pH 14). The WS_2/WSe_2 hybrid structures were characterized using X-ray diffraction (XRD) pattern, Raman spectroscopy and microscopic techniques. Also, the luminescence response was studied using steady-state photoluminescence (PL) spectroscopy. The structural analysis of the synthesized samples indicates the hexagonal phase structure of WS_2 and WSe_2 materials, as well as their hybrid systems conforming to the space group (P63/mmc). Raman spectroscopy reveals the sharp intense peaks of first-order Raman active E^1_{2g} and A_{1g} optical phonon modes of distinct WS_2 and WSe_2 materials. Hence, for the hybrid structure prepared in basic media (pH 14), the vibrational characteristics of individual WS_2 and WSe_2 has remained intact. The morphology of the systems shown in Fig. 1 was studied using field-emission scanning electron microscopy (FE-SEM) imaging, which displayed a hexagonal layered sheets with lateral dimension ranging from 0.5 µm to 1.5 µm.

In addition, the PL spectra exhibited luminescence features, with the emergence of A-excitonic transitions of WS_2 and WSe_2 materials at ~684 nm and 753 nm, respectively, in the WS_2/WSe_2 nanohybrid system at pH 14. Consequently, the hybrid structure exhibited an enhanced luminescence response. These finding paves the path for potential applications in the next generation optoelectronic devices.

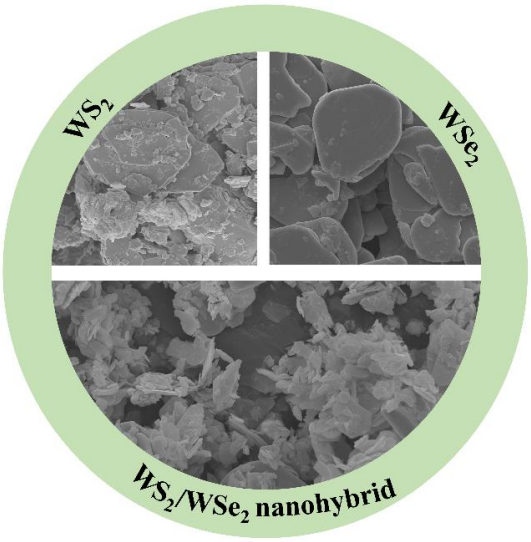

Figure 1. Schematic representation of morphology of WS_2, WSe_2 and their hybrid structure.

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*bdeka261995@gmail.com
rbharlina@gmail.com
best@tezu.ernet.in

Application of Kronig-Penney model potential in the study of Photofield Emission in Silicon

Dandeswar Deka[1], S. K. Sharma[2] and R. K. Thapa[3]
[1]Physics Department, B. H. College, Howly-781316.
[2]Physics Department, Assam Don Bosco University,
Tapesia Gardens, Sonapur - 782402, Assam.
[3]Physics Department, Mizoram university, Aizawl-796009, Mizoram
[1]Author for correspondence : d.deka2010@rediffmail.com

Kronig-Peney model had been used in solid state physics usually to define a periodic type of potential in understading the band structures in solids.[1] Thapa and others have used it to understand the photoemission from solids and surface states in metals like d-band metals tungsten, palladium,[2] etc and semiconductors like Si, GaAs[3] etc. In this report, we are trying to understand the photofield emission phenomena from semiconductor Si. Photofield emision (PFE) is a technique in which a metal is irradiated by an incident laser radiation of photon energy $\hbar\omega$. The incident radiation photoexcites the electrons to final state which lies between the Fermi level and the vacuum level, hence these electrons are confined within the metals surface. A strong electric field (10^9 Vm^{-1}) is applied to the surface of the metal which then causes the photoexcited electrons to tunnel through the surface potential barrier into the vacuum region. The potential of the periodic solid is considered to be Kronig-Penney potential which is periodic with the periodicity of the bulk lattice. On this concept, Thapa[4,1] had deduced the initial state wave functions by simple wavefunction matching technique and this had been used in the matrix element <i|H|f> for calculating the photofield emission current formula given by Gao and Reifenberger[5]. In the earlier case, Thapa had used the experimental data for the values of the real and imaginary dielectric constants for calculating the PFEC from solids like W, ZrC, GaAa as well as from Si and GaAs. In this approach, we will use the theoretically calculated values of real and imaginary values of the dielectric constants of Si. The dielectric constant in this case is calculated by using the FP-LAPW method of Density Functional.

Technique using the Generalised Gradient Aapproximation (GGA)6 method. We will present here the results of PFEC obtained by DFT method and compare with the results obtained earlier by Thapa and others by using the experimental data of dielectric constants.

We will study the effect of the location of the electrons in the vacuum, surface and bulk states on the photofield emission current. Photofield emission current will be investigated as a function of incident photon energy, location of the electrons with reference to Fermi level and also as a function of the applied high electric field. Results will be compared with the previous data and the experimental results.

Keywords: PFE, FP-LAPW, Dielectric Constants, Photon Energy, Vector Potential

PACS: 71.15.-m, 73.20.Hb, 78.67.-n, 73.61.-r, 79.60.-i

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email:d.deka2010@rediffmail.com

Magnetic Hyperthermia by Thermal Plasma Synthesized Magnetic Nanoparticles

Kashmiri Deka[1], Gauri A. Deshpande[1], Vijaykumar B. Varma[2], R. V. Ramanujan[3], Vikas L. Mathe[1]

[1]Plasma Nanomaterials Laboratory, Department of Physics, Savitribai Phule Pune University, Ganeshkhind, Pune, Maharashtra-411007, India

[2]Luxembourg Institute of Science and Technology, 41 Rue Du Brill, Belvaux, L-4422, Luxembourg

[3]School of Materials Science and Engineering, Nanyang Technological University, Singapore, 639798, Singapore

Hyperthermia is one of the remedial methods to cure cancer by producing appropriate amount of heat in the body. Various methods have been employed to produce hyperthermia in the tumour area, but the majority of them trigger side effects in healthy tissues too. Magnetic Hyperthermia (MH) has got attention due to the ability of decreasing medical side effects and removing cancerous tumours [1]. MH is a treatment in which tissue temperature can be raised by subjecting magnetic nanoparticles (MNPs) to an alternating magnetic field (AMF). The basis of MH is the higher heat sensitivity of cancer cells. It has been very well documented that the development of cancer cells can be prevented at a temperature above 42 ℃, while healthy cells endure that temperature [2].

Magnetic manganese ferrite ($MnFe_2O_4$) NPs have low toxicity, high stability, and tunable magnetic properties [1]. Therefore, in the present work, we have synthesized $MnFe_2O_4$ NPs by thermal plasma technique as hyperthermia agents. Thermal plasmas provide tremendous thermal flux and hence this technique is rapid offering one-step processing with no significant hazardous byproducts. Besides, pure magnetic oxide products are attained by this synthesis procedure as the nucleation and growth of the product occur in vaporous phase [3]. A series of characterizations were performed to know the microstructure, composition and magnetic properties of the thermal plasma synthesized NPs. The biocompatibility of the NPs was ascertained by cell viability study. Lastly, the temperature rise caused by 26 mg of the $MnFe_2O_4$ nanosystem and 1 mL of its dispersion in water (concentration 26 mg/mL) was studied under AMF. Temperature over 50 °C was achieved within 2 seconds and 5 seconds of AMF treatment (375 kHz and field strength of 4 kAm^{-1}) for the $MnFe_2O_4$ nanosystem and its dispersion respectively [Fig. 1]. This indicates the excellent magnetic heating performance of the $MnFe_2O_4$ nanosystem. The specific absorption rate (SAR) of the thermal plasma synthesized $MnFe_2O_4$ NPs was determined to be 546.1 Wg^{-1}, which was much higher than the SAR value of the earlier reported $MnFe_2O_4$ nanosystems synthesized by various methods.

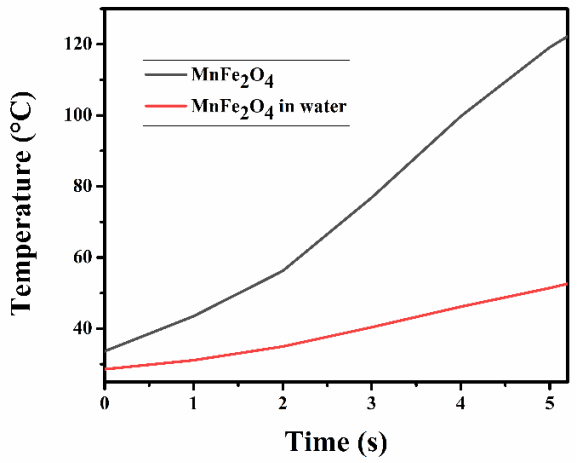

Figure 1: Temperature change with time under AMF

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*email: vlmathe@physics.unipune.ernet.in

Zinc doped Cobalt ferrite nanoparticles for hyperthermia application

Mehak, Rajkumar P. Thummer, Lalit Mohan Pandey*
Department of Biosciences and Bioengineering, Indian Institute of Technology, Guwahati, Guwahati, Assam-781039, India

Ferrite nanoparticles or iron-oxide nanoparticles (IONPs) find wide applications in various fields due to their magnetic properties, ease of separation, cytocompatibility, and high surface area-to-volume ratio. Cancer therapy being one of the biomedical applications, in which IONPs are used as heat mediators for thermal therapy of cancer cells. IONPs based thermal therapy of cancer cells is generally termed as "Magnetic Hyperthermia" (MHT). Briefly, IONPs formulation is injected into patient's body and is directed towards the tumour mass where, in presence of an externally applied alternating magnetic field (AMF) these NPs generate heat in order to ablate cancer cells. A temperature range of 40-45 ℃ is referred as the hyperthermia range [1].

However, there are a few practical constraints in the use of bare/pure SPIONs for biomedical applications. In order to tune the physiochemical properties of these NPs, doping is considered to be a prominent and simple technique. Dopants could be magnetic or non-magnetic/divalent or trivalent metal ions [2].

Table 1: Magnetization saturation (M_s) values of the prepared samples

NPs	M_s
Bare	57.48
FC	65.96
X2	76.29
X4	64.33
X6	51.44
X8	19.07
FZ	0.64

In the present work, we have synthesized zinc doped cobalt ferrites for their application in hyperthermia treatment for cancer therapy. The nanoformulation can be expressed as $Zn_xCo_{1-x}Fe_2O_4$. Dopant amount was varied from x = 0-1 (M), with an interval of 0.2. Co-precipitation synthesis was employed to obtain the aforementioned NPs. Afterwards, the obtained NPs were calcined at 800 ℃ for 3 h to obtain the pure phases. Characterization techniques such as, Fourier Transform Infrared spectroscopy (FTIR), X-Ray Diffraction (XRD) (plot is shown in Figure 1), X-Ray Photoelectron Spectroscopy (XPS), Vibrating Sample Magnetometer (VSM) measurement were used to characterize the prepared NPs. These NPs were also analysed for their cytocompatibility using HEK293 cells and antibacterial potential against both, gram-positive (*Staphylococcus aureus*) and gram-negative (*Salmonella paratyphi*) bacteria at various concentrations.

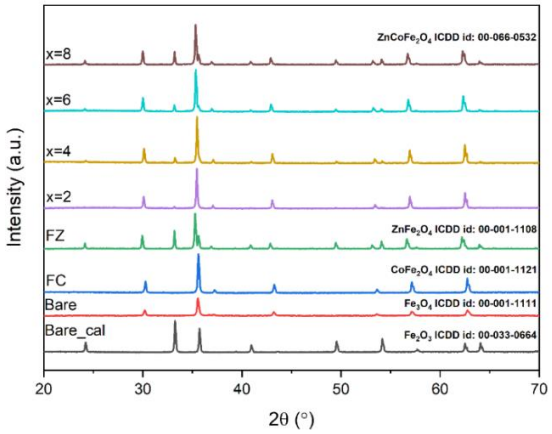

Figure 1: XRD plot of the prepared samples showing shift from the characteristic peak of Fe_3O_4 (311) peak in doped samples

It was observed that the M_s value for the prepared samples was improved upto doping of 0.4 M (as shown in Table 1), beyond which it starts to decrease with the increase in non-magnetic dopant (Zn^{2+}) amount. Besides, all the samples were found to exhibit biocompatibility even at higher concentration of 1000 µg/mL along with bacterial growth inhibition at even lower concentration of 200 µg/mL. Thus, the prepared samples can serve as hyperthermia agents owing to their improved magnetic properties, cytocompatibility and antibacterial potential.

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*email: lalitpandey@iitg.ac.in, mehak1998@iitg.ac.in
email: rthu@iitg.ac.in

Photoresponsivity of silver nanoparticle incorporated core-shell structure of Zr based UiO-66 metal organic framework (MOF)

Kakoli Doloi and Dambarudhar Mohanta

Tezpur University, Tezpur University

UiO-66 is a well-known, stable metal-organic framework (MOF) with the chemical formula $[Zr_6O_4(OH)_4(BDC)_6]$ where Zr^{4+} nodes coordinated to 12 benzene dicarboxylate ligands [1]. It is ideal for a wide variety of applications due to its great thermal and chemical stability and three-dimensional porous microstructure. Although UiO-66 is frequently investigated for its gas sorption characteristics, catalysis, and medication delivery, its use in photoexcitation and photoconduction studies have also been considered [2]. However, UiO-66 requires high energy photons (low wavelength) to generate charge carriers because of its wide bandgap (2.5-4 eV). Also, due to its insulating nature mobility of the charge carriers is hampered. To overcome these limitations, here in this work, photosensitive plasmonic silver nanoparticles (Ag NP) have been loaded to the UiO-66 structure. Two different approaches have been adopted to incorporate Ag NP in UiO-66 namely, "ship in a bottle" and "ship around the bottle" methods. Both these routes resulted in a core-shell structure of UiO-66 and Ag NP as confirmed by x-ray diffraction, Fourier transform infrared spectroscopy, scanning electron microscopy, transmission electron microscopy. The samples prepared have a core of Ag NPs and shell of UiO-66, hence they are named as UiO-66@Ag-1 and UiO-66@Ag-2.

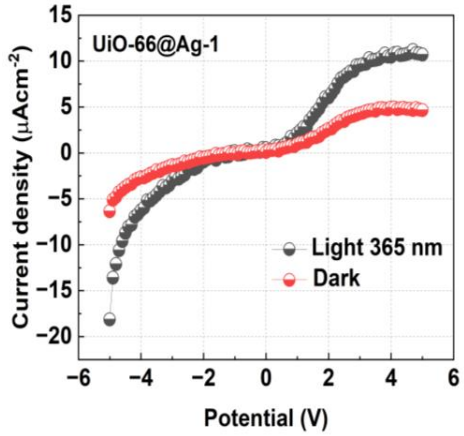

Fig.1 I-V plots of UiO-66@Ag-1 in dark and in presence of 365 nm UV light.

Photo-sensitive behavior was measured by coating the as synthesized UiO-66@Ag samples in an ITO glass with Au contacts under UV light simulator and with the help of a two-probe current-voltage setup.

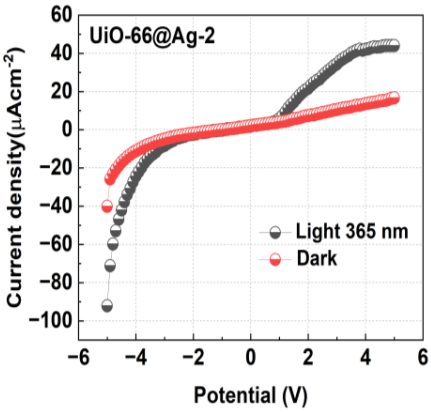

Fig.2 I-V plots of UiO-66@Ag-2 in dark and in presence of 365 nm UV light

When using UV light of 365 nm to illuminate the photoresponsive materials, it showed a better responsivity with detection value of 1.05×10^{11} and 5.15×10^{12} Jones; respectively (in Fig.1 and Fig.2). Exhibiting a nearly constant photo-response the device also ensures a good stability as observed up to 5 days.

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*email: kakolia@tezu.ernet.in

email: best@tezu.ernet.in

Bioinspired fabrication of anisotropic superhydrophobic surfaces

Mahesh C. Dubey*, D. Mohanta

Nanoscience and Soft Matter Laboratory, Department of Physics, Tezpur University, PO: Napaam, Tezpur-784 028, Assam, India

The occurring of wettability on structured solid surfaces is of significant interest both in terms of fundamental and industrial applications. The engineered water-repellent superhydrophobic surfaces have been explored and demonstrated at laboratory level but remains challenging for many applications. The Wenzel and Cassie models deal with wettability, high and low adhesion of liquids on textured surfaces [1]. The wetting conditions in Cassie regime ensure water droplet for self-cleaning, microfluidics, and lab-on-chip etc. The anisotropic wetting behavior of textured surfaces has been observed and artificial surfaces have been developed through surface patterning [2].

In this study, we highlight the artificially grown superhydrophobic surface inspired from natural leaf surface, which possesses a two-tier surface texture leading to anisotropic wetting behavior. Inspired from natural water-repellent hierarchical surface, polystyrene (PS) replica has been obtained using the soft lithography technique. The anisotropic wetting, demonstrating anisotropic superhydrophobicity with water contact angles (WCA's) exceeding 145°. The anisotropic wetting, featuring a unidirectional flow of droplets, holds promise for applications in lab-on-a-chip devices, and microfluidic devices, etc.

Wettability of surfaces is the ability of liquid to spread on solid surfaces. The relationship between three phase interfacial surface tension and WCA is given by Young's equation, $cos\theta_Y = (\gamma_{SA} - \gamma_{SL})/\gamma_{LA}$, here θ_Y is the Young's CA, γ_{SA} , γ_{SL} and γ_{LA} are solid-air, solid-liquid, and liquid-air interfacial surface tensions, respectively [3].

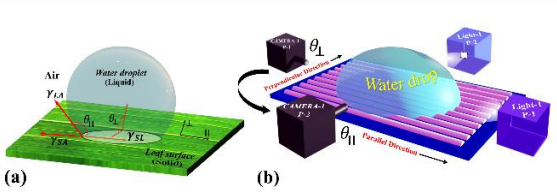

Figure 1. (a) Schematic of suspended state of water droplet on textured surface. (b) schematic of WCA measurement on anisotropic surface.

Fig. 1 (a) illustrates anisotropic wetting state of the droplet along parallel and perpendicular directions, respectively. Fig. 1(b) is the scheme of anisotropic WCAs measurement depict positions of camera, light source and the droplet.

Inspired from water-repellency of sword lily leaf surface texture, polystyrene (PS) leaf replica has been developed employing a soft lithography technique. The artificially fabricated PS leaf surfaces tested with different water droplet volume, give perpendicular ($\theta_\perp$) and parallel ($\theta_{||}$) WCA's in the range, ($\theta_\perp$) ~142°-145°, ($\theta_{||}$) ~130°-139°; respectively [Fig. 2]. The droplet with different volumes (~4-6 µL), the mimicked surface shown droplet roll-off angles in range, ~21°-49° and ~40°-55° along parallel and perpendicular directions, respectively.

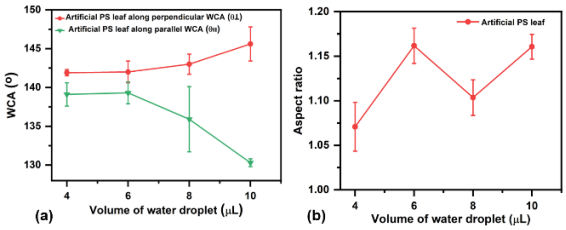

Figure 2. (a) The WCAs vs droplet volumes plots shown for artificial PS leaf surfaces along parallel and perpendicular directions, respectively. (b) Water droplet volume dependent aspect ratio (contact line along two perpendicular directions) plot of artificial PS leaf surface construct.

The anisotropic wettability together with superhydrophobicity, follows the Cassie-Cassie model. The fabricated PS surface shows anisotropic wetting, which characterize unidirectional self-cleaning activity, and holds promise for various applications such as lab-on-a-chip, digital microfluidics, droplet transportation, drug delivery and many more.

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*email: chandramaheshdubey@gmail.com, best@tezu.ernet.in

Efficiency enhancement in Natural Dye-Sensitized Solar Cells through Co-Sensitization Strategies on TiO_2 Photoanodes

Amrit Dutta[1,*], Bikashjyoti Gohain[2], Surajit Konwer[2], Ankur Gogoi[1]

[1]Department of Physics, Jagannath Barooah College, Jorhat 785001, Assam;
[2]Department of Chemistry, Dibrugarh University, Dibrugarh 786004, Assam

A mixed dye composed of chlorophyll-a (CA) and curcumin (CU), extracted from the leaves of giant exhibition palisandra and turmeric respectively, was employed for the fabrication of a dye sensitized solar cell (DSSC) system.The extraction utilized a solvent extraction approach, employing ethanol as the solvent to extract the dyes. The absorbance spectrum of pristine organic photosensitizers CA and CU along with mixture of CA and CU (cocktail) dye was recorded using UV-visible spectroscopy. Density functional theory (DFT) was used to analyze the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) of the dyes to ensure its compatibility with TiO_2 photoanode and the redox mediator. The HOMO energy levels of CA (-4.96 eV) and CU (-5.46 eV) were found to be lower in energy compared to I_3^-/I^- redox couple (-4.77 eV) [1]. Moreover, the LUMO energy levels of CA(-2.52 eV) and CU (-2.25 eV) were found to be higher in energy, compared to conduction band (CB) edge of TiO_2 (-4.2 eV) [2]. This energy alignment is crucial for the efficient regeneration of the dye and the injection of electrons into the conduction band of TiO_2.

