Indian Institute of Technology Mandi

ABSTRACTS

08:45 - 12:15: Session-I on 'Metamaterials'

Talk: M-I-T1:

Metamaterials: A new frontier of science and technology

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The essence of the metamaterial concept from the structural point of view will be discussed. General advantages of metamaterials will also be discussed. Next, the main research directions related to meta materials will be briefly mentioned.

Talk: M-I-T2

Negative refraction in photonic crystals

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Metamaterials are engineered structured materials which have both negative dielectric permittivity and negative magnetic permeability. Recently, there has been a lot of interest in synthesizing metamaterials by designing periodic metallic structures much smaller than wavelength of electromagnetic field. Metamaterials can have many striking applications such as sub-wavelength imaging and achieving invisibility. However, the losses occurred in these materials are an important obstacle in these applications. A possibility to minimize the problem of losses, due to the metallic character of the metamaterials, is to obtain negative refraction by using photonic crystals based on dielectric materials.

References:

S. A. Ramakrishna, Rep. Prog. Phys. **68**, 449 (2005).

Talk: M-I-T3

Implications of negative refractive index

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Metamaterials refers to engineered materials which show properties that are not present in the individual constituent components . Negative refractive index is an example of such a property which is not inherent to the naturally occuring materials. In a work by Veselago[1] theoretically predicted the properties of materials having negative refractive index. Recently it has attracted considerable attention [2] because of the potential application of such materials. I will be reviewing some of these exotic properties.

References:

1. V. G. Veselago, Sov. Phy. Usp 10, 509 (1968).

2. W. J. Padila, D. N. Basov and D. R. Smith, Mat. today 9, 28 [2006].

Talk: M-II-T1

Recent Advances in the fabrication of optical-negative index metamaterials

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The advantages, drawbacks and challenges of different fabrication techniques of optical-negative index metamaterials, such as electron beam lithography (EBL), focussed-ion beam (FIB) milling, Interference Lithography and nanoimprint lithography (NIL) and direct writing will be discussed. The breakthrough in fabrication of optical-negative index metamaterials as well as challenges facing future manufacturing of optical metamaterials will also be discussed.

Talk: M-II-T2

Three-dimensional optical metamaterial with a negative refractive index

Dr. Pradeep Parameswaran (pradeep@iitmandi.ac.in)
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Metamaterials are artificially engineered structures that have properties, such as a negative refractive index, not attainable with naturally occurring materials. Negative-index metamaterials (NIMs) were first demonstrated for microwave frequencies, but it has been challenging to design NIMs for optical frequencies and they have so far been limited to optically thin samples because of significant fabrication challenges and strong energy dissipation in metals. In this presentation, a 3D optical metamaterial having negative refractive index with a very high figure of merit of 3.5 (that is, low loss) will be presented. This metamaterial is made of cascaded 'fishnet' structures, with a negative index existing over a broad spectral range. Moreover, it can readily be probed from free space, making it functional for optical devices. A prism made of this optical NIM is used to demonstrate negative refractive index at optical frequencies, resulting unambiguously from the negative phase evolution of the wave propagating inside the metamaterial. Bulk optical metamaterials open up prospects for studies of 3D optical effects and applications associated with NIMs and zero-indexmaterials such as reversed Doppler effect, superlenses, optical tunneling devices, compact resonators and highly directional sources.

Reference:

J. Valentine, S. Zhang, T. Zentgraf, E. Ulin-Avila, D. A. Genov, G. Bartal and X. Zhang, Nature, 2008, 455, 376.

Talk: M-II-T3

Bottom up synthesis of metamaterials through self-assembly of colloidal nanoparticles

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Bottom-up assembly of functional materials has been a frontier research area for quite some time. The concept of self assembly spans many length scales- from micro to nano to molecular length scales. Nanoparticles have unique size dependant properties that differ from their bulk particles and this has been the driving point for the active research on nano materials. A number of synthetic strategies are now available to achieve precise control over size, shape and composition of nanomaterials. Self assembly of nano-sized building blocks is an ultimate method for achieving functional architectures or superlattices with tuneable properties. Such superlattices can be self assembled from highly uniform nanoparticles of same or different materials and find applications as metamaterials. Precise ordering across large dimensions offers a unique opportunity to control the electronic, optical and magnetic properties to achieve new collective properties. Recent studies on these metamaterials revealed vibrational coherence, reversible metal-to-insulator transitions, enhanced p-type conductivity, spin dependent electronic transport, enhanced ferro- and ferrimagnetism and variable range electron hoping. The state-of-the art in the preparation and characterisation of single- and multi-component self assembled superlattices of colloidal nanoparticles will be reviewed in the presentation.

