Ph.D. Program
Centre for Research in Nanotechnology & Science (CRNTS)
Indian Institute of Technology - Bombay

Topics for CRNTS Ph.D. Program (AUTUMN SEMESTER) (May 2023)

Candidates are encouraged to contact faculty members by e-mail directly in case they have any query.

Sr. No.	Name of Topic	Guide Name	Co-Guide Name	Category
1	Defects in Semiconductor Nanodevices	Sandip Mondal, Electrical Engineering 10001970@iitb.ac.in	Prof M Maniraj, Physics maniraj@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Defects in Semiconductor Nanodevices Abstract :The revolutionary impact of advanced semiconductor physics on our daily lives remains unabated. We continually interact with computational, memory, and imaging devices where a large number of electrons are pushed around various defect states at every nanosecond inside semiconductors. As these technologies are rapidly evolving from traditional circuit boards to flexible electronics, new materials, physics, and processing technologies are being explored to improve their functionality and efficiency. This brings unique experimental challenges to evaluate the fundamental interaction of defects with electrons in novel semiconductors. In this project, we will first design a prototypical MIS capacitive device architecture to illustrate the electron trapping in memory devices fabricated at low temperatures. Unlike the conventional measurement system, we will then focus on the challenges in measuring the defect state in semiconductors and our approach to probing the defect state during charge pumping operations.			
2	Neuromorphic Memory Devices for Artificial Intelligence	Sandip Mondal, Electrical Engineering 10001970@iitb.ac.in	Prof M Maniraj, Physics maniraj@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Neuromorphic Memory Devices for Artificial Intelligence Abstract :Biological neural systems can learn and forget information which is one possible mechanism for the stability and lifelong learning of neural circuits. Emulating such features in electronic devices is essential for advancing neuromorphic electronics for Artificial Intelligence. In this project, we will explore memory devices using oxides to illustrate learning behavior. We will examine the transient memory and forgetting dynamics by controlling the materialâ€™s chemistry. Using examples of prototypical Mott insulators such as NiO and VO2 and nanoparticles, we will present our vision for a neuromorphic platform utilizing quantum materials. Our studies will inform the design of electronic hardware in emerging Artificial Intelligence and can in the future be extended to brain-machine interfaces.			
3	Spintronics-Based Neuromorphic Computing	Debanjan Bhowmik, Electrical Engineering debanjanb@iitb.ac.in	Avradeep Pal, Metallurgical Engg and Materials Science avradeep@iitb.ac.in	TAP/PS
	Topic Name :Spintronics-Based Neuromorphic Computing Abstract :Electronic crossbar arrays of non-volatile memory (NVM) synaptic devices are known to implement machine learning/ neural networks very fast and with high energy efficiency. Nanomagnetic and spintronic NVM devices are very useful in this regard because of the stability of their conductance states, the electrical control and read-out of the states, and the linearity and symmetry of their synaptic characteristics. This project aims at experimental fabrication and characterization (through magneto-transport and magneto-optics measurements) of these spintronic synaptic devices.			

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4	Detection of organic and inorganic contaminants in water using Optical or Electrochemical means.	Soumyo Mukherji, Biosciences and Bioengineering mukherji@iitb.ac.in	Suparna Mukherji, ESED mitras@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Detection of organic and inorganic contaminants in water using Optical or Electrochemical means. Abstract :Organic and inorganic contaminants in water not only directly affect human health, but have the potential to affect plants, animals and microbes, with a deleterious effect on human society. In keeping with the sustainable development goals (SDG) of the UN and the â€œOne-Healthâ€• approach adopted by G20 nations, it is of critical importance to remove such contaminants or control the influx of such contaminants in water. However, since we cannot control what we cannot measure, it is just as important to develop inexpensive technologies for both qualitative and quantitative assessment of such contaminants in water. Such inexpensive technologies can be developed using nanostructured surfaces. This project will use, adapt, further develop the custom designed instrument and sensor-head. The latter will involve with noble metal nanostructures or nanolayers of polymers and composites.			
5	Transient Pump-Probe Spectroscopy of Semiconductor Nano-structures	Dipankar Saha, Electrical Engineering dipankarsaha@iitb.ac.in	1, Chemistry adutta@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Transient Pump-Probe Spectroscopy of Semiconductor Nano-structures Abstract :Semiconductor nanostructures play important roles in various electronic, optoelectronic, and quantum devices. The research work involves understanding the various microscopic mechanisms in semiconductor nanostructures by using transient pump-probe spectroscopy techniques, which include absorption, emission spectroscopy, and single photon counting.			
6	Development of Hybrid nanostructures for Li ion supercapacitors	Sumit Saxena, Met.Engg & Mat.Science sumit.saxena@iitb.ac.in	V. Ramadesigan, DESE venkatr@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Development of Hybrid nanostructures for Li ion supercapacitors Abstract :Energy storage is one of the most important research directions especially with development and use of electric vehicles. Traditional li-ion battery technology is plagued by large charging times and safety issues. In this perspective development of fast charging hybrid li ion supercapacitors an be used. The scope of the thesis would be develop novel nanomaterials which can be used as electrodes for these devices.			