In the preliminary assessment of the fabricated DSSCs, the power conversion efficiency was determined as 0.25% and 0.40% for DSSCs sensitized with pristine CA and CU, respectively. On the other hand, the DSSC sensitized with the mixture of CA and CU (cocktail) dye showed remarkably improved performance and demonstrated a short circuit current density (J_{sc}) of 0.15 mA/cm², open circuit voltage (V_{oc}) of 768 mV, fill factor (FF) of 42.7, and energy conversion efficiency (η) of 0.60%. The performance parameters of the DSSCs are summarized in Table 1.

Table1. Measured photovoltaic parameters of the DSSCs

Dye	J_{sc} (mA/cm^2)	V_{oc} (mV)	FF	Efficiency (%)
CA	0.08	760	40	0.25
CU	0.13	813	37.3	0.40
CA and CU	0.15	768	42.7	0.60

Acknowledging the imperative for refinement, concerted endeavors are underway to meticulously optimize fabrication conditions, with the primary objective of significantly elevating the overall efficiency of the solar cell. Notably, the cost-effectiveness, straightforward preparation technique, and the ready availability of the natural dye make DSSCs a promising and viable option for harvesting solar energy.

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*email: amritdutta1993@gmail.com

Precision Hyperthermia: Self-Regulating Gadolinium Garnet Nanoparticles for Cancer Therapy

Rushikesh Fopase*, Lalit M Pandey

Bio-Interface & Environmental Engineering Lab, Department of Biosciences and Bioengineering, Indian Institute of Technology Guwahati, Guwahati, Assam 781039, India

Magnetic hyperthermia is one of the alternative clinical approaches in the focal treatment of cancer in which targeted tissues/cells are exposed to elevated temperature (between 42 to 45℃). The magnetic nanoparticles (MNPs) generate heat when subjected to high frequency alternating magnetic field (AMF) via relaxation and hysteresis losses. Thus elevated temperature (up to 45℃) causes irreversible damage to cancer cells while keeping the healthy cells unaffected [1]. The heat generation by MNPs can be autonomously regulated by tuning the Curie temperature (TC), above which MNPs show a paramagnetic nature with the inability to heat generation [2]. The TC is the function of super-exchange interactions of ions within the crystal and can be altered by doping of larger or diamagnetic ions.

The present work explores the self-regulating heat generation by gadolinium iron aluminum garnet (GFA) nanoparticles for potential hyperthermia applications. The GFA MNPs (Gd3Fe5-xAlxO12) were prepared through the coprecipitation method using different dopant ratios of Fe and Al. The X-ray diffraction analysis confirmed the formation of Fe-Al doped Gd garnet. The GFA MNPs displayed superparamagnetic behavior with very low coercivity and retentivity values. The magnetization values were observed to decrease with increasing Al amount from 28.3 emu/g to 1.2 emu/g at room temperature. The samples were observed to lose magnetization with the increasing temperature. The GFA3 with the magnetic saturation value 7.2 emu/g showed a TC value of 52℃, which is slightly above the desired hyperthermia range, as shown in the Figure 1. The heat dissipation to the surroundings through conduction and convection is anticipated to maintain the temperature within safe limits. The halted heat generation after reaching its TC value evidenced the self-regulating characteristics of the sample. The TC can be further lowered with the increased Al content in the GFA samples. Thus, the synthesized GFA MNPs can be safely applied for magnetic hyperthermia application with self-regulating features.

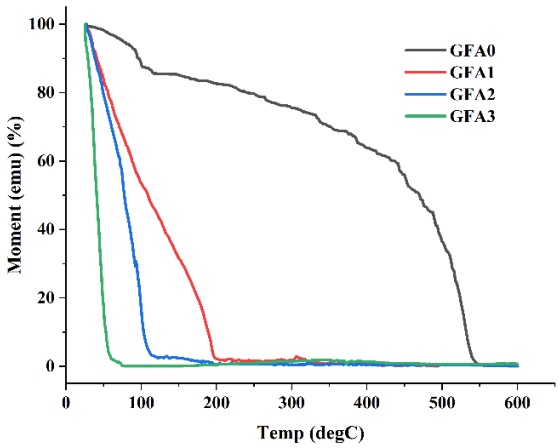

Figure 1: Variation of Curie temperature with different dopant amount

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*email: rushikes@iitg.ac.in

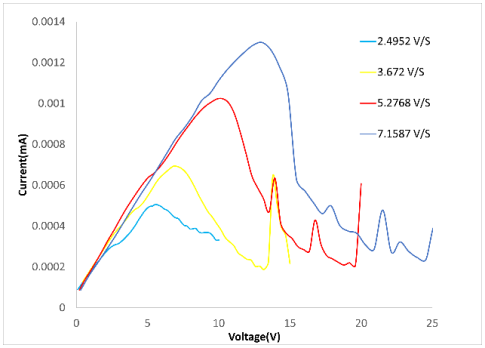
email: lalitpandey@iitg.ac.in

Voltage rate dependent NDR behaviour in SnS_2/GO nanocomposite

Anubhab Parashar Gogoi*, Lohnye Tangjang, Prof. Pradip Kalita

Department of Physics, Rajiv Gandhi University, Arunachal Pradesh, India-791112

Negative Differential Resistance (NDR) is observed in SnS2/GO nanocomposite which is synthesized using chemical bath deposition method. The formation of nanostructure is confirmed by the XRD pattern. The quantum confinement effect of the nanostructures was achieved using PVP as an effective capping agent. The Tauc plot analysis revealed band gap energies within the range of 2.4-2.8 eV. Photoluminescence spectra demonstrated near band gap emission at four distinct peak of 488.04 nm originated from likely radiative recombination of exciton and 533.96 nm, 576.02 nm are might be originated due to the impurities or defect level present in the sample [1]. The electrical properties are measured in planar and Schottky geometry shows Negative Differential Resistance (NDR) behaviour. The Negative Differential Resistance is voltage rate dependent [2]. The voltage rate is measured from 2.492 V/s to 7.1587 V/s (figure) for planner geometry. In addition, the peak current shifts to higher-voltage position as a function of increasing rate. It is located at 5.75 V for 2.4952 V/s and shifts to 13.03 V when rate is increased to 7.1587 V/s. In this case, the current of the NDR peaks increases linearly when voltage rate is increases from 2.4952 V/s to 7.1587 V/s. This NDR behaviour may be attributed to possible modulation of Schottky barrier by defect control mechanism.



Figure

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*email: anubhabgogoi88@gmail.com,
email: Pradip.kalita@rgu.ac.in

Effect of variation of doping concentration upon PVA/ZnS/ZnO:Fe Nanocomposites and their Characterization

Arista Gogoi* and Suparna Bhattacharjee

Department of Applied Sciences, Gauhati University, Guwahati-781014, Assam, India

*Presenting Author

Nanoparticles derived from Group II-VI semiconductors, such as Zinc Sulphide (ZnS) with a direct band gap of 3.68eV, boast diverse applications in various fields such as optoelectronics, UV sensors, field effect transistors and many others. Doping is frequently employed to enhance the conductivity of semiconductors exhibiting low conductivity [1-4]. Zinc oxide (ZnO), is also a member of group II-VI of the periodic table possessing a wide band gap of 3.2 eV and displaying n-type conductivity due to inherent defects or impurities [5-6].

This study focuses on the synthesis of PVA/ZnS/ZnO:Fe core/shell nanocomposites utilizing chemical precipitation method. Polyvinyl alcohol (PVA) has been used as the matrix while Zinc Chloride (ZnCl2) and Sodium Sulphide (Na2S) has been used as the precursors for the synthesis of ZnS nanoparticles. For the synthesis of ZnO nanoparticles, Polyvinyl alcohol (PVA) have been used as the capping agent and Zinc Nitrate ($Zn(NO_3)_2$) and Sodium Hydroxide (NaOH) have been employed as the precursors. In the work, one core PVA/ZnS sample has been synthesized and five PVA/ZnS/ZnO:Fe samples have been synthesized varying the concentration of Fe doping, maintaining a constant reaction time. Characterization of the synthesized nanoparticles is achieved through UV-visible Spectroscopy (UV-vis), Photoluminescence Spectroscopy (PL), Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD). The UV-visible Spectroscopy results reveal the absorption edges at 250.07nm for PVA/ZnS core samples and in the range of 253.96 nm- 257.09 nm, for the PVA/ZnS/ZnO:Fe composite samples. Band gap calculations via Tauc's plot yield values of 6.16 eV for PVA/ZnS samples and in the range of 5.11eV-5.32eV for PVA/ZnS/ZnO:Fe samples, confirming the formation of PVA/ZnS/ZnO:Fe nanoparticles.

PL spectra show emission peaks at 291.66 nm for PVA/ZnS samples and at 291.43 nm for PVA/ZnS/ZnO:Fe samples, indicating a well-formed crystal structure. The XRD patterns have been used to determine the crystalline nature and crystal size of the samples. SEM images reveal the cuboidal microstructures in ZnS samples and predominantly rod-like structures in ZnS/ZnO:Fe samples. The impact of varying dopant concentration on the samples is thoroughly investigated and discussed in this study.

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*email: gogoiarista93@gmail.com
email:suparna@gauhati.ac.in

Electrical properties of calamatic liquid crystal compound hexyloxybenzylidene pentylaniline

Binod Gogoi[*1] and P.R.Alapati[2]

[1]Department of Physics, Kherajkhat College, Lakhimpur, Assam 787033,

[2]GKCIET, Malda, West Bengal, 732141.

This Study reports the electrical proprties of a calamatic liquid crystal compound N (4-n hexyloxy benzylidene) 4-n-pentyl aniline (6O.5). This liquid crystal compound has been sythesised folowing a standard procedure [1] and characterised with the help of differential scanning calorimetry, polarising thermal microscopy and dielectric spectroscopy study of the sample. The compound 6O.5 exhibits four different liquid crystalline phases including nematic phase. This work presents the dielectric permittivity, dielectric anisotropy and dielectric loss of the liquid crystal compound in both planar and homeotropic alignment of LC molecules in the frequency range of 100Hz to 100MHz. Variations in conductivity, activation energy, and relaxation times had also been investigated in all liquid crystal phases exhibited by the sample. Figure 1 (a) and 1(b) shows the variation of magnitude of dielectric anisotropy

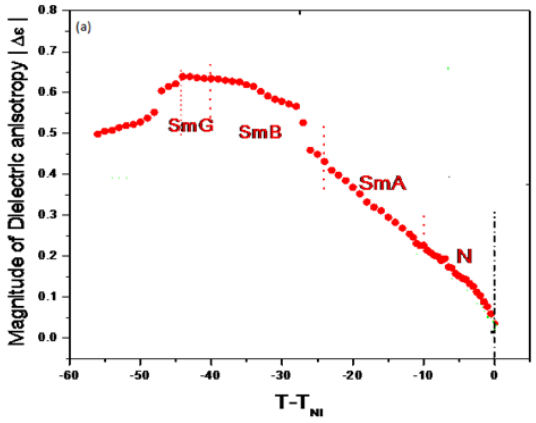
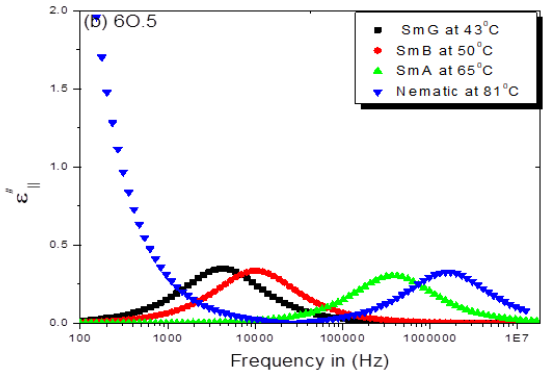


Figure: 1 (a) and (b) shows the variation of dielectric anisotropy and dielectric loss as a function of temperature .

'|ΔЄ|' and dielectric loss 'Є//' as a function of temperature of the compound 6O.5.Studies on temperature-dependent dielectric relaxation shows that the compound exhibit negative dielectric anisotropy. The relaxation mechanism is characteristic to different phases that can be related with certain type of molecular organization and their rotations [2-3]. When dielectric permittivity and activation energy were measured as functions of temperature and frequency, substantial variations in dielectric studies were identified near phase transitions. In the specified frequency range, an ordinary Debye-type relaxation mechanism can be seen in the sample.



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*email: 1. binodgogoi2014@gmail.com

2. snigsam@yahoo.com

Charge Generation and Transfer Due To Inter-band and Intra-band Transition in Gold and Silver Nanoparticle Based Independent Hot Carrier Photovoltaic Devices

Deepshikha Gogoi[1] and Arup R Pal[2]
Presenting author: gogoideepshikha4@gmail.com

[1]Abhayapuri College, Abhayapuri, Bongaigaon, Assam-783384, [2]Plasma Nanotech Laboratory, Physical Sciences Division, Institute of Advanced Study in Science and Technology, Paschim Boragaon, Garchuk, Guwahati-781035, India.

We report hot carrier generation and injection in independent hot carrier photovoltaic devices based on Au and Ag nanoparticles where excitonic contribution is not present. The devices have been fabricated by depositing Au and Ag nanoparticles by pulsed dc magnetron sputtering on plasma polymerized aniline (PPA), a p-type organic semiconductor that facilitates the injection and transport of hot carriers generated due to plasmon decay in nanoparticles. Study of relevant energy levels of the materials used, reveals that the PPA/Au device works due to inter-band transition while intra-band transition dominates the working mechanism in the PPA/Ag device.

Metal nanoparticles like Au and Ag are being extensively studied as plasmonic materials for photodetectors, spectroscopy, catalysis and solar energy harvesting.[1]-[3] As far as independent plasmonic photovoltaic device is concerned, reports are still very limited and in most of the available reports, n-type semiconductor is used as a charge transport layer. The process of harvesting light energy by photon absorption in metal nanostructures followed by the generation and collection of photo-generated hot carriers across a metal-semiconductor junction is known as internal photoemission.[4] The aim of this study is to investigate the effect of change of metal nanoparticles (Au and Ag) in the generation of hot electrons and holes in internal photoemission Schottky junction photovoltaic devices.

Here, Au and Ag nanoparticles are taken as model plasmonic absorbers and plasma polymerized aniline (PPA) is taken as a wide bandgap p-type semiconductor. Au nanoparticles have a lower plasmon optical excitation cross section and a larger work function than Ag nanoparticles.[5] Thus the type of hot carriers generated in both the cases should be quite different. A comparative study of the hot carrier photo-chemistry of chemically prepared Au and Ag nanoparticles has been reported recently.[5] However, the different plasmonic properties of these two nanoparticles will definitely affect the device photo-physics of solid-state optoelectronic devices.

In this study, the effect of the change of metal nanoparticles (Au and Ag) is studied in hot carrier generation and injection in the device with Anode/Semiconductor/Metal nanoparticle/Cathode structure.

Study has been performed in a wavelength range higher than the bandgap of the semiconductor to avoid the effect of plasmon exciton interaction or contribution from exciton generation and dissociation. This study provides an insight into the understanding of the operation of hot carrier devices which will be helpful in the development of next generation photodetectors and solar cells.

The *I-V* characteristics of both the devices show a nonlinear behavior which is due to the formation of the Schottky barrier at the metal-semiconductor interface.

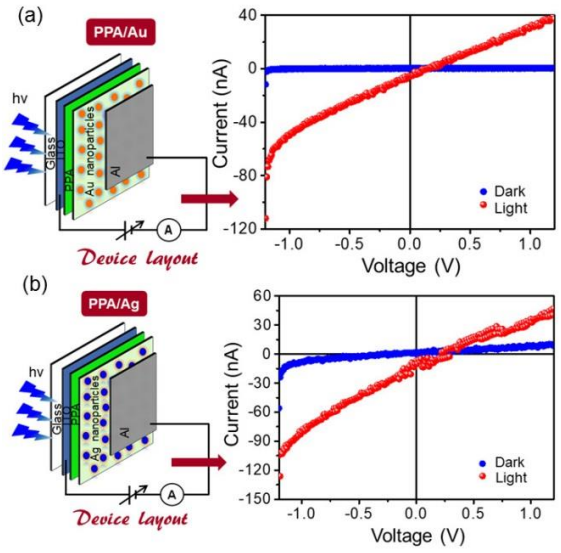

Figure 1: *I-V* characteristics of (a) PD1 (PPA/Au based device) and (b) PD2 (PPA/Ag based device) in dark and under illumination of white light of intensity 10 mW cm^{-2}.

From the *I-V* characteristics in Fig. 1, the photosensitivity is calculated using the relation, Sensitivity (S) = $\Delta I / I_{dark}$ where $\Delta I = I_{light} - I_{dark}$. The Au based device PD1 is found to exhibit more photosensitivity (~70) than the Ag based device PD2 (~4) for white light of intensity 10mWcm^{-2}, which is quite obvious as the dark current of PD2 is comparatively more. Upon photo-illumination, a photo-voltage of 0.15 V and 0.22 V is generated in PD1 and PD2 respectively.

email:gogoideepshikha4@gmail.com

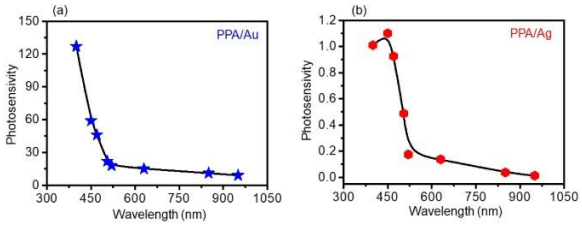

Figure 2: Photosensitivity vs wavelength plot of (a) PD1 and (b) PD2.

From the measured *I-V* characteristics for different wavelengths ranging from near UV to near IR, wavelength dependence of the photosensitivity for both the devices is studied and are shown in Fig. 2. Consequently, it can be seen that PD1 is more sensitive towards the light of wavelength 400 nm as shown in Fig. 2(a). PD2 also shows less sensitivity in the IR region and sensitivity starts increasing towards the visible region with a maximum at the wavelength 450 nm, which is shown in Fig. 2(b). The plots in Fig. 2 clearly show that photosensitivity of PD1 is considerably higher than that of the PD2.

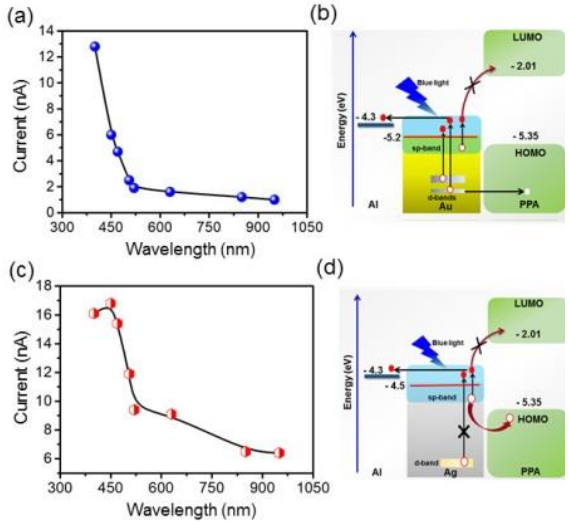

Figure 3: (a) Current *vs* wavelength plot of PD1 (PPA/Au based device). (b) Relevant energy level diagram for PD1. (c) Current *vs* wavelength plot of PD2 (PPA/Ag based device). (d) Relevant energy level diagram for PD2.

The carriers generated in the two different metal nanoparticles as well as their transport mechanism in the device are studied from the relevant energy level diagrams and measured photoelectrical characteristics of the devices. Effective hot hole transport is observed in both the devices while it is notable that the Au nanoparticle-based device PD1 shows better photosensitivity than the Ag nanoparticle-based device PD2.

However, a direct comparison between the performances of both the devices cannot be drawn because interband transition is found to be the dominating carrier generation mechanism in case of PD1, while intraband transition dominates the carrier generation in case of PD2. The favorable electronic band structure of Au for interband transition in the blue region of the spectrum as well as the higher density of states for holes in the inner d-band of Au creates energetic hot holes in the Au nanoparticles. These hot holes find a barrierless path to the HOMO of PPA and hence effective hole transport takes place in PD1. While in case of Ag, bimodal energy distribution leads to the generation of equally energetic electrons and holes due to intraband transition. These hot holes find a low barrier Schottky contact with the HOMO of PPA and thus transported via internal photoemission in PD2. Therefore, we get a better photosensitivity of PD1 than that of PD2.

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` email:gogoideepshikha4@gmail.com

Electrically driven layer-dependent magnetization reversal in Janus CrSTe

Liyenda Gogoi and Pritam Deb

Advanced Functional Materials Laboratory, Department of Physics, Tezpur University

Switching magnetic ordering in specific layers of a material using electric effect is highly desirable for advanced spintronic devices. In this work, we demonstrate that breaking of out-of-plane symmetry by creating structurally asymmetric Janus [1] materials exhibits layer-dependent magnetic controllability. Our first-principle investigation [2]-[3] of Janus CrSTe reveals that Janus CrSTe possesses strong magnetic anisotropy and facilitates a unique controllable layer-specific magnetization reversal through electrical means.

The Janus structure's diverse elemental composition allows for multiple stacking possibilities, leading to three distinct bilayers of CrSTe with S-S, S-Te, and Te-Te interfacial atoms respectively. All the Janus systems exhibit Ferromagnetic (FM) ground state and perpendicular magnetic anisotropy (PMA).

To explore CrSTe's response to an electric field, electric fields are simulated in a range from $-0.5\ V/Å$ to $0.5\ V/Å$. Under the electric field, anisotropic change in magnetic moment is observed in the monolayer and bilayer systems.