13:30 - 17:30: Session-II on 'Science, Engineering and Technology of Solar Energy'

Talk: S-I-T1

Organic polymers solar cells: The challenges and improvement

Dr. Chayan K Nandi (chayan@iitmandi.ac.in)& Dr. Subrata Ghosh (subrata@iitmandi.ac.in)
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An alternative source of the renewable energy resource, globally, is to produce efficient solar energy from sunlight. Though organic polymer solar cells has decreases the cost over inorganic semiconductor solar cell but still a major challenge is to produce efficient organic polymer molecules for producing efficient low cost solar energy. The main disadvantages associated with organic solar cells, which is formed by the formation of localized electron- hole pair i.e Frenkel type exciton, are low efficiency, low stability and low strength compared to inorganic photovoltaic cells. The exciton binding energy is typically very large in organic solar cells, which leads a critical component in the architectures of organic solar cells is the design of the heterojunction between an electron-donor material and an electron acceptor material. In this talk we will discuss the detail optical processes and advantages of organic solar cells and the possibility of designing followed by synthesis of suitable polymerizable monomers which could produce low band gap polymers or copolymers through the incorporation of proper donor-accepter units.

References:

1. Gunes, S.; Neugebauer, H. L. Sariciftci, N. S. *Chem. Rev*. 2007, 107, 1324-1338.
2. Service, R. F. *Science* 2005, *309*, 548–551
3. Yu, G.; Gao, J.; Hummelen, J. C.; Wudl, F.; Heeger, A. J. *Science* 1995, *270*, 1789 1791.
4. Bredas, J.-L.; Norton, J. E.; Cornil, J.; Coropceanu, V. *Acc. Chem. Res*. 2009, 42, 1691-1699.
5. Bundgaard, E.; Krebs, F. C.; *Sol. Energy mater. Sol. Cells* 2007, 91, 945-985

Talk: S-I-T2

Polymer solar cells: optimizing solar energy harvesting by simultaneous process, product and property modeling

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Being easy to manufacture in an inexpensive and environmentally preferable way, polymer solar cells are gaining a lot of popularity. There is still a huge potential for optimizing the solar harvesting process using polymer solar cells, since they can only achieve 6% of power conversion efficiency, which is way too low for daily applications. Some examples of possible routes for improving the performance include improving absorption of the solar spectrum, improving open circuit voltage, optimizing the morphology of the photoactive layer, developing new device structures, improving the stability of polymer solar cells etc. [1]. The process of solar energy harvesting takes place in mainly five steps, where each step is associated with its respective efficiencies. These efficiencies greatly depend not only on the microscopic properties of the polymer blends that could be used in solar cells like, the chain length, the branch length, the orientation of the monomer units, the kind of monomer units etc. but also on macroscale parameters like the geometry of the device, thickness of the polymer layer, orientation of the solar panels etc.
A simultaneous process and product design is proposed which would combine optimization of multiscale parameters relating to the process, the product and the properties using a model based design approach.

Reference:

Wanzhu Cai, Xiong Gong, Yong Cao, Solar energy materials & solar cells 94 (2010) 114-127

Talk: S-I-T3

Technical & economic issues for grid connection of solar power in India

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Talk will be focus on present status, challenges and future scenario of technical and economic aspects for grid connection of solar power in India. Off-grid utilization will be briefly touched.

Talk: S-II-T1

Plastic solar cells: Science, expectations and challenges

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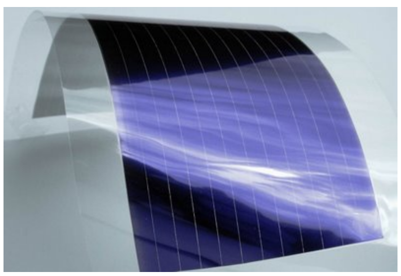
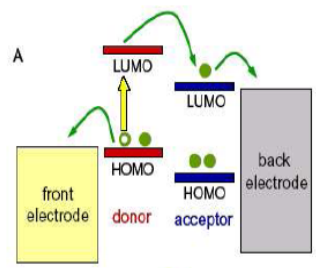
The adverse environmental effect of the use of fossil fuel and their limited resources are stimulating research on renewable energy sources, in particular, on the photovoltaic conversion of solar energy. Among various kinds of solar cells, plastic solar cells have attracted huge scientific attention because of the possibility of fabricating large-area, lightweight, and flexible devices using simple





techniques with low environmental impact.