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7	Development of photothermal catalysts for sustainable carbon dioxide conversion using solar energy	Sonali Das, Chemical Engineering sonali.das@iitb.ac.in	Debabrata Maiti, Chemistry dmaiti@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Development of photothermal catalysts for sustainable carbon dioxide conversion using solar energy Abstract :The concept of converting CO2 into synthetic fuels and chemicals using sunlight as the sole energy source holds tremendous prospects for establishing a sustainable carbon-neutral economy. Unfortunately, the light utilization efficiency of CO2 conversion via traditional photocatalytic processes, that utilize only UV/purple light, remains too low for practical use. â€œPhotothermalâ€• catalysis is an emerging field that employs plasmonic materials to utilize the full spectrum of sunlight (UV, visible, and IR spectra) and can combine both thermal and photochemical contributions of sunlight to drive catalytic reactions at unprecedented rates.However, the research area is new, and catalyst development for photothermal CO2 conversion remains in an under-utilized and rudimentary stage. The choice of appropriate catalysts is critical to ensure effective combination of light and heat to achieve practically relevant product yields under realistic sunlight conditions. Photothermal conversion of CO2 is a multi-step and multi-functional process, with various functional sites operating in tandem to harvest light and photothermally convert CO2. Intricate design and engineering of the catalyst structure and morphology at the nano scale is required to maximize the synergetic functioning of the various functional sites. The proposed research aims at developing tailormade photothermal catalysts for light-driven CO2 hydrogenation to solar methane by engineering hierarchical carbon-containing nanostructures derived from metal organic frameworks (MOFs), that can facilitate synergistic functions of light harvesting, photon-to-heat conversion, heat retention, and CO2 activation. A primary focus of catalyst synthesis and development would be to study the effect of catalyst morphology on photothermal activity and to develop rigorous structure-property relations that can be used to develop catalysts with high solar-to-fuel conversion efficiency.			
8	Sustainable and green synthesis of electrospun nanofibers for environmental applications	Tabish Nawaz, E.S.E.D. tnawaz@iitb.ac.in	Hemant Nanavati, Chemical Engineering hnanavati@che.iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Sustainable and green synthesis of electrospun nanofibers for environmental applications Abstract :Electrospun nanofibers have been reported to show unique tunable surface properties. However, most of the synthesis processes reported in the literature have explored polymeric substances which are synthetic and the resulting nanofibers are non-biodegradable in nature. This leads to long-term applicability issues for electrospun nanofibers. The role of biopolymers or polymers from waste origin have not been explored enough mainly due to their polymeric solution properties like viscosity and surface tension do not meet the criteria of electrospinnable solution. In this project, the focus would be to understand electrospinnability of a solution from fundamental perspective, and develop a green, sustainable, materially closed-loop nanofiber synthesis process. Further, the nanofibers will be tested for their applications in environmental remediation and contaminant sensing.			
9	Molecular Elasticity of Spider Silk and Related Biopolymers (TA / FA)	Hemant Nanavati, Chemical Engineering hnanavati@iitb.ac.in	Kamendra Sharma, Chemistry k.sharma@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Molecular Elasticity of Spider Silk and Related Biopolymers (TA / FA) Abstract :In this project, the aim is to understand quantitatively the molecular elasticity of biopolymers with potential engineering applications. The first example is Spider Dragline Silk, which may be several times stronger than steel (after normalizing the density). The work involves experimental, computational and theoretical analyses of the molecular structure of the biopolymer system.			