Collectively, the analyses reveal signatures of layer-dependent variation of magnetism under electric field. Magnetic moments of Cr atoms of particular layer change, while that of specific Cr atoms remains impervious to electric fields. This prompts us to propose a hypothesis that under electric field, a mechanism shields these particular Cr atoms from electric effects. This hypothesis is validated by investigating extended three-layered S-Te interface structures. Magnetic profile of the system under electric effects shows that Cr atoms positioned within the systems remain unaffected and Cr atoms at the surface layers are affected by electric fields. This observation substantiates the presence of a shielding effect. Remarkably, the magnetic moment of the surface Cr layer changes magnetic alignment under electric field. This profound magnetization reversal arises from spin-polarized electron spin-flipping under electric field influence as shown in figure 1. However, this reversal is confined solely to a single surface layer.

Figure 1 illustrates the atomic-resolved spin polarization percentage variation of Cr atoms in the trilayer system under both electric biasing. These figures distinctly reveal that local spin polarization of Cr1 (top surface) atom flips from positive to negative after an applied electric field of $-0.4\ V/Å$, while the spin polarization of the other two Cr atoms remains positive.

Intriguingly, there's no spin polarization flip under positive bias. Furthermore, Figures 1(a-f) showcase substantial spin polarization variations in surface Cr atoms only, which support the concept of a shielding effect emerging under electric fields.

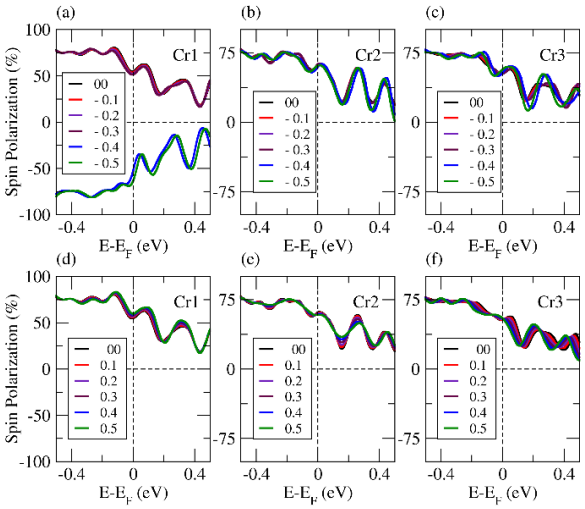

Figure 1: Variation of spin polarization percentage of Cr1, Cr2, Cr3 with negative (a,b,c) and positive (d,e,f) electric bias in trilayer. Insets show the applied electric field.

Our analysis of magnetic moment and charge redistribution reveals that electrically induced charge redistribution at the Te atoms on the surface shields the interior atoms from electric field effects, whereas S atoms lack this behavior, regardless of their location or exposure to electric perturbation.

In summary, our study reveals an electrically driven, layer-dependent, localized magnetization reversal mechanism facilitated by shielding through charge redistribution in Janus CrSTe.

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*email: liyenda@tezu.ernet.in email: pdeb@tezu.ernet.in

Nanomaterials for scientific societal responsibility (SSR)

Madhulekha Gogoi[1,2]*, Sujata Hazarika[2], Supriya Borah[2], Purashri Basyach[1,3], Koushik Saikia[4], Lakshi Saikia[1] and Pritam Deb[5]

[1]Advanced Material Group, Materials Science & Technology Division, CSIR -NEIST, Pulibor 785006, Jorhat, Assam, India

[2]Knowledgepie Private Limited, Bio-NEST, CSIR -NEIST, Pulibor 785006, Jorhat, Assam, India

[3]Department of Chemistry, Rangia College, Rangia 781354, Kamrup (Rural), Assam

[4]Intellectual Property Rights Cell, Tezpur University, Napaam 784028, Sonitpur, Assam, India

[5]Department of Physics, Tezpur University, Napaam 784028, Sonitpur, Assam, India

Our research is positioned at the intersection of nanoscience, optics, materials science, and catalysis. This work encompasses the synthesis and application of nanomaterials, with a particular emphasis on quantum dots. Noteworthy contributions include the development of multicolored, highly luminescent, and biocompatible CdTe quantum dot-based fluorophores tailored for bioimaging applications [1]. Our investigations extend into the realm of magneto-optics, as evident in studies on the anomalous magneto-optic Faraday rotation behavior resulting from resonant tunneling of magnetic moments [2]. Additionally, the expertise in magnetic nanoparticles is evident in the direct monophasic replacement of fatty acid by DMSA on SPION surfaces [3] and the creation of magneto-fluorescent hybrids with ordered and radially distributed porous structures [4]. Our research portfolio also spans materials engineering, as demonstrated by the work on the facile development of iron-platinum nanoparticles, showcasing a multifunctional single-entity approach [5]. Furthermore, the exploration of white light emission from quantum dots and Pd-complexes on their surfaces illustrates this researcher's commitment to advancing the field of optics [6]. In recent publications, we delve into environmental applications, demonstrating the separation of ultrafine chalcogenide particles [7] and developing quantum dot complexes for selective detection of anions [8]. The breadth of my research, from fundamental optical properties to applications in catalysis and environmental sensing, underscores our multidisciplinary approach and commitment to advancing knowledge across diverse scientific domains.

Our research holds significant potential to contribute to scientific societal responsibilities across several domains. The multidisciplinary nature of our work has implications for both scientific advancements and addressing societal challenges. Here are several ways in which our research can lead to scientific societal responsibilities:

Figure 1: Diving into the nano-verse: Advancing research on nanomaterials for diverse application

Biomedical Applications for Improved Healthcare:

The development of biocompatible quantum dots and their application in bioimaging holds promise for advancing diagnostic techniques and medical imaging. These innovations can contribute to improved healthcare outcomes, early disease detection, and personalized medicine, aligning with societal needs for better healthcare solutions.

Environmental Monitoring and Remediation:

The research on the separation of ultrafine chalcogenide particles and the development of quantum dot complexes for selective detection of anions have direct implications for environmental monitoring and remediation. These technologies can

be employed for detecting pollutants in air and water, contributing to environmental sustainability and the well-being of communities.

*email: knowledgepie22@gmail.com

Energy Harvesting and Storage:

The exploration of controlled Ni doping on a g-C3N4/CuWO4 photocatalyst for improved hydrogen evolution addresses challenges in sustainable energy [9]. Such advancements in energy materials and catalysis have the potential to play a role in the development of clean energy technologies, aligning with societal responsibilities towards sustainable and renewable energy sources.

Materials for Advanced Technologies:

The development of multifunctional nanoparticles, such as iron-platinum nanoparticles, showcases the potential for innovative materials in various technological applications. These materials can be crucial in the advancement of electronic devices, sensors, and other technologies that contribute to societal progress and technological innovation.

Educational Outreach and Skill Development:

Engaging in interdisciplinary research provides opportunities for educational outreach and skill development. This expertise can be shared through mentorship and collaboration, contributing to the training of future scientists and researchers. This aligns with societal responsibilities to foster scientific literacy and expertise.

Ethical Considerations and Responsible Research:

As advancements in nanotechnology and materials science continue, our research contributes to discussions around ethical considerations and responsible research practices. This includes considerations related to the environmental impact of nanomaterials and the responsible development of new technologies, promoting a balanced approach between scientific progress and societal well-being.

In summary, our research has the potential to directly address societal challenges and responsibilities, ranging from healthcare and environmental monitoring to energy solutions and educational outreach. By advancing knowledge and technology in these critical areas, our work contributes to the broader societal goals of health, sustainability and responsible scientific progress.

Acknowledgement

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⁎email: knowledgepie22@gmail.com

A simple model for zipping and unzipping of bird feathers

Tonmoy Gogoi *[1] and Ritupan Sarmah †[2]

[1]Department of Physics, Tezpur University

The stick-slip phenomenon is ubiquitous in many physical systems ranging from geology, engineering, and physics to biological systems. Examples of such systems are solid friction [1], jerky flow in materials, peeling off adhesive tapes [2] etc. Generally, a characteristic feature of all stick-slip systems is the existence of slow and fast time scales. The slow time scale usually represents the stick phase while the fast-time scale characterizes the slip phase. The dynamics become more complex in spatially extended systems due to mutual interactions, nonlinearity, and multiple time scales, including spatiotemporal chaos. Novel instability may arise in such a system when driven by external stimuli. The complex interplay among the existing multiple time scales often manifests as intermittent behavior in the observed physical variable. Recently, Kovalev et al. [3] performed an experiment on unzipping a bird feather. They show that the force-displacement curve is intermittent and is attributed to the feather's interlocking microstuctures of barbs, barbules and hooklets. A similar experiment by Zhang et al. [4] shows that a cascading slide-lock system is responsible for the durability of feathers to multiple cycles of zipping and unzipping.

In this work, we present a dynamical stick-slip model to understand the experimentally observed force-displacement fluctuation in unzipping a bird feather. We consider the force-displacement fluctuation to be a result of collective nonlinear interaction between two kinds of hook populations assumed to represent the internal degrees of freedom and their mutual interaction with applied experimental conditions. The unzipping mechanism in our approach is attributed to the plastic deformation of the hooklets that hold the barbs together. We show that interactions among these degrees of freedom lead to a stick-slip process that results in intermittent force fluctuations.

Numerical investigation of our model successfully exhibits a series of force fluctuations implying underlying intermittent dynamics. To further address the physical extension of a feather, we developed a spatially extended model for the bird feather dynamics. The spatial coupling is introduced through a diffusive coupling term that represents the influence of one deformation event with its neighboring events, while the stress is taken as the average of the spatial responses. It is observed that, in the absence of diffusive coupling, while interacting with only global stress distribution, our spatially extended model successfully captures all the experimental results (shown in Fig. 1). However, in the case of nonzero spatial coupling, the deformation events are found to be synchronizing, leading to diminishing force drops. This result is surprising since it demonstrates that the deformation events in an unzipping process of a spatially extended bird feather are independent of each other. Our findings may unleash new avenues in understanding the collective dynamics of spatially extended nano-rod-like systems.

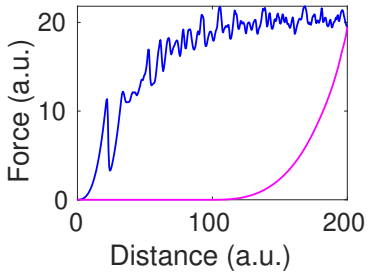

Figure 1: Numerically obtained evolution dynamics using the extended bird feather model.

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*email: tonmoy@tezu.ernet.in
†email: ritupan@tezu.ernet.in

Polymer-based liquid phase exfoliation of graphite to obtain highly stable and well-dispersed graphene nanosheets

Rajesh Ghosh, Hrishikesh Sarma, Anurag Kashyap, Hemen Kalita*

Nanomaterials and nanoelectronics Laboratory (NAMONICS),

Department of Physics, Gauhati University, Guwahati-781014, Assam

Liquid phase exfoliation of graphite using branched polymers is a promising approach to obtain individual layers of graphene for the ability of the polymer molecules to efficiently penetrate between the layered structures [1]. The long-chain branched polymers facilitate graphite exfoliation by overcoming the van der Waals interactions. The polymer molecules adsorb onto the exfoliated graphene sheets through noncovalent interactions, like hydrophobic and π–π stacking, preventing restacking and ensuring stable dispersion[2]-[3].

In this work, we describe a scalable exfoliation method to produce graphene sheets from pristine graphite using polyethyleneimine (PEI), as a stabilizer and deionized water as an aqueous medium. A top-down approach was used to synthesize the polymer-based well-dispersed and stable dispersion following ultrasonic bath sonication. The graphite exfoliated using PEI solution remains in a homogenous dispersion over a period of about 6 months. The obtained graphene sheets are characterized via various morphological and spectroscopic techniques using FESEM, XRD, Raman spectra and UV-visible absorption spectroscopy.

The wettability and spreading behavior of the prepared graphene dispersion are also studied on various substrates. The prepared graphene dispersion with PEI is found to have low spreadability and thus have higher contact angle on different substrate as compared to other commonly used solvents for dispersion. The low spreadability leads to control deposition of droplets containing graphene within the predefined channels in interdigitated electrode (IDE) structure on different substrates. This type of homogenous or uniform dispersion of graphene is highly desirable for controlled fabrication of micropatterns in devices.

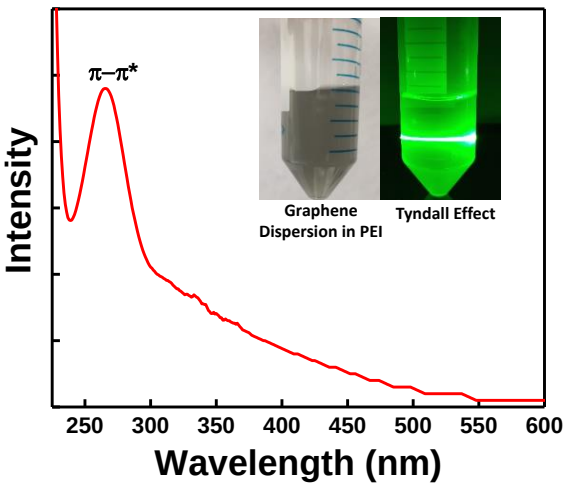

Figure 1: UV- Visible absorption spectra for Graphene-PEI dispersion. Inset shows the graphene-PEI dispersion and the Tyndall effect indicating the uniform dispersion.

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*email: hemenkalita@gauhati.ac.in

Extraction and characterization of natural dye extracted from *Hibiscus Acetosella* leaf and its application in dye-sensitized solar cell

Bikashjyoti Gohain[1], Amrit Dutta[2], Surajit Konwer*[1] and Ankur Gogoi*[2]

[1]Department of Chemistry, Dibrugarh University, Dibrugarh-786004, Assam;

[2]Department of Physics, Jagannath Barooah University, Jorhat-785001, Assam

The primary environmental issue that drives the search for alternative energy sources is the release of greenhouse gases into the atmosphere when fossil fuels are burned. Dye–sensitized solar cells (DSSC) are photoelectrochemical cells that transform solar energy into electrical energy. DSSCs have gained interest due to their low production cost and considerable conversion rates. The dye plays a crucial role in amending the efficiency of DSSCs. At the interface between an electrolyte and a semiconductor, dye molecules function as light-absorbing species that, upon excitation, introduce electrons into the electrolyte and semiconductor, respectively [1]. In this work, a natural dye has been extracted from Hibiscus Acetosella by solvent extraction method as a single dye source is used to examine the performance of the cell. This article presents the results of the analysis of the anthocyanin sensitizers via UV-Vis spectroscopy and Fourier transform infrared spectroscopy and its application in DSSC. The optical band gap and the HOMO and the LUMO levels of the sensitizer are calculated based on absorption spectroscopy and Density functional theory (DFT). From the DFT it has been found that the Anthocyanin pigment exhibited a highest occupied molecular orbital (HOMO) of -9.21 eV, a lowest unoccupied molecular orbital (LUMO) of -6.59 eV, and a band gap of 2.62 eV, also from the UV-Vis spectroscopy it has been found that the energy band gap of 2.13 eV. The UV-vis spectroscopy data revealed that a strong absorption peak at 583nm within a range of 498-585nm depicts the presence of anthocyanin pigment, the chief component in the dye extract. Also an absorption peak in the range 650nm – 670 nm indicates the presence of chlorophyll pigment in the Hibiscus Acetosella dye (figure 1). The functional groups of Hibiscus Acetosella were confirmed under FTIR spectroscopy (figure 2). The intense broadband at 3350 cm-1 was assigned to -OH stretching vibrations. The aliphatic C-H stretching occurs between 2941 cm-1 and 2834 cm-1. Weak peak vibrations which came in 1018 cm-1 were attributed to the C-O stretching. The dye showed C=O stretching vibrations at about 1795 cm-1. The extracted dye has the potential to be used as a natural photosensitizer in DSSC applications.

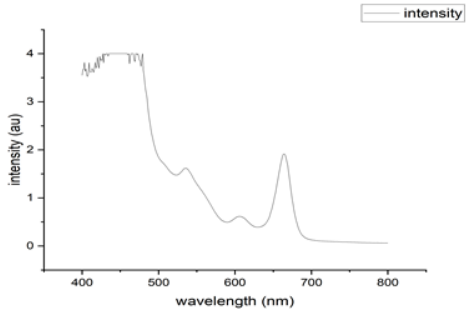

Figure 1: UV-Vis spectrum of Hibiscus Acetosella dye

Keywords: DSSC, photosensitizers, anthocyanin, dye-sensitized solar cells.

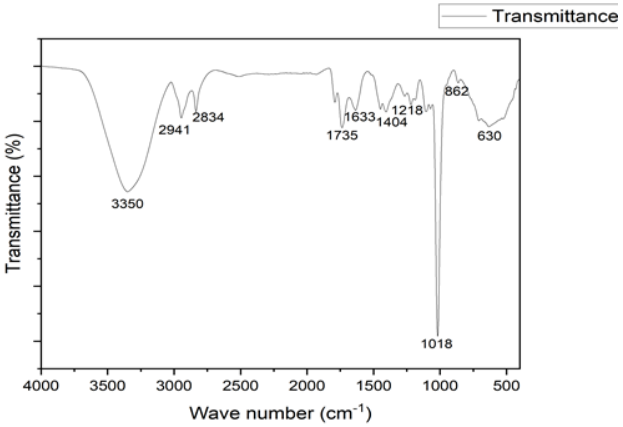

Figure 2: The FTIR spectrum of Anthocyanin dye extracted from Hibiscus Acetosella leaf extract

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email: surajitkonwer@dibru.ac.in

Comprehensive scrutiny on the Role of Dipolar Interactions in Biopolymer coated Eu doped Magnetite Nanoparticles

Krishna Priya Hazarika[1], J.P. Borah[1]*

[1]Nanomagnetism Group, Department of Physics, National Institute of Technology Nagaland, Dimapur, Nagaland-797103, India

Numerous research groups have contributed to a better understanding the physical mechanisms governing self-heating study in single-domain magnetic nanoparticles (SDMNPs) for magnetic fluid hyperthermia (MFH) applications. However, the role of all relevant parameters concerning magnetic relaxation still sparks debates among researchers. In this study, we conduct a comprehensive experimental analysis on the magnetic relaxation of SDMNPs with effective anisotropy, assessing the impact of particle-intrinsic factors and experimental conditions on self-heating efficiency in both noninteracting and interacting systems, with a particular focus on the dipolar interaction effect. Our study successfully reconciles conflicting findings on the interaction effects in the agglomeration and less agglomerated arrangements for MFH applications, as previously documented in the literature. We discuss an analytical approach and its thermal interpretation, which are both focused on nanoparticle design and selecting experimental conditions to achieve optimal heating. The results indicate that polymer (Chitosan/Dextran) coated MNPs with low Eu doping exhibit improved characteristics and hold promise as potential candidates for applications due to their high specific absorption rate (SAR) values. Analyzing these profiles, we can obtain more profound insights into temperature variations, structure, morphology, and self-heating efficiency during magnetic hyperthermia experiments. Utilizing this method and analysis, we can detect aggregation inhomogeneities in samples, including the interplay between effective anisotropy and dipolar interaction of the designed magnetic nanoparticles, which proves extremely useful for advancing *in vitro* therapy development and *in vivo* application analysis.

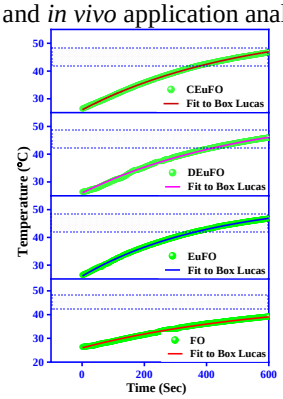

Fig 1. Box-Lucas fit of time-dependent temperature deviation curve for synthesized MNPs for 1 mg/mL concentrations

Fig.1 illustrates the time-dependent temperature profile at a concentration of 1 mg/mL, wherein the Box-Lucas model[1] was applied to determine the specific absorption rates (SAR) and intrinsic loss power (ILP) of the reference MNPs.

In summary, this study outlines a method for designing Eu-doped FO nanoparticles functionalized with chitosan and dextran, representing how biopolymer encapsulation offers a promising approach to control agglomeration of the reference MNPs. The investigation delves into the impact of controlling dipolar interactions through the relaxation mechanism. The inclusion of chitosan and dextran in the EuFO MNPs contributes to precise structural control and fine-tuned magnetic properties, further enhancing the self-heating efficiency of the characterized MNPs.

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*email: krishna7priya7@gmail.com

Influence of Cu^{2+} substitution on the structural and magnetic properties of strontium hexaferrites for recording media applications.

Imlinola Jamir*[1], J.P. Borah[1]

[1]Department of Physics, National Institute of Technology Nagaland, Chumukedima

PO: Dimapur-797103, Nagaland, India

In this work, strontium hexaferrite, have been synthesized by substituting with varying concentration of Cu^{2+} through chemical co-precipitation method for tuning its structural and magnetic properties. The structural properties were characterized by X-Ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR). Thermogravimetric analysis (TGA) was performed to find the stability of the sample by comparing the weight changes at a given temperature. Magnetic parameters: coercivity (Hc), saturation magnetization (Ms), squareness ratio (SR) as well as remanent were calculated using M-H hysteresis loop procured from the VSM. Admirable values of Ms (17.01–27.20 emu/g) and Hc (261.07–727.02 Oe) were obtained and all of the samples showed squareness ratio ranging between 0.21 to 0.25, indicating that they are multi-domain. The low value of coercivity makes these Y-type hexaferrites a potential candidate for switching, sensing and high frequency applications and exhibits considerable favorability for applications involving high-density magnetic recording.

Table.1. Average crystalline size for all the samples using Debye Scherrer equation.