In plastic solar cells, heterojunctions are formed due to contact of electron donor (conjugated polymer) and acceptor materials [1]. The primary photoexcitations do not directly lead to free charge carriers but to the formation of excitons, which are dissociated to free charges at the heterojunctions [1-4]. The free charges are finally transported to the electrode to produce photovoltaic effect. Recently, the power conversion efficiency of plastic solar cells has reached the value more than 6% [5,6]. Future improvement in power conversion efficiency will depend on our ability to combine aspects of synthetic and physical chemistry, condensed matter physics, and materials science. In this talk, I address the basic operating principles of plastic solar cells and their various architectures. The limiting factors on power conversion efficiency and scope of future research to overcome them will also be discussed.

References:

1. S. Gunes, H. Neugebauer, N. S. Sariciftci Chem. Rev. 107 (2007) 1324
2. C. D. Dimitrakopoulos, P. R. L. Malenfant, Adv. Mater. 14 (2002) 99.

3. S. De, T. Pascher, M. Maiti, K. G. Jespersen, T. Kesti, F. Zhang, O. Inganas, A. Yartsev, V. Sundstrom, J. Am. Chem. Soc. 129 (2007) 8466.
4. S. K. Pal, T. Kesti, M. Maiti, F. Zhang, O. Inganas, S. Hellstrom, M. R. Andersson, F. Oswald, F. Langa, T. Osterman, T. Pascher, A. Yartsev, V. Sundstrom. J. Am. Chem. Soc. *132* (2010) 12440.
5. H. Y.Chen, J. H. Hou, S. Q. Zhang, Y. Y. Liang, G. W.Yang, Y. Yang, L. P. Yu, Y. Wu, G. Li, Nat. Photonics 3 (2009) 649–653.
6. J. H. Hou, H. Y. Chen, S. Q. Zhang, R. I. Chen, Y. Yang, Y. Wu, G. Li, J. Am. Chem. Soc.131 (2009) 15586–15587.

Talk: S-II-T2

Mechanical analysis of solar panels

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Power subsystem of any microsatellite consists of a group of solar panels and a battery frame module. Solar panels are the main power source during the satellite operation-life time (5 years). Solar panel structure is designed to withstand mechanical loads such as vibrations due to transportation and launch, and buckling during solar panel release. Thermal control of solar panels is achieved by applying high-emittance black paint on the back of array to keep temperature as low as possible. So, the thermal radiative properties are controlled by the high-absorptance/high emittance solar cells themselves. Solar panel structure consists from honeycomb made from aluminum, composite laminates on top and bottom, and embedded parts for the rotation mechanism and electric brackets. Thermal analysis is performed to predict solar panel temperature profile, then thermal Stress analysis is performed to predict thermal stress, and then fatigue calculations are performed to check fatigue damage for the embedded part of the rotation mechanism and honeycomb near it. Failure of the embedded part of the rotation mechanism may lead to partial separation of the solar panel and unpredicted response that reduces power subsystem efficiency. While damage of the honeycomb strucsture near the embedded part will lead to decrease of rigidity in solar panel structure which may lead to increase of solar panel fluctuations. This increase of solar panel fluctuations will affect the dynamic response of the satellite in-orbit and reduce the ADCS (Attitude Determination Control Subsystem) performance. These fluctations can be controlled by the smart material technology. Smart materials, such as
piezoelctirc led zirconate titanate (PZT) patches and Polyvinylidene fluoride (PVDF), have been used extensively as distributed sensors and actuators. Control methodologies are also very important for fluctations control. Since the flexible solar panel is a distributed parameter system of infinte order, modal inacuraices or uncertainties will have strong adverse effecton control system, when it is approximated by a lower-order model and controlled by a finite-order controler. In the absence of sufficiently precise process mathematic model and in the presence of non linearity, fuzzy logic or neural network based control usually have an adavantage over calssical control and modern control.

Talk: S-II-T3

Solar energy for building cooling and heating

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Adverse weather - heat wave in summer and cold wave in winter – has been claiming thousands of lives in India every year. Simmering summers and chilling winters, in general, have been causing lot of human discomfort and reducing productivity and efficiency. Solar thermal cooling (vapour absorption based) and heating system is proposed for buildings. Some regions (e.g, Rajasthan and Delhi) experience very high temperatures during day time and very low temperatures during night time. Night time low temperatures coupled with vapour absorption system can be used for daytime cooling and daytime high temperatures coupled with solar-heating can be used for night time heating in these regions.

References

M. Qu *et al*., A solar thermal cooling and heating system for a building: Experimental and model based performance analysis and design, Solar Energy 84 (2010) 166–182.

M. Kenisarin and K. Mahkamov, Solar energy storage using phase change materials, Renewable and Sustainable Energy Reviews, 11(9), 2007, 1913-1965.