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10	Experimental and Simulation Studies on the behavior of Proteins in Polymeric, Liquid Crystal and Ionic Liquid Environments	Kamendra Sharma, Chemistry k.sharma@iitb.ac.in	Ajay S. Panwar, MEMS panwar@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Experimental and Simulation Studies on the behavior of Proteins in Polymeric, Liquid Crystal and Ionic Liquid Environments Abstract :Development of protein-based nanomaterials is fundamental to fabrication of biosensing platforms and devices. This will drive future economies in the healthcare sector. In order to develop such nanomaterials, proteins would have to be conjugated/mixed with some auxiliary components like polymers, liquid crystals or some green-solvents like ionic liquids/deep eutectic mixtures. In this context, intrinsically disordered or random-coil proteins are very important. For e.g. Î±-synuclein is an intrinsically disordered protein (IDP) with 140 amino acid residues abundantly found in the presynaptic terminals of neurons, and is known to show important biological functions. It is also responsible for in-vivo formation of Î²-sheet rich amyloidal fibrillar aggregates known as Lewy bodies that result in various neurodegenerative disorders such as Parkinsonâ€™s disease, etc. Another class of random-coil protein, regenerated silk fibroin (RSF) is known for its important material properties and excellent biocompatibility. RSF can be easily obtained from silk fiber and can be degummed to be converted in to a solution. Many in-vitro studies with these proteins have been performed at low concentrations for amyloid-like aggregate formation, however, effects of crowded environments due to different polymers, non-aqueous solvents (ionic liquids/deep eutectic mixtures) or even liquid crystals (for optical biosensing) can be of great significance towards developing nanomaterials with exquisite properties. This project will revolve around designing and studying such materials. Experimental and molecular simulation will be utilized in tandem to investigate into important transitions in protein secondary and tertiary structure, spectroscopic investigations for inter-molecular interactions and nanometer-scale dynamics of proteins. Molecular dynamic simulations will complement experimental measurements by providing molecular-level insight into structural dynamics and molecular re-organization. Knowledge of various inter-molecular interactions from experiments and simulations can also help build physical models of protein organization in crowded environments.			
11	Molecular mobility in nano-scale polymers probed through Single Molecule Tracking	Mithun, Met.Engg & Mat.Science mithunc@iitb.ac.in	Arindam Chowdhury, Chemistry achowdhury@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Molecular mobility in nano-scale polymers probed through Single Molecule Tracking Abstract :Single-molecule tracking (SMT) techniques have been extensively used to study synthetic polymers at high resolutions under ambient conditions, which has significantly improved our comprehension of their unique material properties. SMT involves the systematic monitoring of individual fluorescent dye molecules' diffusive motions in thin polymer films or thicker monoliths. To quantify the SMT video data, the diffusion trajectories of individual molecules are analyzed using established methods. This analysis has provided new insights into the structural alignment, orientational order, and long-range continuity of polymer microdomains, the nanoscale heterogeneity arising from defects, misalignment, and poorly controlled preparation conditions, as well as the different probe-host interactions at the single-molecule level.In the proposed project we will aim to understand the molecular mobility and their heterogeneity associated with crystallization, glass transition and presence of non-polymeric interface to underpin the outstanding physical phenomena in nano-scale polymers and thin films. Further connection will be made connecting polymer flow in thin polymer films following via in-situ optical microscopy, dielectric spectroscopy measurements.			

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12	The cloud twilight zone: aerosol-radiation interaction and the role of fluid dynamics	S. Ravichandran, Climate Studies sravichandran@iitb.ac.in	Ratul Dasgupta, Chemical Engineering dasgupta.ratul@iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :The cloud twilight zone: aerosol-radiation interaction and the role of fluid dynamics Abstract :Clouds in the atmosphere act to both cool and warm the planet, by reflecting away incoming short-wave radiation and absorbing outgoing long-wave radiation respectively. Studies suggest that the regions surrounding clouds may also be radiatively active due to the presence of humidified aerosol particles. The radiative contribution of these so-called twilight zones, which provide a transition between cloudy and non-cloudy regions of the atmosphere, can be significant, with estimates suggesting a value of about 0.75 W/m2. The radiative properties of humidified aerosols, which have typical sizes of 10 nm - 1 micrometre, are a function of their shape as well as their composition. Two processes--aerosol activation due to the presence of water vapour, and the scattering of light by these humidified aerosols--are involved in the 'aerosol effect' on the planetary radiative budget.We plan to employ recent advances in the theory of aerosol formation and activation to ask how the transient diffusion of water vapour from the edges of a cloud changes the radiative properties of an atmospheric layer. We will also examine how these changes in the atmospheric layer feed back on the dynamics of the cloud.			
13	Layered transition metal dichalcohgenide heterostructure for optoelectronic applications	Tanushree Choudhury, Met.Engg & Mat.Science tanuhc@iitb.ac.in	Saurabh Lodha, Electrical Engineering slodha@ee.iitb.ac.in	TA/FA/SW/SF/IS/EX/CT
	Topic Name :Layered transition metal dichalcohgenide heterostructure for optoelectronic applications Abstract :Layered transition metal dichalcogenides are atomically thick semiconductors with promising electronic and optical properties. These properties are enhanced while new exotic features emerge by mechanically stacking these materials to form designer layered heterostructures. van der Waals bonding, characteristic of these layered materials, allows the synthesis of these stacks without stringent lattice matching. Large-area synthesis of these heterostructures would improve their applicability. The potential of these materials can be realized when the structure-property- application correlation is done cohesively. This project will integrate the synthesis of these materials designed for specific optoelectronic applications.			