Sample	**Average Crystallite size (nm)**
SHF	37.39
CuSHF 3%	38.41
CuSHF 5%	41.24
CuSHF 7%	48.55

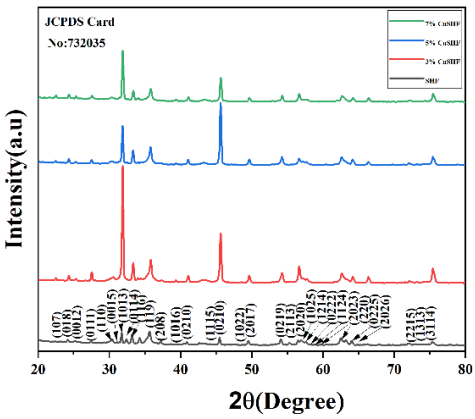

Figure 1: X-ray diffraction patterns of Copper substituted strontium hexaferrite.

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*email: nolajamir27@gmail.com

email: jpborah@nitnagaland.ac.in

Development of 2D/2D heterostructure based coating in food packaging

Manmayuri Kataki, Monika Sharma and Pritam Deb

Department of Physics, Tezpur University, Napaam, Tezpur, Assam, India-784028

Non-biodegradable petroleum-based plastics are widely used for food packaging purposes. These single-use plastics pose a threat to the environment due to their non-biodegradability and release of hazardous chemicals which cause land and marine pollution. Moreover, microplastics present in food are carcinogenic [1]. Recognizing these threats, the focus has shifted to biodegradable food packaging materials. 2D nanomaterials can be a preferred choice for food packaging applications due to their flexibility, enhanced mechanical properties, durability etc. [2]. In this report, a 2D/2D g- C3N4@CuSe heterostructure based coating and film have been developed in PVA/Chitosan matrix [3].

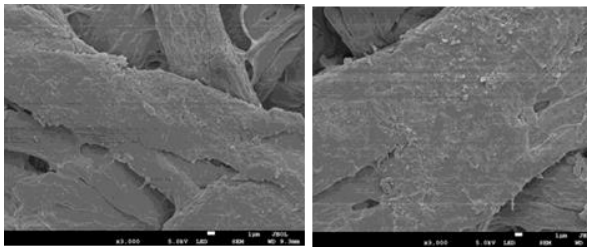

Figure 1: FESEM images of the coated packet

The shelf life of various food items in different biodegradable packets coated with this hybrid coating has increased. Moreover, this coating has shown anti-fungal properties. The increase in contact angle of the coated packets is beneficial for the packaging material. It reduces the likelihood of moisture-related deterioration and helps preserve the texture, flavor, and overall quality of the food over time. The findings presented herein pave the way for future advancements in eco-friendly packaging materials, fostering a paradigm shift towards a more sustainable and responsible approach to food packaging.

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*[1]email: susmita1@tezu.ernet.in [1]email: best@tezu.ernet.in [2,3]email: bettyca@barc.gov.in

Improved Conductivity through Barrier Inhomogeneity Modification via TiO_2 Nanoparticle Integration in Sunset Yellow Dye-Based Schottky Diode

Arnab Kanti Karan*, Dipankar Sahoo, Nabin Baran Manik

Condensed Matter Physics Research Centre, Department of Physics Jadavpur University, Kolkata-700032, India

This investigation delves into the influence of TiO_2 nanoparticle doping on the barrier inhomogeneity (BI) of Sunset-Yellow (SY) dye-based Schottky diode, renowned for its vibrant hue and photoactive nature, provides an intriguing platform to explore the synergy between organic dyes and NPs modifiers. BI within organic dye-based cells leads to non-uniform energy barriers at the metal-organic interface. This inconsistency can originate from various factors, such as variations in surface chemistry, defects, and organic layer thickness. It affects charge injection, transport, and recombination, impacting the device's performance and conductivity. The modification of BI at the metal-organic interface plays a pivotal role in improving the charge transport properties.

The quest for optimizing the performance and stability of organic semiconductor devices has led to the promising strategy of nanoparticle (NPs) integration [1]. Specifically, the attention has centered on titanium dioxide (TiO_2), celebrated for its unique electronic, optical, and surface properties, wide bandgap, high electron mobility, and potential to modulate charge transport in organic materials. The setup uses ITO-coated glass as the front electrode and a gold plate as the back electrode. A 1:1 dye-nanoparticle mixture is sandwiched between them. I-V-T tests are conducted with a Keithley-2400 source meter at temperatures between 288 K and 333 K. C-V-F measurements are performed using an Agilent 4649A LCR meter from 0.5 kHz to 100 kHz. The nonlinear increase of ϕ_{b0} and n with rising temperature, confirming barrier height at the interface [2].

Simultaneously, the ideality factor decreases with increasing temperature. Post-incorporation of NPs, we observe enhanced nonlinearity, indicating improved inhomogeneous distribution. Figure 1 schematically illustrates BI and its modification.

$$\ln(A^*_{eff}) = \ln A^* + \left(\frac{q}{kT} - \frac{kT}{q\beta^2\sigma^2}\right)(\phi_{b0} - \phi_b)$$

From the C-V-F analysis, we can see that the depletion layer width lowers with frequency due to the greater charge buildup at the interface.

We have the variation of calculated ϕ_b with the temperature and the depletion layer width (W_L) with the frequency.

We can see that both the W_L and ϕ_b decrease in the presence of NPs. Considering Gaussian distribution of BI with mean barrier height ϕ_b [2], we can express the Homogeneous Richardson Constant as equation 1. Table 1 represents the values of calculated BI parameters.

Fig.1. BI modification by incorporation of NPs

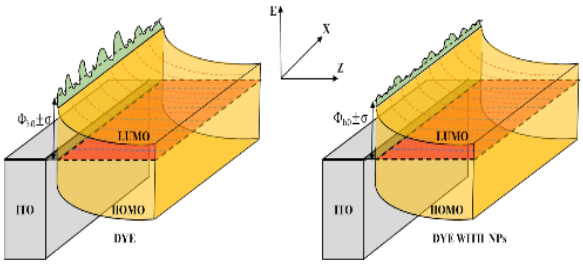

Table 1. Value of BI parameters for dye with and without TiO_2 nanoparticles.

Cell Configuration	Standard Deviation "σ"(V)	Mean Barrier Height "ϕ_b" (eV)	Homogeneous Richardson Constant (A^*) ($Am^{-2}K^{-2}$)
Dye	0.13	0.93	0.71×10^{-3}
Dye + TiO_2	0.08	0.67	8.78×10^{-2}

We can see that the incorporation of nanoparticles in optoelectronic devices can modify the BI by improving the interface properties, charge transport, electron injection/ejection processes, and energy band alignment. This result hence increases in the overall conductivity and semiconducting property of the SY dye based cell.

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*email: First author: akkaran.physics@gmail.com
akkaran.phys.rs@jadavpuruniversity.in

Eco-Friendly Liquid-Phase Exfoliation of Molybdenum Disulfide (MoS_2): Unveiling the Potential of Green Surfactant

Anurag Kashyap [a,1], Rajnandan Lahkar [a,1], Hemen Kalita [a,*]

[a] Nanomaterials and Nanoelectronics Laboratory, Department of Physics, Gauhati University, Jalukbari, Guwahati-781014, Assam

A simple, cost-effective, and eco-friendly green method for the efficient exfoliation of transition metal dichalcogenides (TMDs) to produce mono and few-layer nanosheets is desired for a variety of applications. Surfactant-assisted liquid phase exfoliation (LPE) of two-dimensional (2D) materials is one of the widely used methods to produce stable dispersions in different solvents. There are many reports available where chemical surfactants such as Cetyltrimethylammonium bromide (CTAB), Sodium Dodecyl Benzene Sulphonate (SDBS), and Titron X100 are used for the exfoliation of 2D materials in DI water or Mixed DI water [1],[2]. However, the primary issue with the available commercial and reported surfactant sources is their inability to produce high yields using a small quantity of sustainable and affordable surfactants. Inspired by the age-old medicinal properties of Sapindus mukorossi (SM), a natural surfactant, we present a green-surfactant-assisted LPE method using SM for the efficient exfoliation of MoS_2 in water. SM is a complex molecule with a large molecular weight and non-ionic surfactant with aglycone, which functions as a hydrophobic tail, and glycone, a hydrophilic head made of sugar molecules [3]. The hydrophilic head and hydrophobic tail of SM produce steric repulsive forces against aggregation leading to high stability of the MoS_2 dispersion.

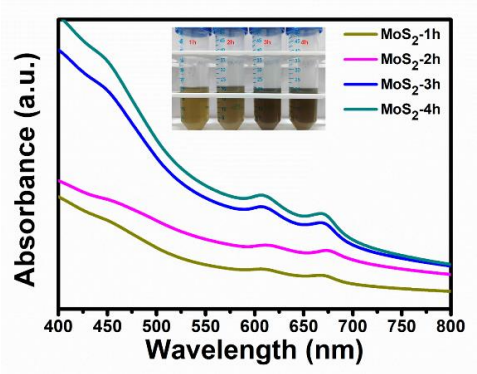

Figure 1: UV-Vis spectra of exfoliated MoS_2 sonicated for different time. Inset: Digital image of the samples.

Figure 1 shows the UV-Vis spectra of exfoliated MoS_2 solutions bath sonicated for four different times. The UV-Vis spectra shows the absorption peaks at ~ 620 nm and ~ 670 nm, which confirms the formation of MoS_2 nanosheets.

Previous studies have shown the humidity-sensing potential of exfoliated MoS_2 [4]. However, green surfactants assisted exfoliation of MoS_2 in humidity sensing is less explored. Here, we have also explored the potential of the exfoliated MoS_2 as a capacitive humidity sensor. The humidity sensing capability of the MoS_2 humidity sensor is tested under different humidity conditions, showing stable and sensitive behavior (Figure 2).

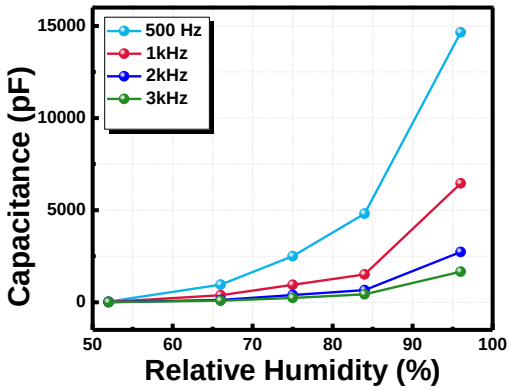

Figure 2: Capacitance variation of the MoS_2 humidity sensor under different humidity conditions.

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*email: angkashyap@gmail.com, rajnandanlahkar4163@gmail.com, hemenkalita@gauhati.ac.in.

Structural and Electrochemical Studies on Zr doped $Na_4Mn_2O_5$ for Application as Electrode in Sodium-ion Coin Cell

Bristisnata Kashyap[a,b], Dimple P. Dutta[b,c]
[a]Chemistry Division, Bhabha Atomic Research Centre, Mumbai 400085, India
[b]Homi Bhabha National Institute, Mumbai 400094, India
[c]HRDD, Training School Complex, Mumbai 400094, India

Sodium ion batteries are being considered as viable alternative to lithium ion batteries due to their low cost and abundant availability. Identifying earth-abundant, low-cost, and safe materials that can function as intercalation cathodes in Na-ion batteries is an important challenge facing the field. In this context, the structure and electrochemical properties of Zr^{4+} doped $Na_4Mn_2O_5$ has been explored to evaluate its performance as electrode material for sodium ion battery.[1] Both pristine and Zr^{4+} doped $Na_4Mn_2O_5$ was prepared by solid-state reaction between appropriate molar ratios of Na_2CO_3 and Mn_3O_4 at 1223 K under O_2 flow for 72 h. The prepared compounds were characterized by XRD and ICP-AES methods.

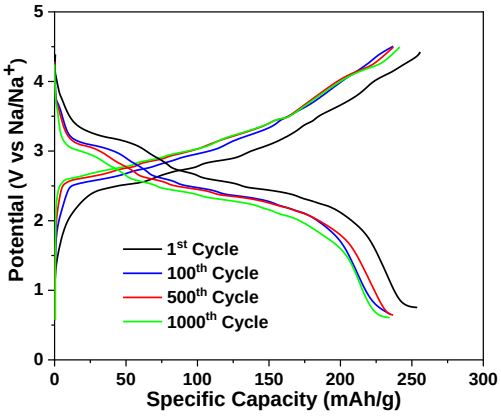

Figure 1: GCD plot of $Na_4Mn_{1.96}Zr_{0.04}O$

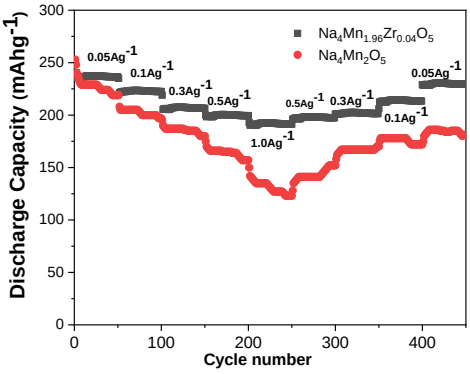

Figure 2: Rate capability of $Na_4Mn_2O_5$ and $Na_4Mn_{1.96}Zr_{0.04}O_5$

Electrical conductivity of $Na_4Mn_2O_5$ was measured by impedance spectroscopy. $Na_4Mn_2O_5$ exhibits reasonably high conductivity of 2.1×10^{-3} Smm^{-1} s^{-1} at 438 K, the mean temperature of measurement. The electrochemical performance on sheet structured Zr^{4+} doped $Na_4Mn_2O_5$ in sodium ion battery were carried out and it was found to exhibit a high discharge capacity of ~400.7 mAh g^{-1} after 3000 cycles run at rate of 0.1A g^{-1} when tested within a voltage range of 0.5-4.5V in sodium-ion batteries. The compound also shows good rate capability and delivers a reversible capacity of 356 mA h g^{-1} at a current rate of 1A g^{-1}. The Na^+ ion diffusivity is high in case of the sheet structured $Na_4Mn_2O_5$ and the reason is currently being explored via theoretical studies.

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bristisnatakashyap@gmail.com,
dimpled@barc.gov.in

Thermoelectric properties of MoS_2, $MoSe_2$, and WS_2: Ab initio model using Boltzmann transport (aMoBT) equation

Shweta Kumari *and Surender Pratap †

Department of Physics & Astronomical Science,
Central University of Himachal Pradesh-176206, India

We conducted a comparative study of the thermoelectric properties of monolayer MoS_2, $MoSe_2$, and WS_2 using an *ab-initio* transport model based on the Boltzmann transport equation (BTE). We aimed to better understand their transport phenomena using first-principles calculations. We used the Faghaninia et al. [1] transport model referred as the aMoBT model for calculating mobility and the Seebeck coefficient. In contrast to other popular models that rely on semi-empirical and constant relaxation time approximation solutions to the BTE, this model takes into account all scattering mechanisms (i.e., elastic and inelastic), uses DFT computations as inputs, and yields exact transport variables [1]. In this model, Rode's iterative method is used to solve the BTE and obtain the electron distribution in response to a small electric field or temperature gradient. To calculate perturbation to the electron distribution, the BTE is solved self-consistently to obtain $g(|\vec{k}|)$

$$g(|\vec{k}|) = \frac{(S_i[g(|\vec{k}|)] - \frac{e|\vec{E}|}{\hbar}\frac{\partial f}{\partial k} - v|\vec{k}|\frac{\partial f}{\partial k})}{(v_{el}(|\vec{k}|) + S_0(|\vec{k}|))} \quad (1)$$

where the terms that reflect the in and out-scattering are S_i and S_0 respectively. $|\vec{E}|$ denotes the low electric field. The group velocity of electrons is denoted by $|\vec{k}|$, whereas v_{el} stands for elastic scattering rates. Ref. [2] provides a depiction of the derivation (1).

Table 1: Calculated mobility (μ), Seebeck coefficient (S), and Figure of merit (ZT) for carrier concentration ($n = 10^{18}\ cm^{-3}$) at T = 300K.

Materials	$\mu(cm^2/V.s)$	S ($\mu V/K$)	$ZT(10^{-3})$
MoS_2	402.64	261	3.9
$MoSe_2$	287.03	308.96	7.4
WS_2	287.7	287.69	3.6

The thermoelectric performance of semiconducting GaAs and InN is successfully calculated using this model. We have calculated the thermoelectric properties of n-type monolayers MoS_2, $MoSe_2$, and WS_2 within the framework of this model over a range of temperature (T) and carrier concentration (n). Our main focus is on studying the role of in-elastic scattering by polar optical phonons. The obtained results are in good agreement with the results obtained by other models like [3]. The outcomes are presented in Fig. 1 and Table 1.

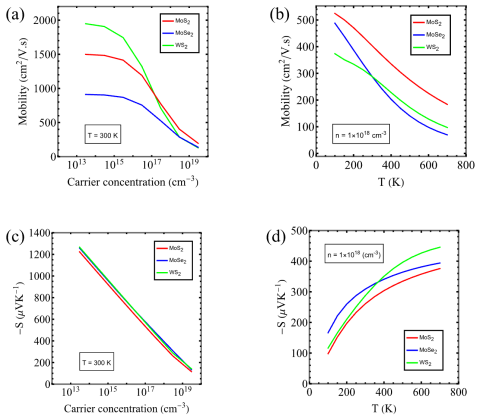

Figure 1: For monolayer MoS_2, $MoSe_2$, and WS_2. (a) The variation of mobility (μ) with carrier concentration (n), and (b) with temperature (T). (c) The variation of Seebeck coefficient (S) with carrier concentration (n), and (d) with temperature (T).

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*email: shwetashweta444@gmail.com
†email: suren1986dhalaria@hpcu.ac.in

Experimental studies on decomposition of Carbon Dioxide Gas in a Glow Discharge Plasma

Deepjyoti Mahanta[1], Rakesh Moulick[2], M. Chakraborty[2] and Ngangom Aomoa[2]

[1]Assam Don Bosco University, Sonapur - 784028, Assam, India
[2]Centre of Plasma Physics - Institute for Plasma Research, Sonapur - 782402, Assam, India

It is known that the planet Mars has an atmosphere of about 6 Torr of which about 96 % is carbon dioxide (CO_2). So, studies are being conducted to see the feasibility of converting carbon dioxide into useful oxygen for use by astronauts during Mars exploration[1]. In these studies, plasma has proved to be one of the promising ways for the decomposition of carbon dioxide and its conversion into oxygen.

In this paper, we present results of experimental study on the breakdown and decomposition of carbon dioxide gas into carbon monoxide and oxygen in glow discharge (GD) plasma. The degree/rate of decomposition of carbon dioxide was studied by optical emission spectroscopy and MQ-7 sensors.

It has been observed that when we have applied a perpendicular magnetic field, the breakdown voltage of CO_2increases, whereas in the case of an axial magnetic field, it decreases compared to the scenario without a magnetic field and Optical emission spectra show the presence of oxygen in theCO_2 plasma ie; the glow discharge plasma was able to breakdown and decompose carbon dioxide.By using the technique of actinometry, the amount of oxygen present in the plasma was measured for various experimental parameters. The effect of perpendicular and axial magnetic field on the decomposition rate was also studied.

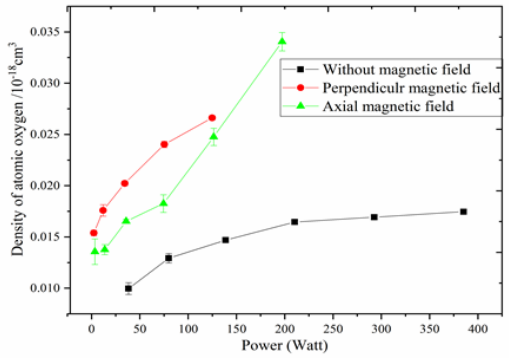

Figure 1: Variation in of O-atom Density with increasing the Power.

From Fig. 1it has been observed that that with increasing the Power the O-atom density also increasing in the presence of perpendicular and axial magnetic fields, as well as without a magnetic field. When we applied a axial magnetic field, the density of atomic oxygen increases whereas in the case of an without a magnetic field, it decreases compared to the scenario with perpendicular magnetic field.

Further, MQ-7 sensors detected carbon monoxide at the exhaust of the rotary pump of the set-up, which further proves the decomposition of CO2in the plasma.

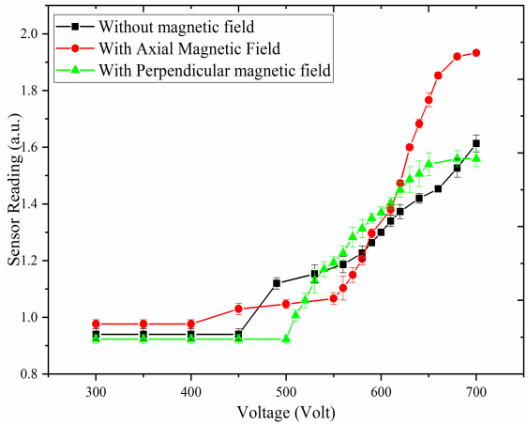

Figure 2: Variation of Sensor Reading with increasing the Applies Voltage.

It was also observed that the presence of magnetic fields increases the rate of decomposition of carbon dioxide in the plasma.

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*[1]email: susmita1@tezu.ernet.in

[1]email: best@tezu.ernet.in

[2,3]email: bettyca@barc.gov.in

Structural and Optical Properties of Undoped and Ni-doped ZnO Nanostructures for Optoelectronic Applications

Debashis Mandal[1,2,#], Pinaki Chakraborty[2] and Pijus Kanti Samanta[3,*]

[1]Department of Physics, Mahishadal Raj College, Purba Medinipur, West Bengal India

[2]Department of Physics, Raiganj University, Uttar Dinajpur, West Bengal, India

[3]Department of Physics, Prabhat Kumar College, Contai-721404, West Bengal, India

A simple wet chemical method has been successfully deployed to synthesize undoped and Ni-doped ZnO nanoparticles. X-ray diffraction data revealed the formation of well crystalline material. The diffraction data suggests the formation of hexagonal unit cell structure. No impurity peak was found indicating the formation of pure material. The UV-visible spectra revealed that the materials have high transparency in the visible region for both the undoped and Ni/ZnO nanostructures. The band gap enhancement was observed for the synthesized undoped and Ni/ZnO sample owing to quantum confinement effect. The material exhibits strong PL emission peaked at 327 nm. UV emission peak in this region is a very rare finding. However, there are some theoretical reports on the UV-PL peak in the lower UV region.

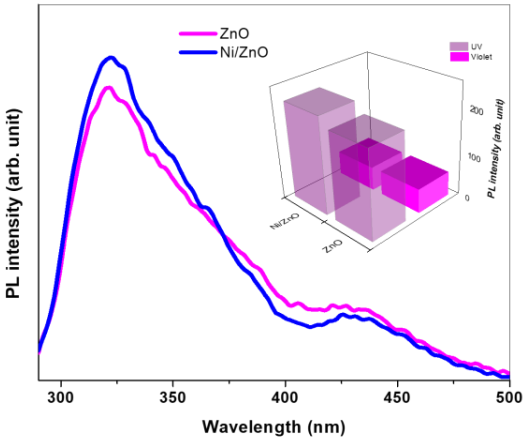

Figure 1: Room-temperature PL spectra of ZnO and Ni/ZnO. Inset shows the relative intensity comparison of the UV and violet emission peak for both the samples.

The UV peak (327 nm) is located hundreds of meV lower in energy than that of the confined exciton when a surface bound ionized acceptor-exciton complex is present in the system, as demonstrated theoretically by Fonoberov et al. and others [1-5]. The emission's origin in exciton localization is yet another explanation. A broad peak was also observed at 429 nm. This emission peak in the violet emission is the result of the recombination of electrons at zinc interstitials and holes in the valence band [6].

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#email: debashismandal43@gmail.com
*email: pks.pkcphy@gmail.com

Structural and Optical Properties of Cupric Oxide (CuO) Nanostructures for Optoelectronic Applications

Suvayan Mandal[1,2,#], Pinaki Chakraborty[2] and Pijus Kanti Samanta[3,*]

[1]Department of Physics, Midnapore College (Autonomous), Paschim Medinipur, West Bengal India

[2]Department of Physics, Raiganj University, Uttar Dinajpur, West Bengal, India

[3]Department of Physics, Prabhat Kumar College, Contai-721404, West Bengal, India

We have adopted a simple aquash chemical reaction method to synthesize CuO nanostructures. FESEM images confirms the formation of CuO nanostructures with distorted octahedral structures of size ~ 500 nm. The structure and purity of the material were investigated using X-ray diffraction analysis which indicates the formation of well crystalline particles (appearance of sharp diffraction peaks in the diffraction pattern). No peak of Cu_2O was observed confirming the formation of single phase CuO. The unit cell is monoclinic. The crystallite size was calculated to 20 nm as calculated from the XRD data. Other parameters such as d-values, strain, degree of orientation, dislocation density and density were also calculated from the diffraction data. The band gap was determined from the UV-visible absorption data using Tauc equation and was calculated to be 2.53 eV. The band gap enhancement was due to the occurrence of quantum confinement effect in the nanostructures.

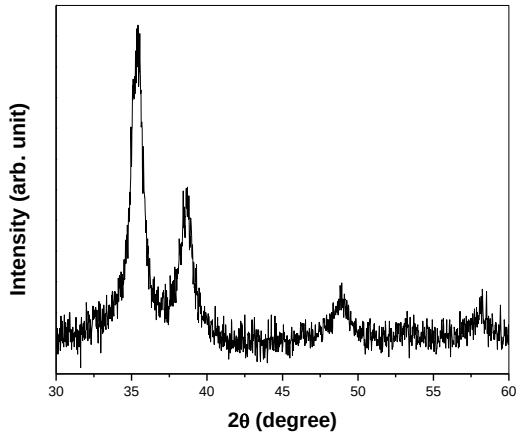

Figure-1: XRD pattern of CuO nanostructures.

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#email: mandalsuvayan@gmail.com
*email: pks.pkcphy@gmail.com

First principles electronic structure calculations on copper substituted silver bromide through modified Becke-Johnson potential

Sahab Uddin Mazumder[1] and Y. Sundarayya[1, *]

[1]Department of Physics, Nagaland University, Lumami-798627, Zunheboto District, Nagaland, India

Silver bromide (AgBr) has a rich phase diagram with the γ-AgBr being one of the forms. γ-AgBr is a n-type semiconductor that crystallizes into zinc blende structure and found to be stable at ambient temperature and pressure. The electrical transport in γ-AgBr is mediated by the migration of cationic defects (Ag^+ interstitials), that further gets generated more between 250 - 420K. On the other hand, γ-CuBr is a p-type semiconductor in which the Cu^+ Frenkel defects are responsible for the conduction [2]. This intrigues to understand the transition of the nature of electrical transport with the replacement of Ag by Cu [3]. In this regard, we report the computational study on the Cu substituted γ-AgBr using the density functional theory (DFT) with Generalized Gradient Approximation (GGA) scheme.

Table 1: Calculated lattice parameter with Cu composition.

Cu composition x	Lattice constant a (Å)
0.00	6.31
0.03215	6.29
0.0625	6.28
0.09375	6.26
0.125	6.25
0.15625	6.25
0.1875	6.23
0.25	6.19
0.5	6.12
0.75	5.93
1.00	5.74

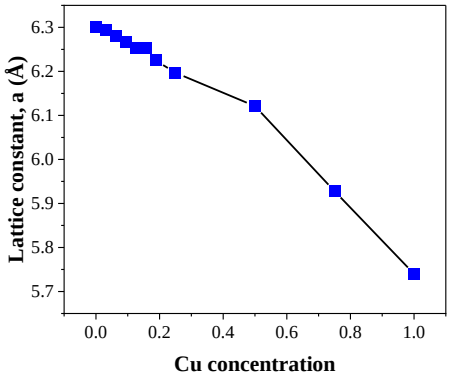

Figure 1: Variation of lattice constant with Cu concentration in γ-$Ag_{1-x}Cu_xBr$ (x = 0.00 – 1.00)

We have also discuss the overall progress of the results using Tran-Blaha modified Becke-Johnson (TB-mBJ) potential. The calculations are performed on 2×2×2 supercell of γ-$Ag_{1-x}Cu_xBr$ (x = 0.00 – 1.00) using full potential linearized augmented plane wave (FP-LAPW) method. The structural properties, the energy gaps, density of states and optical properties are obtained using the optimized structural parameters. The lattice parameter and bulk modulus are found to vary nearly linear with copper concentration x, whereas band gap values are found to follow a non-linear variation.

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*email: sahab.physics@gmail.com, email: ysundar@nagalanduniversity.ac.in

Effect of Electron Beam Irradiated Polymer Based Bakelite RPC Detector Material

Hemen Ch. Medhi

Department of Electronics, St. Edmund's College, Shillong-793003, Meghalaya, India

Resistive plate chambers (RPCs) are rugged and affordable gaseous detectors that have found wide application in high energy physics experiments. The main features of these detectors are large pulse height, low cost per unit area of coverage and good time resolution (about 1ns) [1]. The RPCs are made basically by using very high resistive materials like Bakelite and Glass whose resistivity is of the order of 1010Ωcm - 1012 Ω cm [2]. Bakelite RPC exhibits undesirable high leakage current compared to the Glass RPC detector materials on account of polymer aging [3]. It is confirmed that high energy Electron Beam is the only way to study the detector problems. The appropriate energy of electron Beam irradiates on Bakelite sample might reduce the leakage current of Bakelite RPC detector material and hence improves the performance of the detector.

The X-ray diffractometry (XRD) result endows the changes of crystallinity between Electron Beam irradiated and non irradiated Bakelite samples [4]. Fig. 1 shows the XRD spectra of non irradiated Bakelite sample. The induced changes in the samples due to irradiation have been confirmed from the Fourier Transform Infrared (FTIR) spectra. The microstructural arrangement was investigated by Scanning Electron Microscopy (SEM) images reveal that there is a substantial improvement in the surface morphology in irradiated samples.

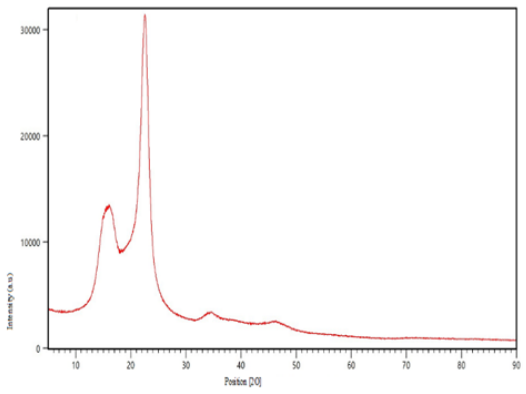

Figure 1: XRD spectra of Non irradiated Bakelite RPC detector materials

To understand the charge transfer kinetics between the electrode and electrolyte interface the prepared electrodes have been characterized by cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) in a three-electrode setup. Our results indicate that the gold nanoparticles decorated GO functionalized PEDOT-PSS based electrodes provide better charge transfer kinetics as compared with the pristine and binary. Presence of the oxidizing functional groups on the surface of GO makes it suitable for the efficient immobilization of the biomolecules by covalent linkage. Moreover, deposition of AuNPs over the electrode can enhance the conductivity and charge transport mechanism and may offer better sensitivity and linearity. This study explores AuNP/GO/PEDOT-PSS composite electrodes as an excellent candidate for electrochemical sensing application.

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*[1]email: hemenmedhi1984@gmail.com

Twist control inhomogeneous magnetism in a van der Waals moiré ferromagnet

Saransha Mohanty[1], Weibo Gao and Pritam Deb*[1]

[1]Dept. of Physics, Tezpur University,Tezpur

[2]Nanyang technological University, Singapore

The next generation of quantum materials, namely two-dimensional (2D) van der Waals (vdW) moire magnets, holds immense potential for unlocking unprecedented properties in the realms of twistronics and spintronics due to their robust electron correlations. The strong electron correlations within twisted geometries of vdW layers play a pivotal role in the emergence of unique magnetic characteristics, including skyrmions, noncollinear magnetic textures, moire Zeeman effect, and more. Therefore, the identification of ideal materials for moire materials is crucial for realizing such exotic quantum phenomena [1].

The emergence of a moiré superlattice occurs when two crystal sheets undergo a relative shift in atomic positions, introducing a twist angle [2]-[3]. Twisted crystal lattices exhibit periodic rearrangements in electron density and elongated lattice parameters. The moiré superlattice in twisted crystal sheets gives rise to strong electron-electron $(e^- - e^-)$ interactions, distinguishing them from non-twisted counterparts. This leads to a diverse range of electronic properties, including the Hofstadter Butterfly effect, superconductivity, noncollinear phases, and a substantial anomalous Hall Effect. These electronic phenomena have significant implications for cutting-edge technologies and directly impact fundamental research. Notably, these electronic correlations play a crucial role in the manifestation of magnetism in twisted layered solids. Two-dimensional (2D) crystals can fall into one of these categories: (i) involving at least two nonmagnetic materials (NM) with a relative rotational angle; (ii) comprising at least two magnetic materials (e.g., a combination of ferromagnet (FM) and antiferromagnet (AFM)); and (iii) featuring one nonmagnetic (NM) and one magnetic material, respectively, with a twist to exhibit magnetism.

In this study, we present a novel quantum mechanical phenomenon: twist-regulated on-site magnetism in a vdW bilayer composed of non-magnetic 1T-$NbSe_2$ and ferromagnetic 1T-VSe_2 monolayers at various twist angles. Specifically, our observations reveal the emergence of an inhomogeneous mixture of quenched and augmented magnetic moments per V and Nb atoms (Refer figure 1).

The degree of inhomogeneity in the magnetic moments per V and Nb atoms is strongly influenced by the twist angles, demonstrating a significant variation in the variance of magnetic moments with twist angles.

The moiré superlattices undergo a loss of localized magnetic moment homogeneity due to the rehybridization of atomic orbitals resulting from the reconstruction of atoms within twisted cells.

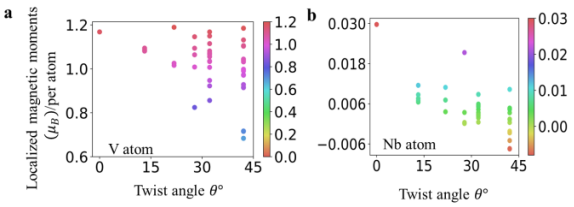

Figure 1: Twist dependent inhomogeneous magnetic moment in (a) V-atom and (b) Nb-atom.

Our investigation reveals that the twist angle has a negligible effect on the total magnetic moment; instead, it significantly influences the local magnetic moments corresponding to the constituent monolayers. In all examined configurations, the Stoner criteria for ferromagnetism are satisfied. Interestingly, the nonmagnetic trigonal phase of the $NbSe_2$ monolayer exhibits weak ferromagnetic ordering in van der Waals conjunction with the VSe_2 monolayer across all investigated configurations. The process of orbital hybridization is found not only to be responsible for the creation of tailored magnetic moments but also to have a substantial impact on the electronic properties of the $NbSe_2$-VSe_2 van der Waals moiré magnet.

The findings indicate that the local moments of the system can be suitably tuned with twist angles. This research sheds light on the intricate interplay between twist angles, electron correlations, and magnetic properties in 2D vdW moire magnets, offering valuable insights for the exploration and utilization of these materials in advanced quantum technologies.

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*email: firstau- saramoh@tezu.ernet.in.email: pdeb@tezu.ernet.in

Investigating the presence of capacitive non-volatile memory in e-beam evaporation deposited HfO_2 thin film-based device

Borish Moirangthem[1]*, Elangbam Rameshwar Singh[1], and Naorem Khelchand Singh[1]

[1]Department of Electronics & Communication Engineering, National Institute of Technology Nagaland, India-797103

In this study, we have reported the presence of capacitive memory in the HfO_2 TF deposited over p-Si substrate with Au top electrode using electron beam evaporation deposition technique. The surface morphology of HfO_2 TF was studied using AFM analysis. The device showed a clockwise capacitive-voltage hysteresis loop at sweeping voltages of ± 5 V to ± 8 V, indicating the mechanism of trapping charges. The memory window along with trapped charge density (*N*) of the device increased from 2.3 V to 2.7 V and 2.04 × 10^{10} cm^{-2} to 2.41 × 10^{10} cm^{-2}, respectively with sweeping voltages increases from ± 5 V to ± 8 V. Th shifting of flat band voltage (V_{fb}) illustrated the electron and hole trapping density. The capacitive-voltage and conductance-voltage characteristic for different frequencies of 700 kHz to 5 MHz was conducted to investigate the charge-trapping nature of the device with low interface trapping density (D_{it}) value of 1.02 × 10^{11} eV^{-1}/cm^2 at 1 MHz. Thus, with the above results of the various parameters of capacitive memory, the HfO_2 based device can be a good candidate for non-volatile memory application.

Graphical Abstract

AFM analysis

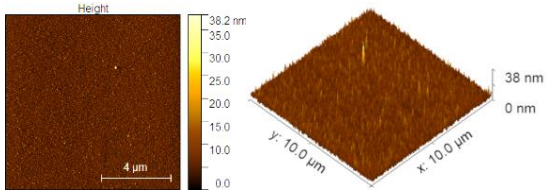

Figure. 1 2D and 3D AFM image of HfO_2 TF

Figure 1 illustrates the 2D and 3D AFM analysis which gives better understanding of the microstructure of HfO_2 TF. The surface morphological characteristics for the TF was recorded for a 10 × 10 µm. The sample exhibits a root mean square (RMS) surface roughness of 2.23 nm. The deposited HfO_2 TF is amorphous in nature as from the image, it is almost flat showing few nanoparticles on the surface. The same AFM nature was also reported by A. Hakeem et al [1].

Capacitive-Voltage (C-V) analysis

Figure 2 (a) demonstrated the C-V hysteresis loop of the TF device for sweeping voltage of ± 5 V to ± 8 V. The memory window was increasing with increase in the sweep voltage as shown in Figure 2 (b).

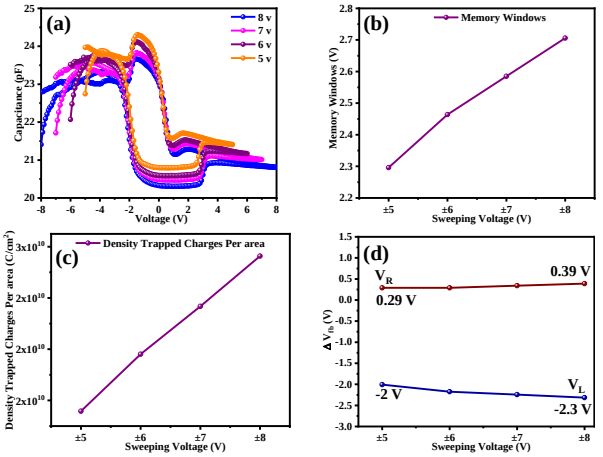

Figure 2 (a) C-V hysteresis loop (b) Memory window versus sweeping voltage (c) Density trapped charge per unit area versus voltage (d) Flat band voltage shifting

The capacitive memory window was increased from 2.3 V at ± 5 V to 2.7 V at ± 8 V. Figure 2 (c) shows the density trapped charges per unit area which was also increases with increase in sweeping voltage from 2.04 × 10^{10} cm^{-2} at ± 5 V to 2.41 × 10^{10} cm^{-2} ± 8 V. Figure 2 (d) reveals the change in shifting of flat band voltages where V_R and V_L indicates flat band voltages found from CV, negative to positive gate voltage sweep and vice versa. It is found that the V_L shift is higher than the V_R , which shows increase in hole injection and helps in V_{fb} shift of HfO_2 TF[2].

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*Corresponding email- borishm2017@gmail.com. Second author: rameshwarela@gmail.com

Novel Dressing Platform with DBD plasma treated PVA/Aloe Vera Nanofiber

Kaushik Kokil Nath[1*], Lakshya Pratim Bora[2*], Gazi Ameen Ahmed[3*], Rajib Biswas[4*]

*Department of Physics, Tezpur University Assam

Atmospheric dielectric barrier discharge, or DBD, is a useful method for changing the surface characteristics of polymers. There has been a noticeable interest in the development of novel wound dressings due to its capacity to modify the bulk and chemical characteristics of material surfaces at room temperature without affecting them.

Aloe vera, which is valued for its biodegradability, body-friendliness, and low toxicity, has a number of bioactive compounds with beneficial properties like antibacterial, anti-inflammatory, and immune-stimulating properties. These attributes have the potential to significantly accelerate the healing of wounds.

Aloe vera gel and 12 weight percent Polyvinyl Alcohol (PVA) are combined at a 5:1 ratio for this investigation. The produced nanofiber mats are treated with DBD plasma in atmospheric pressure oxygen (O_2) gas.

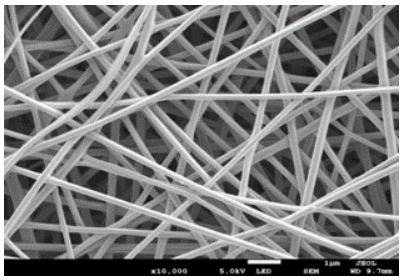

Figure 1: FE-SEM images and diameter distribution of PVA/AV

An examination of the generated nanofibers' morphology using a Field Emission Scanning Electron Microscope (FE-SEM) verifies that they are electrospun nanofibers free of beads. In addition, a range of physical attributes of the nanofiber mat are evaluated through the use of methods such as mechanical property testing, powder X-ray diffraction (PXRD), and attenuated total reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy.

In addition, measurements of the nanofiber mat's contact angle before and after plasma treatment showed positive results. These results imply that the DBD plasma-treated electrospun PVA/Aloevera nanofibers have potential for use as wound dressings in the management of skin and wound infections.

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*email: nathkaushik72@gmail.com

: rajivb27@gmail.com

Development of Barium Vanadate nanophosphor for tunable white light emission

James Oinam[1] and Laishram Robindro Singh[1*]

[1,1*]Department of Nanotechnology, North-Eastern Hill University, Shillong-793022, India

Rare earth doped nanophosphor materials plays a crucial role in development of phosphors converted white light emission. In the present work, wet chemical technique has been approached to synthesis single phase Barium Vanadate doped with europium. Prepared nanophosphor underwent a heat treatment at 900^0C for 6hrs. XRD confirmed that as prepared sample $Ba_3V_2O_8$:xEu^{3+} have rhombohedral phase with space group R-3m. FTIR spectra was analyses to reconfirmed phase purity of prepared sample. PL excitation and emission spectra was investigated and upon excitation with 330nm wavelength, $Ba_3V_2O_8$:xEu^{3+} emitted blue, cyan white and red colours, resulting in tunable emission of light.

Key words: Nanophosphors, wet chemical method, tunable emission.

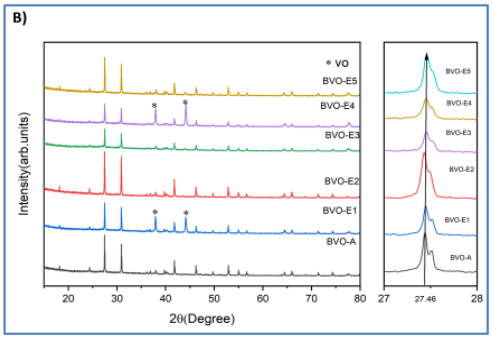

Figure1: X-Ray Diffraction pattern $Ba_3V_2O_8$:Eu^{3+} (at.% 1,2,3,4,5).

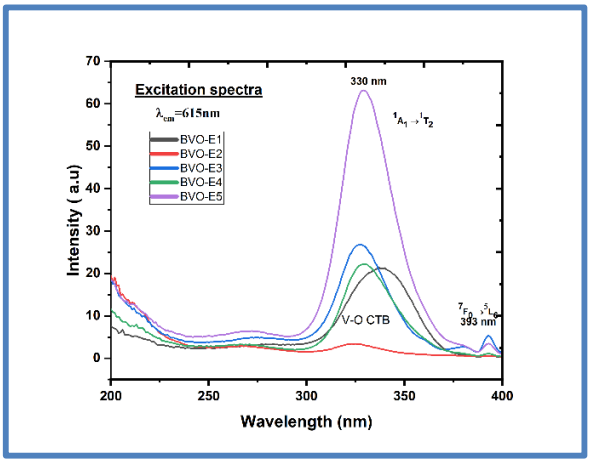

Figure 2: Photoluminescence excitation spectra of prepared nanophosphor $Ba_3V_2O_8$:xEu^{3+} (x=at. % 1,2,3,4,5).

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*email: lrsingh@nehu.ac.in email: jamesoinam707@gmail.com

Two-dimensional α-Fe_2O_3 nanoflakes as MRI Contrast agents

Sayoree Purakayastha[†] and Pritam Deb[†]

[†]Department of Physics, Tezpur University, Assam- 784028

The structure of the Magnetic Nanoparticles (MNPs) plays an important role on their corresponding magnetic characteristics, such as saturation magnetization M_s, remanent magnetization M_r, Blocking temperature T_B, etc. MNPs consist of magnetic moments interacting amongst themselves, and the type and extent of their interaction depends also on their physical parameters, such as their size, shape, surface modification, etc. The value of saturation magnetization is one of the factors that determines the transverse relaxation time, T_2 by the quantum mechanical theory of motional averaging regime (MAR) [1], given by (1)

$$\frac{1}{T_2} = \frac{\left[\frac{256\pi^2\gamma^2}{405} V^* M_S^2 r^2\right]}{D\left[1+\frac{L}{r}\right]} \qquad (1)$$

Hence, the magnetic relaxivity properties are thus inadvertently dependent on the physical parameters of the nano system. Along with the shape or size of the MNPs, the dimension of the system may also play a factor on their magnetic parameters. We aim to study the correlation between the lateral confinement of spins and the corresponding manifestation of the magnetic characteristics for specifically two-dimensional nano system. We have thus synthesized two-dimensional iron oxide (α-Fe_2O_3) nanoflakes via a microwave-assisted liquid exfoliation method.

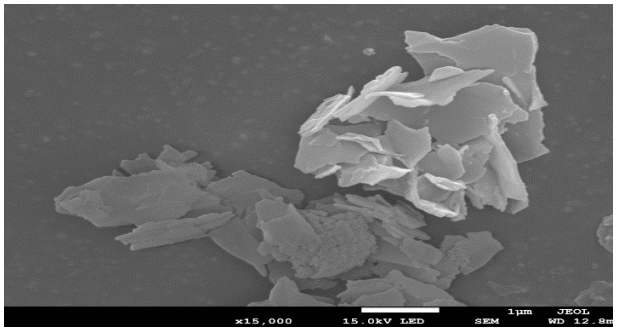

Figure 1: TEM micrograph of the synthesized α-Fe_2O_3 nanoflakes.

Iron oxide nanoparticles (IONPs) are known to have superparamagnetic properties and according to their size limit, they can act as T_2 or T_1 MRI contrast agents. The system which we have developed is novel in its proposed application as MRI contrast agents for its two-dimensional morphology as opposed to previously used 3D shapes like spheres, cubes, octapods [2], etc. The characterization of the synthesized nanomaterial was done with Raman spectroscopy and XRD, while the morphology and microstructural study was done with FESEM and TEM data. The morphology was found to be an assembly of 2D nano flakes of α-Fe_2O_3 as shown in Fig.1. The preliminary signature of a possible MRI contrast agent can be determined by the MR relaxivity behavior of the concerned nanoparticle. The relaxivity coefficients r_1 and r_2 can be determined from Time domain-NMR experiments after analyzing the longitudinal and transverse relaxation profiles respectively. The two-dimensional iron oxide (α-Fe_2O_3) nanoflakes that we have developed hold promise as either a T_1 or T_2 MRI contrast agent where the inhibition of one dimension leads to unique magnetic properties and relaxivity behaviors.

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*email: Sayoree Purakayastha- sayoree@tezu.ernet.in.

email: Pritam Deb- pdeb@tezu.ernet.in

Bio-hybrid reinforced rGO/SnO_2 nanocomposites and investigation of Sn^{+4}-initiated, green rGO-mediated photolytic degradation of toxic pollutants

[1]Nandini Priyam Rajkumari and [2]Pallabi Goswami

[1]Department of Chemistry, Gauhati University, Guwahati 781014, Assam, India, [2]Department of Chemistry, Nowgong College (Autonomous), Nagaon 782001, Assam, India

The application of transition metal semiconductors in the photocatalytic degradation process, under solar irradiation, generates hydroxyl and oxide radicals, as well as superoxide and peroxide radicals [1]. This eco-friendly, sustainable, and secure approach is facilitated very well by p-block metal Tin (Sn) [2]. Tin dioxide (SnO_2) emerges as a promising photocatalyst due to its outstanding light absorption and low band-gap energy [3].

Additionally, the introduction of reduced graphene oxide (rGO) aids in charge separation, reducing the recombination of photogenerated charges [4].

In our study, we incorporate environmentally friendly reduced graphene oxide into the nanocomposite with SnO_2. The rGO enhances absorption in the UV-visible range and minimizes the electron-hole recombination rate. The rGO/SnO_2 composite efficiently promotes water oxidation through the 2e reduction of O_2, leading to the generation of oxide, superoxide, hydroxide, and peroxide radicals (Figure 1). Furthermore, when combined with an organic electron donor (OED), the composite materials enhance the production of H_2O_2, with the reduced graphene moiety serving this purpose.

Consequently, our research offers valuable insights into the mechanism of reducing graphene oxide in an environmentally conscious manner, facilitating the design of efficient photocatalysts for pollutant degradation.

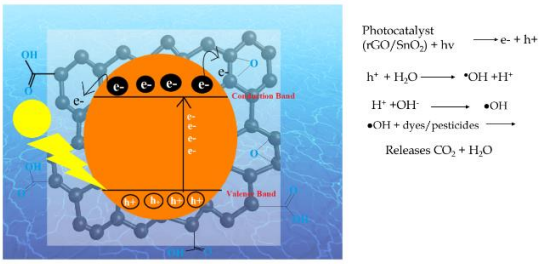

Figure 1:Photocatalytic mechanism

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*email: nandinipriyam942@gmail.com

Intrinsic Valley Polarization in Half-Metal VSSe-VSe_2 Heterostructure

Deepshekhar Roy [*1] and Pritam Deb [†1]

[1]Advanced Functional Material Laboratory (AFML), Department of Physics, Tezpur University (Central University), Tezpur 784028, India

This study delves into the manipulation of the valley degree of freedom, akin to well-known charge and spin, within two-dimensional (2D) half-metal van der Waals heterostructures. Due to their broken inversion symmetry, this 2D ferrovalley material shows two inequivalent valley states at $K+$ and $K-$ of the hexagonal Brillouin zone. The degeneracy in the energy at the valley point can be broken by applying different methods such as proximity effect [1], external magnetic field, optical pumping, etc. which leads to the valley polarization as shown in Figure 1. Achieving substantial valley polarization through external interventions remains challenging, impeding precise control over these valley properties. Notably, recent advancements have introduced the concept of ferrovalley materials [2], a novel class characterized by intrinsic spontaneous valley polarization induced by inherent ferromagnetism. These ferrovalley materials present a compelling avenue to address the challenges associated with extrinsic valley polarization, offering a potential solution to the complexities in controlling these intricate valley properties [3].

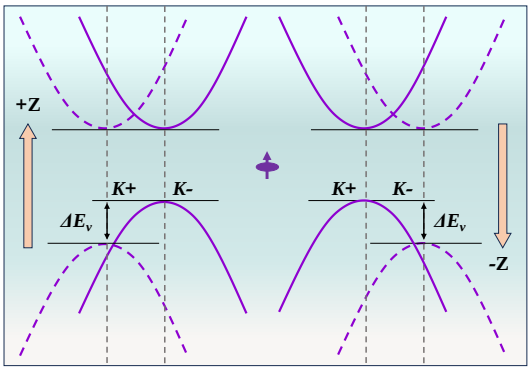

Figure 1: Illustration of valley polarization having only spin-up channel

Herein, using the first principal calculation, the valley polarization of 45.7 meV is obtained in spin-up channel with the implication of the spin-orbit coupling effect (SOC). Remarkably, the valley polarization can be toggled by altering the magnetization of the V atom, transitioning from a positive Z-direction to a negative Z-direction. Additionally, the application of biaxial strain further enhances the splitting in the valley. This property showcases significant promise for manipulating valley pseudospin in quantum information processing and fostering the development of valleytronics devices.

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*email: deeproy@tezu.ernet.in
†email: pdeb@tezu.ernet.in

Machine learning assisted electrochemical SERS substrate for rapid identification of poultry antibiotics

Dipjyoti Sarma *[1] and Pabitra Nath †[1]

[1]Dept. of Physics, Tezpur University

Antibiotic resistance (AR) poses a growing global concern that affects a significant portion of the population. Minimal exposure to antibiotics leads to the promotion of microbial resistant genes in animals [1]. These resistant microbial strains come into contact with humans, giving rise to severe issues such as the ineffectiveness of antibiotics in human medicine. Consequently, the detection of trace amounts of antibiotic molecules in food matrices like chicken, milk, and eggs becomes crucial in preventing diseases caused by AR. Traditional detection methods, including Liquid chromatography–mass spectrometry (LC-MS), Gas chromatography–mass spectrometry(GC-MS), and High-performance liquid chromatography (HPLC), are widely regarded as the gold standard [2]. However, they encounter challenges such as high instrumentation costs and prolonged sample preparation times. Surface-enhanced Raman spectroscopy (SERS) emerges as a promising alternative sensing platform that overcomes these issues associated with traditional detection techniques. SERS, a variant of Raman spectroscopy, significantly enhances the sensitivity of scattered Raman signals when recorded in proximity to a metal nanostructured surface [3]. The proposed sensing work illustrates the fabrication of a sensitive SERS substrate using AuNP-decorated ITO-glass for the trace detection of oxytetracycline (OCT) and azithromycin (AZ). Figure 1 presents preliminary SERS results for OCT and AZ at a concentration of 1 ppm.

The SERS substrate fabrication was carried out by electrodeposition of AuNPs over ITO-glass by cyclic voltametry. Further, the sensing platform is coupled with an optimized Machine learning(ML) classification algoritm Kernel Support Vector Machines(SVM) for rapid identification of the analytes in mixed samples. Figure 2 depicts the accuracy plot of the different ML algoritm for the designed sensing setup. This research showcases the potential of SERS as an effective and cost-efficient method for detecting antibiotics in food matrices, addressing the limitations of traditional detection approaches.

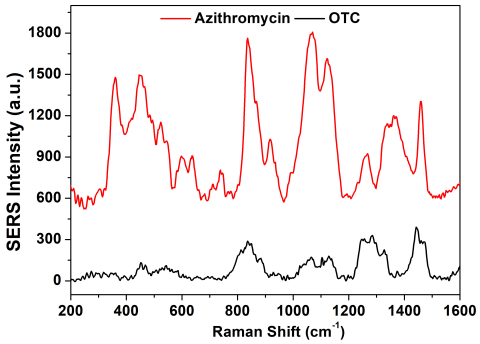

Figure 1: Comparison of SERS spectra of OCT and AZ

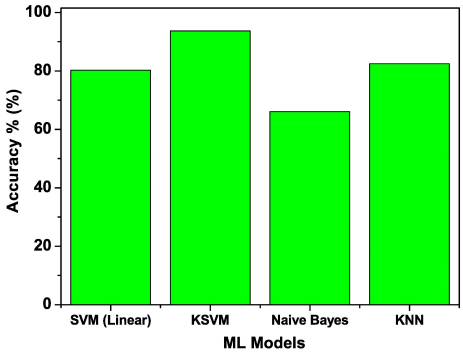

Figure 2: Comparison of ML performance

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*email: dsarma7@tezu.ernet.in
†email: pnath@tezu.ernet.in

Nanostructured copper oxide thin film for visible light photocatalysis

M. Sarma[1]*, Manju Kumari Jaiswal[2], Biswajit Choudhury[2], A. R. Pal[2] and S. Karmakar[1]

[1]Dept. of Instrumentation and USIC, Gauhati University, Guwahati-781014, Assam.

[2]Physical Sciences Division, IASST, Paschim Boragaon, Garchuk, Guwahati-781035

Copper oxide semiconductor is a very important low-cost material that can be used as a visible light photocatalyst. We have synthesized nanostructured copper oxide thin film (CuO-TF) by reactive magnetron sputtering. The synthesized CuO-TF is confirmed by XRD and their intrinsic characteristics are also studied. The diffraction peaks seen in XRD patterns and their corresponding planes revealed the crystalline characteristics having a monoclinic phase. The almost spherical-sized nanoparticles are clearly visible in FESEM images. The average particle size is found to be 6.07 nm. The HRTEM images reveal the inter-planer spacing which is found to be 0.22 nm. The band gap energy of CuO-TF is determined using the Davis-Mott equation and Tauc plot subsequently, which is found to be 2.17 eV. The photocatalytic behavior of CuO-TF is studied in the degradation of methylene blue (MB) dye solution under visible light irradiation. The MB dye degradation under 23 Watt LED bulb is found to be 83.8 % after 150 minutes irradiation. This work reveals that copper oxide thin film may be useful as a very good visible light photocatalyst.

The photo degradation efficiency (η) is calculated by the following equation.,

$\eta(\%) = \frac{C_o - C_t}{C_o} \times 100$ where Co and Ct are the initial absorbance and the absorbance at time t of the solution respectively.

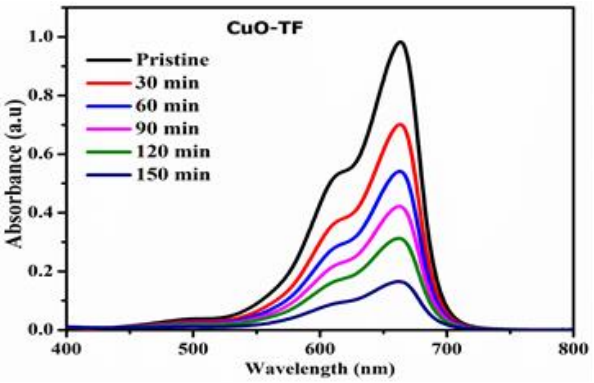

Fig.1 MB degradation by copper oxide thin film (CuO-TF).

Keywords: Thin film, photocatalyst, degradation, visible light

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*Corresponding Author, E-mail: sarmamintu9@gmail.com

2D/2D hybrid nanostructure in symmetric and asymmetric supercapacitor application

Monika Sharma, and Pritam Deb*

Advanced Functional Material Laboratory (AFML), Department of Physics, Tezpur University (Central University), Tezpur 784028, India.

Tungsten metal sulfides (TMS) is a kind of intriguing electrode materials for supercapacitors, however due to their propensity for agglomeration and substantial volume variations during repetitive charge-discharge cycles; they are indeed constrained by cyclic instability and poor energy storage performances. To address these limitations, the introduction of heteroatoms into graphene sheets (DGS) has proven to be a successful and simple method for enhancing their electrochemical performance. The heteroatom can tune the electrical and chemical reactivity of rGO, induce defects, and possibly result in doped rGO with increased functionality. Notably, N-doped rGO exhibits better electrochemical performances compared to untreated GO, attributed to its contribution to the electrode's pseudo-capacitive properties. Therefore, research efforts have been emphasised on exploiting doped rGO-based nanosheets as support materials for the fabrication of TMS and DGS composites in storage applications [1, 2]. Further, Lin's research team has synthesized rGO-MoS_2-WS_2 nanocomposites via a facile chemical approach, exhibiting impressive capacities of 365 F g^{-1} at 1 A g^{-1} and 70% capacitance retention after 1000 cycles at 4 A g^{-1} [3]. In addition, Li et al. has developed N-MoS_2@N-rGO nanocomposites via hydrothermal approach, where N-rGO not only delivers favourable open structures for easy ion diffusion but also enhances accessible active sites, ensuing improved electrochemical performance with specific capacitances of 340 F g^{-1} at current densities of 0.5 A g^{-1} and excellent cycling stability of 98% after 5000 cycles [4]. Recently, Shrivastav's research group has synthesized an oxide/carbon composite consisting of WS_2 nanorods and ZIF-8 derived nano-porous carbon. The composite is utilized as the positive electrode, while the negative electrode was made of ZIF-8 derived nanoporous carbon where asymmetric supercapacitor (ASC) accomplishes an energy density of 25 Wh/kg when discharged at a power rate of 801 W/kg. Even after undergoing 3000 cycles, the ASC retained nearly 78% of its initial capacitance. In this study, nanoflakes-on-nanosheets WS_2/N doped reduced graphene oxide (N-rGO) hybrid nanostructure were developed, wherein intertwined N-rGO nanosheets serve as supports and effectively spread WS_2 nanoflakes over the N-rGO surface, supplying a large number of electroactive sites. Significantly, the C−O−W bonds connect the flakes and sheet together, form a highly coupled interface that efficiently facilitates interface charge transport and mechanically strengthens it to withstand volume variations.

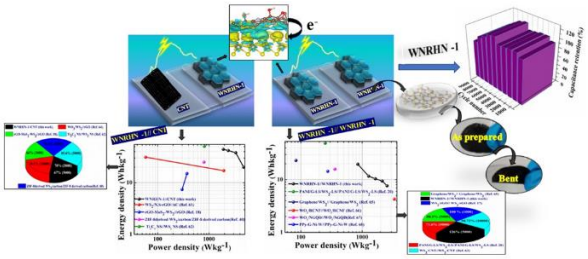

Figure 1: 2D/2D hybrid nanostructure as electrode material for both symmetric and asymmetric supercapacitors.

In the current study, supercapacitors based on WS_2/N-rGO electrode exhibit very high specific capacitance, cyclability, and distinctive structural modifications throughout electrochemical cycling, demonstrating the electrode's significant potential for energy storage. It has a remarkable specific and cyclic stability for symmetric supercapacitor. The asymmetric supercapacitor exhibits higher specific capacitance, maximum energy density and power density. The research should pave the way for the investigation of further TMDs-based electrode materials in the near future for the construction of improved energy storage devices.

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*email: monikas@tezu.ernet.in, pdeb@tezu.ernet.in

Large tunneling magnetoresistance in electrically sensitive $Fe_3GeTe_2/WSe_2/Fe_3GeTe_2$ vertical vdW heterostructure

Anil Kumar Singh[a], Weibo Gao[b], and Pritam Deb[a]

[a]Advanced Functional Materials Laboratory, Department of Physics, Tezpur University (Central University), Tezpur 784028, India, Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 639798, Singapore

The possibilities for low-power spintronics can be expanded through the smooth integration of two-dimensional magnetic materials with diverse materials. From this perspective, magnetic connections with remarkable electrical control and stability can be establish by designing van der Waals (vdW) heterostructure of 2D ferromagnets with semiconducting transition metal dichalcogenides. In this regard, 2D metallic Fe_3GeTe_2 exhibits enormous magneto-anisotropy owing to spin orbit coupling. In order to allow FGT to maintain its inherent electrical characteristics, we have designed the $FGT/WSe_2/FGT$ magnetic tunnel junction. The notable tunable tunneling magnetoresistance (TMR) are achievable with energy dependent spin polarization. We have noticed that, across a broad bias voltage range, relocation of high energy localized minority states toward low energy region results in spin polarization oscillation. This results in high positive as well as negative TMR. The designed spin valve features exceptional anomalous hall conductivity (AHC) characteristics, which is highly tunable. It's interesting to note that MTJ devices offer electrical control, which can integrate such extraordinary electronic behavior, which includes massive and switchable spin polarization, anomalous Hall conductivity, and TMR.

The observed AHC exhibits oscillatory behavior as a function of energy, with a substantial positive value at Fermi level of 626 S/cm as shown in Fig. 1(a). Furthermore, the switching behavior of AHC is confirmed by the largest negative value of -636 S/cm at 7.6 eV. This oscillatory behavior of AHC is emerges due to the presence of both positive and negative Berry curvature as shown in Fig 1(b). Figure 1(c) represents unconventional TMR natures with alteration in polarity and magnitude. Moreover, the transmission in antiparallel configuration (APC) overrides the transmission in parallel configuration (PC) at 0.1 eV resulting in a negative TMR of -100%. The suggested prototype spin valve device is shown in Fig. 1(d).

In summary, the electrical characteristics of $FGT/WSe_2/FGT$ vdW heterostructure is determined using first principle calculations. The vdW interaction between constituent layers allow FGT to persists its intrinsic features. However, the accessible minority spin down states moves towards Fermi energy region, when subjected to an electric field ($0V \leq |Vb| \leq 4V$). This leads to a wide range spin polarization variation over 41% to -42% and 34% to -32%

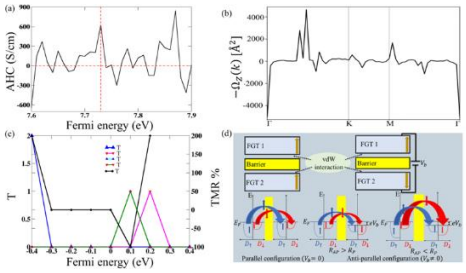

Figure 1: Energy dependent (a) anomalous Hall conductivity, (b) Berry curvature along high symmetry directions, (c) electron transmission in both PC and APC magnetizations and TMR% and (d) schematic of proposed magnetic tunnel junction.

in PC and APC respectively. The observed oscillating spin polarization results in large tunable TMR. Moreover, the great electrical control and AHC establishes the observed unusual TMR behavior. Therefore, the other members of vdW ferromagnet family are also believed to exhibit similar MR behavior, which motivates further investigation on spintronic devices based on these materials

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*email: firstau- thor@xyzuniv.ac.in.email: secondauthor@inpqr.ernet.in

Luminescence studies of Y2O3:Eu nanoparticles by polyol method and incorporation of Li ions for luminescence enhancement

L. Robindro Singh

Department of Nanotechnology, North Eastern Hill Unive4rsity, Shillong, Meghalaya-793022, India.

Small particles 10-20 nm of Y_2O_3 nanoparticles particles were prepared by wet chemical reaction, the prepared nanoparticles were characterized by XRD (x-ray diffraction), TEM (transmission electron micrograph) and FTIR (fourier transform infrared spectroscopy), proving that the prepared nanoparticles are pure within the resolution of the equipment. As-prepared samples, 300 and 500 °C heated samples shows luminescence emission due to transition of $^5D_0 \rightarrow {}^7F_1$ and $^5D_0 \rightarrow {}^7F_2$ but the luminescence due to surface Eu^{3+} ions could not be observed. This luminescence could be observed only for 900°C sample. Luminescence emission intensity could be improved by incorporation of Li ions in Y_2O_3:Eu matrix without disturbing the characteristics of Y_2O_3:Eu emission lines, this could attributed strong energy transfer from Li ions to Eu ions.

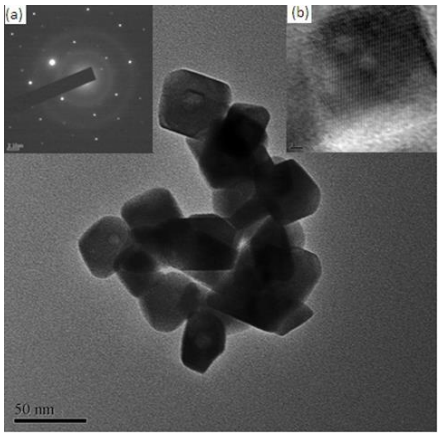

Figure 1: TEM Picture of Y2O3: Eu5 at.% doped nanoparticles the inset (a) the SAD pattern of the particles and (b) expansion of the crystals, showing regular spacing.

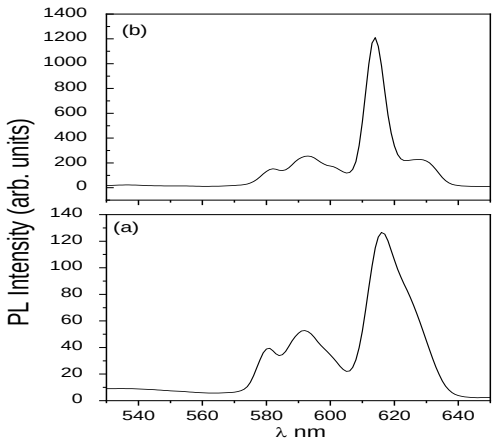

Fig. 2: Emission spectra for Y2O3:Eu (5%) nanoparticles heated at 900°C and excited at (a) 394nm (b) 240 nm.

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*email: lrsingh@gmail.com

Quantum chaos and the arrow of time

Nilakash Sorokhaibam[1]

[1]Department of Physics, Tezpur University, Tezpur, 784028, Assam, India.

All physical systems around us become more and more disordered as time progresses unless an outside agent spends energy and record information for the upkeep of the system. This phenomenon has a beautiful statistical reasoning. There simply are too many possible disordered states compare to the number of possible ordered states. So, the system ends up most likely in a disordered state [1]. Entropy is the quantity which measures the extent of disorder. So, in terms of entropy, this general observation gives rise to the second law of thermodynamics. It states that the entropy of an isolated system does not decrease. This is Planck's statement of the second law of thermodynamics [2]. It gives rise to an arrow of time (called Time's arrow in [3]). All of these results are familiar in the realm of classical physics. But our physical world is governed by quantum mechanics at the microscopic level and so far a complete explanation of the quantum version of the second law is lacking.

In this work, we show that a quantum arrow of time arises naturally in an isolated quantum system which is chaotic. Consider a chaotic quantum system which is initially in a thermal state (a pure state but thermalized). If we perturb the system, the system would be taken out of equilibrium but eventually the system would return back to a final thermal state. The second law would imply that the change in entropy (ΔS) is non-negative. We show that this is indeed the case for a quantum chaotic system. We show this by keeping track of the change in total energy of the system (ΔE). The change in energy is positive if the initial temperature of the system is positive. If the system was initially at infinite temperature then the change in the energy is zero.

$$\Delta E = T\Delta S \tag{1}$$

where ΔE and ΔS are changes in energy and entropy. For systems with finite dimensional Fock space, if the initial temperature is negative, the change in energy is negative and the change in entropy is positive again.

Invoking Berry's conjecture [4] and eigenstate thermalization hypothesis (ETH) [5, 6], we show that this result is true for all chaotic systems at leading order. We also find that this result constraint the off-diagonal elements in ETH statement in a profound manner which has not been observed previously.

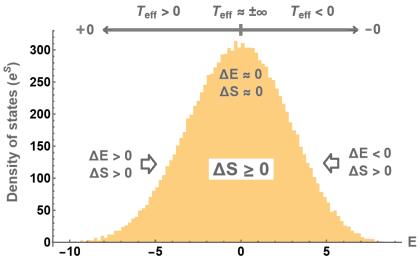

Figure 1: The density of states (e^S) versus energy (E) plot for the chaotic XXZ spin chain. T_{eff} is effective temperature if we are working with eigenstates. Perturbation of the system from an equilibrium state always leads to a non-negative change in the entropy $\Delta S \geq 0$. Note that the spectrum is not fully symmetric due to non-zero magnetization.

We consider a specific model namely the XXZ spin chains and show that the result also holds true non-perturbatively. We also calculate the off-diagonal elements of physical observables and show that they vary according to the new constraint that we have found. In case of an integrable system, second law does not hold true because the system does not thermalize to a generalized Gibbs ensemble after a finite perturbation.

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Green synthesis of ZnO nanoparticles using polyphenolic extract of *Datura metel* and their structural, optical and antimicrobial properties

U S Senapati, M Goswami, A Das, T Barman, H Deka, P Chauhan, and H Kalita

Department of Physics, Handique Girls' College, Guwahati-781001, Assam, India (First and third Author),

Department of Microbiology, Handique Girls' College, Guwahati-781001, Assam, India(Second Author),

Tea Research Association, Upper Assam Advisory Branch, Dikom-786101, Assam, India (Fourth Author)

Biochemistry Department, Tocklai Tea Research Institute, Jorhat-785008, Assam, India (Fifth Author)

Advanced Level Institutional Biotech Hub, Handique Girls' College, Guwahati-781001, Assam, India (Sixth & seventh Author)

Zinc oxide (ZnO) is a wide and direct band gap (~3.37 eV) semiconductor[1]. It has gained considerable interest in scientific and medicinal communities [2]. Some of its applications include light-emitting diodes, optical detectors, chemical and biological sensors[3] and antibacterial therapy[4]. Due to its exciting properties, one dimensional ZnO nanostructures have been the subject matter of intense research in recent years. The emphasis has been on its extraction from natural sources that outperforms chemical and physical methods in terms of cost, environmental friendliness and ease of scaling up for large-scale synthesis.In this study, we report a novel process to extract nano-sized ZnO particles using polyphenolic extract of *Daturametel*leaf asreducing, capping and stabilizing agents. The extraction of polyphenolic compounds from *Daturametel*leaf was carried out using heat extraction method as maximum amount of polyphenol content can be obtained using this method [5]. The total polyphenol contents (TP) were determined according to the ISO 14502-1:2005 method described by the International Standard Organization [6]. The production of hexagonal wurtzite structure in ZnOnanocrystallites is confirmed using X-ray diffraction (XRD). The calculated crystallite size from the prominent (101) plane is found to be 33 nm - 26 nm. To further confirm the presence of Zn and O, Energy Dispersive X-ray analysis (EDAX) was performed. The production of ZnOnanoparticles is also revealed from the transmission electron microscopy (TEM) images.Furthermore, Fourier transform infrared spectroscopy (FTIR) is used to identify the various polyphenolic functional groups present in *Daturametel* leaf extract. The specimens' optical band gaps are determined to be in the range of3.39-4.10 eV. A total of 15 isolates were obtained from fruit and vegetable samples collected from a local market in Guwahati, Assam.

The antimicrobial efficacy of ZnO nanoparticle were studied. The MIC was evaluated using the broth microdilution method [7]. At an average concentration of 4mg/ml of ZnO nanoparticles the isolates showed no visible growth.

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*email:udaysankargu@gmail.com (first author)

Tunable semiconducting nature of hexagonal boron nitride monolayer through point defects

Dhanjit Talukdar and Gazi Ameen Ahmed

Optoelectronic and Photonics Laboratory, Department of Physics, Tezpur University, Napaam 784028, Assam, India

Hexagonal boron nitride (*h*-BN) is a wide band gap semiconductor with a band gap of 4.6 eV. Due to its wide band gap its application mostly centers around dielectric coatings and deep UV emitter [1,2]. This band gap restricts its applicability in fabricating electronic and magnetic devices. This restriction can be overcome by modifying the geometrical structure of the material which tunes its electronic nature towards a narrow gap semiconducting material [3,4]. This theoretical study via first principles calculation focuses on tailoring the structural, and electronic properties of *h*-BN through different point defects and their possible simultaneous existence. Our study shows that upon introducing carbon (C) and oxygen (O) in sites of boron (B) and nitrogen (N), defect states are induced within the forbidden gap, both above and below the Fermi level. These occupied and unoccupied defect states narrow the band gap of *h*-BN making it semiconducting in nature. Results show that the wide band gap of the material drops down to 0.76 eV and 0.44 eV with the presence of C and o dopants in presence of N vacancies. Also, the presence of dangling bonds due to the existence of vacancies in the system delocalizing the electronic states tunes the band gap invariably. Furthermore, we have calculated the possibility of co-existence of vacancy defect along with these dopants based on their formation energies. Thus, this theorical study shows that with the ability of controlling the creation of defects can significantly modify the structural, and electronic nature of h-BN, which could lead to its use as a potential applicant in electronic and magnetic devices eradicating the band gap barrier.

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*email: talukdardhanjit123@gmail.com

gazi@tezu.ernet.in

Solvent-Mediated Liquid Phase Exfoliation of SnSe Nanosheets

Stuti Tamuli[1*], Anubhab Kar[1] and Dambarudhar Mohanta[1]

[1]Nanoscience and Soft-Matter Laboratory, Department of Physics, Tezpur University, P.O: Napaam, Tezpur-784028, Assam, India

The growing interest in two-dimensional (2D) materials arises from their intriguing properties and layered structure. Such layered materials, particularly bulk group-IV metal monochalcogenides (MMCs), have gained significant global attention for their exceptional thermoelectric, optoelectronic, and electrical properties. They exhibit an orthorhombic crystal structure and 1:1 stoichiometry (MX), with M representing group-IV metals such as Ge, Sn, and Si, and X denoting chalcogens [1,2]. They are a remarkably anisotropic group where the atoms are arranged in alternating patterns to form a distinctive puckered structure with an armchair and a zigzag plane as shown in Fig. 1.

Among these, tin selenide (SnSe) stands out due to its outstanding features, including high optical absorption coefficient, tunable band gap, and thermodynamic stability [3]. The versatility of SnSe has been demonstrated across various applications, such as thermoelectrics, supercapacitors, solar cells, photodetectors, photocatalysis, gas sensing, and as an anode material for batteries, along with its potential as a topological insulator. Despite its promising applications, the efficient large-scale production of high-quality SnSe nanomaterials remains a challenge. This study employs liquid phase exfoliation (LPE) to obtain 2D-SnSe nanosheets. The nanosheets were synthesized from their bulk form in a mixture of six different solvents: N-Methyl-2-pyrrolidone (NMP), isopropyl alcohol (IPA), absolute ethanol, acetone, methanol, and deionized (DI) water. The bulk SnSe underwent ultrasonication for 15 hours in various solvents, in a bath sonicator, resulting in the production of few-layer nanosheets. Comprehensive characterization using various techniques was conducted on the exfoliated samples. Structural and vibrational properties were analyzed through X-ray diffraction and Raman spectroscopy. Morphological changes were observed using Field Emission Scanning Electron Microscopy (FESEM) and Transmission Electron Microscopy (TEM), illustrating the formation of few-layer nanosheets. UV-visible spectroscopy was also employed to investigate the optical properties of the exfoliated SnSe samples.

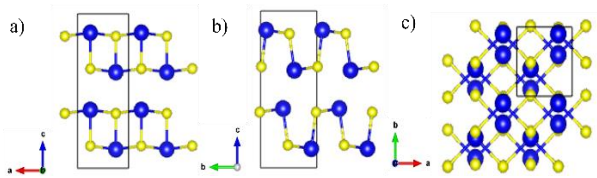

Figure 1: The atomic structures of MMCs: a) zigzag direction and b) armchair direction and c) top view respectively.

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*email: stuti.tamuli@gmail.com email: phi19003@tezu.ac.in email: best@tezu.ernet.in

Modification of Electronic Structure Properties due to Oxygen Vacancies in monoclinic Zirconia

Sanat Kumar Gogoi*[1,2] and Manish Jain[1]
[1]Center for Condensed Matter Theory, Department of Physics, Indian Institute of Science, Bengaluru 560012, India
[2]Department of Physics, Digboi College, Digboi 786171, India

Using a combined density functional theory and GW formalism, we study the electronic structure modification and charge transition levels (CTLs) due to oxygen vacancy defects in monoclinic-Zirconia. Charge transition levels play a crucial role in understanding and manipulating the electronic properties of materials. The CTLs are calculated using two paths and employing electrostatic corrections due to localized charge at the defect site.

The relaxation mechanism of atoms near an oxygen vacancy site is also explored. We report the calculated CTLs using only density functional theory and the combined approach of both density functional theory and GW method with appropriate electrostatic corrections. Our results agree well with the experimental findings of electronic trap level in m-ZrO2 [1, 2].

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*email: gogoi.sanat@gmail.com

An asymmetric Al^{3+} ion supercapacitor/electrochemical capacitor with vanadium oxy-acetylacetonate and polyaniline

Atowar Rahman, Shyamal K. Das*
Department of Physics, Tezpur University, Assam 784028, India
*Department of Physics, Tezpur University, Assam 784028, India

Herein, we illustrate the Al3+ ion storage behavior in Vanadium oxy-acetylacetonate (VOA) and polyaniline (PANI) in aqueous electrolyte. It is observed that both the materials exhibit great electrochemical stability. For example, VOA could deliver a stable specific capacitance of 183 Fg-1 after 50 cycles, and in case of PANI, it is about 282 Fg-1 after 100 cycles at the same current density of 1 Ag-1. addition, the cell delivers enhanced energy density/power density of 15.4 Wh kg-1 / 750 W kg-1 (at current density 1.5 Ag-1) in the potential window of 2 V when compared with 1.5 V and 1.7 V [Figure 1].

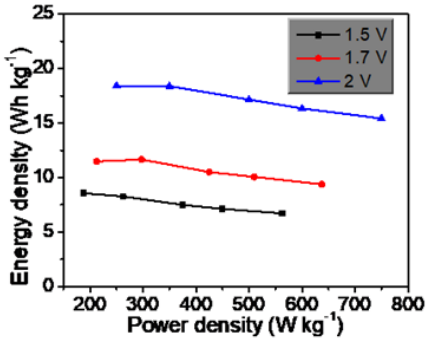

Figure 1. Comparison of energy density/power density in different potential window

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email: atowar.r@gmail.com
*email: skdas@tezu.ernet.in

Increasing the Photocatalytic Activity of MoS_2 by creating interfacial contact with MOF and conducting polymer

Kashmiri Baruah[1,2] and Pritam Deb[1]
[1]Advanced Functional Material Laboratory (AFML), Department of Physics, Tezpur University (Central University), Tezpur 784028, Assam, India,
[2]Department of Physics, Nanda Nath Saikia College, Titabar 785630, Assam, India

Few-layered transition metal dichalcogenide MoS2 possess direct bandgap in the visible region [1]. In this work, a hybrid nanocomposite MoS2 /PEDOT:PSS/MOF is developed to exploit the synergistic contribution of each component. In-situ polymerization of PEDOT:PSS reduces the aggregation of few- layered MoS2 by developing a conducting network between the two components. Porous Metal-organic framework (MOF) UiO-66 increases the surface area and electron-hole recombination time, thereby increasing the photocatalytic activity. The symbiotic effect of conducting polymer, porous UiO-66, and visible light active few layered MoS2 nanosheets offers an excellent improvement of photocatalytic activity to the nanocomposite. The interfacial contact among the component s lead to better charge separation, causing 95% crystal violet degradation in 75 min ofirradiation, which is four-fold higher than pristine MoS2 nanosheet.

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*email: kashmiribaruah93@gmail.com
email: pdeb@tezu.ernet.in

Optical sensing of Anthracene using Natural dye Chlorophyll

Siddhartha Protim Bharadwaj[1], Mondeep Gohain[1], Roshmi Pangyok[1], Chayanika Chetia[1], Purabi Gogoi[2], Pankaj Dutta[1]
[1]Department of Physics, Dibrugarh University
[2]Dibrugarh University Institute of Engineering and Technology

Anthropogenic activities are a major contributor to the release of hazardous pollutants, such as Polycyclic Aromatic Hydrocarbons (PAHs), which adversely impact both the environment and human health. Detection and remediation of these pollutants is very crucial for maintaining a healthy environment. Anthracene, a major constituent of PAH is present in as volcanic eruptions, oil spills, fossil fuel combustion, oil refining procedures, automobile exhaust emissions, industrial effluent discharges, and the presence of domestic sources (e. g. tobacco smoke and residential wood or coal combustion) and area source matter (e. g. forest fires and agricultural burning

In this study, the optical properties of Chlorophyll (Chl), a natural pigment found in plant leaves is utilized as an optically active element for sensing Anthracene. The observed variations in the absorption and photoluminescence (PL) intensities, PL lifetime etc. of Chlorophyll have been used to determine the important sensing parameters limit of detection (LOD). An LOD in the range of picomolar (pM) is observed which is quite good compared to the reported literature. This result highlights th potential of Chlorophyll fluorescence as an effective sensing tool.

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*email:bharadwajsiddhartha944@gmail.com

Study of structural, electronic, magnetic, and thermoelectric properties of LiCaX (X=N, C) half-Heusler alloys

Geetimallika Das[1] and Bulumoni Kalita[1]
1. Department of Physics, Dibrugarh University, Dibrugarh 786004, Assam, India

Half-Heusler (HH) alloys, an intermetallic class of materials with chemical formula XYZ (1:1:1 ratio), have been extensively studied for their promising properties, particularly in thermoelectrics, offering potential solutions to the energy crisis [ ]. Therefore, in the present work, we have examined the structural, electronic, magnetic, and thermoelectric properties of LiCaX (X=N, C) HH alloys. The necessary calculations are performed using Quantum ESPRESSO package and BoltzTrap code. LiCaC and LiCaN exhibit half-metallic and semiconducting properties, with valence electron counts of 7 and 8, respectively [,]. Both the alloys remain structurally stable as shown by the cohesive energy values. LiCaC showcases ferromagnetic ground state, while LiCaN is a non-magnetic alloy. The total magnetic moment of LiCaC is 1 μB and it mainly arises from C atoms as obtained from DOS calculation. The band gap values of LiCaN and LiCaC are 2.26 eV (indirect) and 2.20 eV (direct), respectively. The thermoelectric efficiency of a material is governed by an intrinsic parameter called the figure of merit (ZT). The considered alloys exhibit ZT values as high as 0.839 and 0.998. These properties suggest LiCaX (X=N, C) as promising materials for thermoelectric applications.

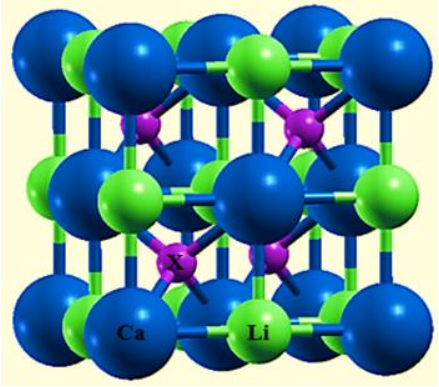

Figure 1: Crystal Structure of LiCaX (X=N, C)

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*email: rs_geetimallikadas@dibru.ac.in
bulumoni@dibru.ac.in

Navigating Challenges, Harnessing Opportunities: Advancing Aqueous Aluminum Ion Batteries for Enhanced Performance

Konica Roy[a], Shyamal K. Das[#a]
[a]Department of Physics, Tezpur University, Assam 784028, India

The surge in incidents stemming from explosions in electric vehicles and energy storage systems, linked to the utilization of lithium-ion batteries, has sparked increased attention and efforts towards the development of safer and more sophisticated battery systems to address this demand. Current endeavours are dedicated to developing battery systems that not only emphasize safety but also integrate advanced features to meet the increasing demand for elevated safety standards. Nowadays, aqueous batteries are gaining traction as a viable alternative for lithium-ion batteries, offering benefits such as cost-effectiveness, safety, robust ionic conductivity, and environmental friendliness. This shift is driving a notable transition in the energy storage landscape. This article delves into the myriad challenges faced and recent strategic approaches employed in diverse aqueous battery systems. It specifically concentrates on systems utilizing aluminum ions as carrier ions, highlighting efforts to overcome existing challenges and drive progress in battery technology.

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*email: konicaroyresearch@gmail.com
email: skdas@tezu.ernet.in

Optical Properties of Copper Nanoparticles Synthesized by Chemical Reduction Method

Sajal Sahu[1,2,#] and Pijus Kanti Samanta[2,3,*]
[1]Department of Physics, Ramchandrapur Raisuddin High School, Purba Medinipur, West Bengal, India
[2]Department of Physics, Prabhat Kumar College, Contai-721404, West Bengal, India
[3]Institute of Astronomy Space and Earth Science, P 177, CIT Road, Scheme 7m, Kolkata-700054 West Bengal, India

The exceptional optical, thermal, chemical, and physical capabilities of metal nanoparticles may be attributed to the combination of a high percentage of high energy surface atoms in relation to the bulk solid and the nanoscale scale. The size, shape, interparticle distance, and dielectric constant of the surrounding medium all affect a nanoparticle's optical characteristics.

A simple chemical reduction method has been followed to synthesize Cu nanoparticles using copper acetate as source of Cu-ions. Ascorbic acid and starch were used as a reducing agent. Scanning electron microscope shows the formation of spherical nanoparticles of average diameter ~ 500 nm. Formation of uniform sized nanoparticles is an indication of homonucleation process. Plasmon peak was observed in the UV-visible absorption spectrum confirming the formation of Cu nanoparticle.

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#email: sahusajal@gmail.com
*email: pks.pkcphy@gmail.com

Liquid phase exfoliation of $MoSe_2$ using different solvents: A comparative study

Shahnaz Shabnam, Dambarudhar Mohanta and Gazi Ameen Ahmed
Tezpur University, Napaam Tezpur- 784028 (First Author, Second Author, Third Author)

Present work illustrates exfoliation of a Transition metal dichalcogenide material (TMDC), $MoSe_2$ in presence of different solvents.

The synthesis process is carried out using liquid phase exfoliation method with the help of sonication process. A few layer $MoSe_2$ has been successfully synthesized using different solvent like DI water, N- methyl pyrrolidone, acetone, chitosan/acetic acid solution etc.

The synthesized $MoSe_2$ nanosheets show significant properties compared to that of bulk MoSe2. X-Ray diffraction (XRD), Raman spectroscopy, Field effect Scanning Electron Microscope (FESEM), Photoluminescence Spectroscopy (PL), UV-spectroscopy were carried out for this exfoliated nanosheets to understand the structure, difference in number of layers, morphology and optical properties. The electrical properties of this exfoliated nanosheets have been studied through I-V characteristics which shows potential for application in semiconducting device.

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*email: shahnazshabnam07@gmail.com
gazi@tezu.ernet.in

Author Index

Condensed Matter and Materials Theory (CMMT) Group

The Condensed Matter and Materials Theory (CMMT) group of the department, led by Dr. Ritupan Sarmah with three active group members (Sita, Prankrishna and Tonmoy), have been actively working in diverse areas of driven far from equilibrium extended systems in condensed matter and materials science. The group focuses on understanding the dynamics displayed by three distinctly different aspects of nonequilibrium statistical physics, namely, collective dynamics of extended defects in crystalline materials systems, active matter systems and intermittent behavior in amorphous systems, nonlinear dynamics & time series analysis, and dynamics of stick-slip systems ranging from materials to active biological systems.

Recently, Sita developed a nonlinear electronic circuit demonstrating most of the nonlinear dynamical phenomena using a single circuit as a function of external stimuli and developed a prototype circuit in collaboration with group led by Dr. R. K. Baruah of the ECE department. Prankrishna studied the collective dynamics of extended defects and the nature of change of patterns and stress-strain behavior in crystalline systems with temperature and intermittent behavior of indentation experiments in amorphous thin films using nonlinear time series analysis. Tonmoy had recently developed a stick-slip dynamical model to explain the dynamic behavior of unzipping bird feathers and is working on understanding the dynamics of active matter systems.

Energy Storage Group

The Energy Storage laboratory is led by Dr. Shyamal Kumar Das. His research group is actively working in the area of electrochemical energy storage devices. The group focuses on understanding the fundamentals and working of various rechargeable batteries and electrochemical capacitors. In the 21st century, "energy" has taken centre focus.

The growing demand for alternative energy storage systems has become more prominent in response to the escalating need for fossil fuels to meet societal requirements. This, coupled with the detrimental environmental impacts associated with their use, has placed a strong emphasis on sustainable "production" and effective "retention" of energy. Rechargeable lithium-ion batteries (LIBs) have garnered widespread attention and adoption in a diverse array of applications, ranging from electronic gadgets to electric vehicles. These batteries have earned their acclaim due to their remarkable attributes, including high specific energy, elevated voltage levels, and remarkable cycle durability. However, the objective of our group extends beyond Li-ion batteries. Our primary area of interest is deeply immersed in materials chemistry, where we engage in the synthesis of materials and investigate their structure and electrochemical properties for use in energy storage devices like rechargeable batteries and electrochemical capacitors. We aim to explore into the possibilities of different ion batteries.

Microwave Engineering Laboratory (MEL) Group

The microwave engineering research group at Tezpur University is headed by Prof. Nidhi S Bhattacharyya and co-advised by Prof. Satyajib Bhattacharyya from the department of ECE, Tezpur University. The team accentuates development of low-profile, flexible electromagnetic shielding materials and compact, reconfigurable antenna systems.

The group indigenously develop industry ready microwave devices and systems at lower cost for defence and communication applications. Their product oriented research encompasses a broad range of domains including RCS lowering in C, X, and Ku-bands with meta structure-based absorbers, Cloaking, Beam forming and phased array antenna systems, 2D metasurface lens antenna, Intelligent surfaces, SAR analysis for body-worn applications, Hyperspectral imaging, Machine learning aided data acquisition and analysis. The laboratory is equipped with state-of-the-art facilities such as Microwave network analysers ranging up to 40GHz, Radiation pattern measuring systems, SAR measuring systems, Additive manufacturing technology, Free space setup, RF digester, well equipped microwave material manufacturing and characterization unit. Recently the group has embarked successfully into development and application of Unmanned Aerial Vehicles for aerial imaging.

Plasma Physics Research Laboratory (PRL)

The Plasma Physics Research Laboratory (PRL) research group led by Prof. Nilakshi Das is actively engaged in investigating two intriguing areas of study: laser-plasma interaction and complex plasmas. Laser-driven ion acceleration is a promising branch of plasma physics that offers opportunities for fundamental research, technological applications and the exploration of extreme conditions. Research on the interaction of advanced targets like spherical targets, nanostructured targets with intense laser is going on with the help of particle in cell (PIC) simulation in this Laboratory. A spherical target with a Gaussian density profile is found to promote the generation of highly energetic and collimated beams of protons, where electrostatic shocks are found to be responsible for the generation of such proton beams. Another recent finding in this laboratory reveals that in the nanostructured foil target, the laser energy absorption by the electrons and ions is found to improve significantly in comparison to conventional flat foil targets.

In the realm of complex plasma, the team is dedicated to unravelling the intricate dynamics of particulate systems consisting of charged particles immersed in a background gas or plasma environment. Research on phenomena in bulk as well as in finite complex plasma systems using both theory and simulations is going on in PPL. Some notable works from this laboratory in recent years include the study on wake potentials in streaming plasma both in the presence and absence of an external magnetic field, study of magnetized wake-driven anomalous diffusion in bulk complex plasma, phase transition of a harmonically confined Yukawa cluster, propagation characteristics of dust density waves, etc.

High Energy Physics (HEP) Laboratory

The research group under the supervision of Prof. Jayanta Kumar Sarma work on different Parton evolution equations and their phenomenological aspects in QCD as well as collider physics. Currently, our focus is on the Balitsky-Kovchegov equation, which is the most suitable QCD evolution equation to work in the context of small-x physics. The equation has been studied numerically many times but we do not see any analytical solution to this equation. Therefore, our focus is to solve this equation analytically in leading and next leading order of strong coupling constant with phenomenological implications at the current and future accelerator facilities. We are also working on generalised parton distribution to study the internal structure of hadrons at the low energy regime where the physics becomes non-perturbative.

Advanced Functional Material Laboratory (AFML) Group

Advanced Functional Material Laboratory (AFML) group of the Physics department, focuses on the physics of functional materials and also quantum phenomena in advanced energy materials, topological quantum physics, biomedical imaging, condensed matter and material science in quantum technology etc. The research interests include understanding structure-property correlation and electronic property of two-dimensional materials and their heterostructure for potential applications. In theoretical aspects, the group is working on first principle studies of 2D materials involving the many-electron interacting Schrödinger equation to study their electronic, magnetic, catalytic, topological aspects and transport properties.

The AFML group have recently identified twist tunable local magnetic moment evolution in moiré ferromagnet. The simple act of rotating two monolayers at various twist angles, produces an inhomogeneous mixture of augmented and quenched localized magnetic moments. Also, AFML group investigated, in a maiden attempt, magnetic proximity induced valley-contrasting quantum anomalous Hall effect in a graphene-$CrBr_3$ van der Waals heterostructure. It is worthwhile to mention that AFML group successfully achieved enhancement in MRI-contrast efficiency by considering manipulation in octahedral site substitution in nanoensembles and attaining the significant association of anisotropy field strength and easy axes alignment toward proton dephasing in the MRI-relaxivity mechanism.

Neutrino and Astro-Particle Physics (νAPP) Laboratory

The nuAPP group, are mainly involved in neutrino physics phenomenology, detector simulation and application of deep learning for event reconstruction in particle detectors. Neutrinos have unique properties which make them an important tool to understand our universe. The subtle new physics phenomenon arising due to the extension of the SM of particle physics may highly affect the production, propagation and precision measurement of oscillation parameters in neutrino experiments. We explore such non-standard physics effects as scalar non-standard interaction, Lorentz Invariance Violation, and quantum decoherence in neutrino and neutrino-dark matter interactions. We focus mainly on the formalism of these effects, the impact they may have in the measurement of oscillation parameters in long-baseline experiments and the discovery and constraining capability of these experiments towards them. Machine learning (ML) has revolutionized different domains of science and high-energy physics (HEP) is no exception. It is a powerful tool that can play a crucial role in the analysis of data produced in particle accelerators and detectors such as Hyper-K, and DUNE. There are many applications of ML in HEP experiments viz. particle identification, anomaly detection, event reconstruction, monte-carlo simulation etc. We have many ongoing works where we have implemented ML in different HEP problems. An MLP-based model is used for tracking muons in a tracker detector and reconstructing the muon energy. We have also worked on developing an image classification model for particle identification, specifically muons and electrons in a water Cherenkov detector.

Applied Photonics and Nanophotonics (APN) Group

The Applied Photonics and Nanophotonics (APN) research group of the department headed by Prof Pabitra Nath has been actively working in different areas of photonics that immediately address various societal issues of this region. To this end, the group has successfully demonstrated the functioning of different low-cost sensing systems that were developed using smartphone as a platform to monitor various water and soil quality parameters. The group further has designed different handheld imaging systems using smartphone to capture images of various micro particles in different modalities. In connection to this field of research, Prof Nath's group has been able to achieve several prestigious awards and has completed several funded projects till date. So far, three patents have been filed from this laboratory as a core inventor while two more have been filed as a collaborator with other groups.

The APN research group is further, involved in another interesting field of nanophotonics - Surface enhanced Raman scattering (SERS), where it primarily is aiming to develop low-cost SERS substrates that yield reasonably high enhancement factor and has good reproducibility characteristic. The utility of the developed SERS substrates has been demonstrated to detect various pesticides and other biomolecular substances in trace concentrations. So far, six students have successfully completed PhD studies while five are currently pursuing their doctoral studies under Prof Nath's supervision.

Neutrino Physics Research Laboratory

The research group under the supervision of Prof. Mrinal Kumar Das focusses on Beyond Standard Model Framework, Neutrino Phenomenology and Dark Matter, Matter-Antimatter asymmetry, Neutrino masses and mixings. Although the Standard Model precisely describes all the phenomenon associated with the fundamental particles and their interactions, however, it also has several drawbacks. Our research group focusses on the study and analysis of Beyond Standard Model framework by the development of different neutrino mass models and the study of phenomenology associated within like Neutrino less Double-Beta Decay, Lepton Flavor Violation, Leptogenesis, Dark Matter etc.

Our primary focus revolves around the development of neutrino mass models aimed at gaining a deeper comprehension of particle physics and unravelling the mysteries surrounding the origin of our universe. Our existing knowledge is not sufficient to explore and understand the origin of our universe, so our work is crucial in shedding light to investigate the fundamentals of particle physics and its connection to the origin of our universe. So far, numerous fundamental particles have already been discovered, our work also postulates the existence of additional particles, with a high likelihood of their actual existence. Consequently, our research serves to inspire and motivate the scientific community to construct high-energy experimental setups that can detect these hypothetical particles in real-time. If these particles are indeed discovered in ongoing and upcoming experiments, it would revolutionize our understanding of particle physics and reshape our perception of the world.

Astronomy & Astrophysics (TUAA) Research Group

TUAA Research Group is headed by Dr. Rupjyoti Gogoi, Assistant Professor, Tezpur University. The team currently has 5 members working in a variety of captivating topics in the field of Astronomy and Astrophysics propelling ground breaking research - from Galaxy morphology to Active galactic nuclei and Interstellar medium. The group has scholars in different stages of their PhD degree.

Anshuman Borgohain's research primarily involves the quest for understanding the assembly and evolution of dwarf galaxies. He recently worked on the mass assembly of star forming dwarf galaxies known as Blue Compact Dwarf Galaxies (BCDs). Olag P. Bordoloi, another senior member of the research group is currently studying the abundance and characteristics of interstellar dust present in a dwarf galaxy Holmberg-II, and neighboring Magellanic clouds. He utilizes AstroSat UV and IR data from different space observatories to examine dust properties in different galactic environments using appropriate dust models. Hritwik Bora is currently involved in the spectral and temporal study of Blazars in the very high energy regime. He tries to investigate accretion disk and blazar jet connection of Active Galactic Nuclei (AGN). Swagat Bordoloi uses AstroSat UV data in conducting Deep Field Imaging Survey of the sky. His work primarily involves preparing FUV catalog of point sources of various field images. Snigdha Sarmah works primarily in the field of supernova dust. She uses Spitzer IR data to study the characteristics of the supernova SN2023ixf and its circumstellar medium in M101galaxy.

Nanoscience and Soft-Matter Laboratory (NSL) Group

The Nanoscience and Soft-Matter Laboratory (NSL) of the department, led by Prof. Dambarudhar Mohanta with nine active members (Ankush, Kakoli, Mahesh, Bhupali, Stuti, Susmita, Bikash, Anuj, and Dipankar), has been actively and extensively working on systems in the nano-dimension, aiming to understand related physical phenomena. The group studies radiation-induced effects on the structural, morphological, opto-electronic, and electrical properties of tungsten dichalcogenides (WS_2, WSe_2), as well as mono-chalcogenide-based nano-systems like SnS and SnSe. Additionally, the group explores carrier transport features of conducting metal-organic frameworks (MOFs) and their applications in electrochemical sensing of heavy metal ions. The group is also focused on developing conducting polymer and layered TMDC-based sensor electrodes for enzymatic and non-enzymatic detection and quantification of biological analytes. Recently, the group has delved into diverse bio-photonic coloration phenomena, ironic wettability features in soft-matter, electro-wetting properties of micro droplets for applications in dielectric lensing and related phenomena and electrophysiology and its related phenomena.

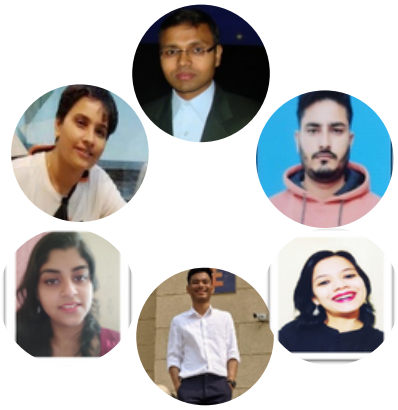
Astrophysical Plasma and Nonlinear Dynamics Research Laboratory

The research group under the supervision of Prof. Pralay Kumar Karmakar focusses on understanding physics of diverse problems in the area of laboratory and astrophysical plasmas. The group is currently studying instabilities in plasma fireball, plasma dynamics in diversified astrophysical environment, acoustic wave dynamics in Saturnian plasma within the magnetosphere. The group is also working on the stability dynamics of star formation in DMCs, astrophysical structure formation in modified gravity frameworks. Recently, the group also extend its bases to study the dark matter cosmology and structure formation.

Neutrino Cosmology Lab

The research group headed by Dr. Ng. K. Francis is working on simulation in neutrino oscillation physics and theoretical model building on neutrino phenomenology.

Applied Optics and Photonics & Geophysical Laboratory



The laboratory under the mentorship of Dr. Rajib Biswas, focuses on two key domains: Applied Photonics and Applied Geophysics. In the realm of Applied Optics and Photonics, our laboratory is actively involved in the development of diverse sensing devices tailored to address the needs of multiple interdisciplinary fields, with a particular focus on addressing socioeconomic challenges such as detection of heavy metal ions, milk adulterants, pesticides and environmental pollutants. Commencing with the exploration of innovative materials to enhance sensing efficiency, our expertise lies in the realm of fabrication of noble nanomaterials, 2D materials and magnetic nanoparticles and finally, exploitation of their fundamentals properties towards detection of specific analytes. Our research team is dedicated to advancing the fundamental aspects of instrumentation with the goal of expanding their applicability in critical sectors such as healthcare and environmental sciences.

In the latter category, we engage in a comprehensive examination of seismic wave dynamics using advanced instrumentation. Additionally, we conduct ambient noise analysis to extract pertinent parameters related to engineering seismology. Furthermore, our research delves into the exploration of earthquake precursors to establish correlations. Moreover, we direct our attention to Probabilistic Seismic Hazard Analysis (PSHA) and Deterministic Seismic Hazard Analysis (DSHA) as part of our research objectives.

Optoelectronics and Photonics Laboratory & Laboratory for Plasma Processing of Materials

The work of Dhanjit Talukdar from the Optoelectronics and Photonics Laboratory focuses on studying various properties (physical, chemical, mechanical etc.) of two dimensional (2D) materials using density functional theory (DFT) and beyond DFT (GW approach). Kaushik Kokil Nath from the Laboratory for Plasma Processing of Materials is working on development of Nanofiber mats with different components of an avian egg followed by treatment with cold plasma is carried out for studying the physio-chemical changes occurred in the mat after the Plasma treatment. Use of this plasma treated mats in biomedical field will be carried out. Shahnaz Shabnam from the same lab is working on transition metal dichalcogenide, exfoliation process, opto- electronic features and its application.

Statistical Physics and Condensed Matter Laboratory

The research group headed by Dr. Diana Thongjaomayum explores the effect of quenched disorder in condensed matter physics. The group have worked on two distinct set of problems: (I) hysteresis in strongly disordered ferromagnets, and (II) electron localization on disordered quantum system.

(I) Hysteresis: random-field ising model

The critical response of complex systems to a smoothly varying force applies to a broad category of interesting nonequilibrium effects in disordered physical systems namely, earthquakes, avalanche, Barkhausen noise in magnetic materials. In particular we have studied hysteresis as a paradigm of nonequilibrium phenomena, and the zero-temperature random-field Ising model (RFIM) of classical spins as the model to understand the critical behaviour in systems with quenched disorder.

(II) Disordered quantum system: Two interacting particles

The study of the manifestation of disorder and interaction in quantum systems has been a hot topic in recent years. The seed lies in the well known single particle Anderson localisation problem where the presence of disorder arrests the transport of particle in spatial dimension 1 and 2. We study the obvious next step of adding one more particle with some interaction and analyse the problem of two interacting particles (TIP) in 1d in the presence of quasiperiodic and box width disorder distribution. With the advances in experimental photonics and ultra cold atoms experiment, it should become feasible to probe such phenomena.

Particle Physics Research Laboratory

The research group is headed by Dr. Jugal Lahkar. The research work is focused on Non-Perturbative QCD and Phenomenology, Extra dimension and Particle Physics.

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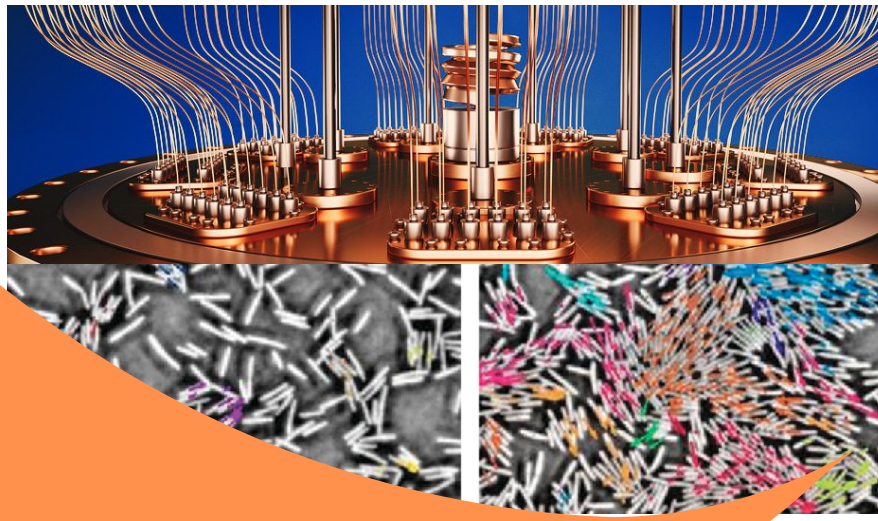

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