Arup Kumar Raychaudhuri

Distinguished Professor Emeritus
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Professor Arup Kumar Raychaudhuri did his M.Sc. from IIT, Kanpur. He obtained his Ph.D. from Cornell University. He joined the Centre in 2004 (Director 2006-2014), worked at Max Planck Institute, Stuttgart as Humboldt Fellow, Indian Institute of Science, Bangalore as Professor and National Physical Laboratory, New Delhi as Director. His research interests cover broad canvas of condensed matter physics and materials science.

Supervision of Research / Students

Ph.D. Students

1. Rishiram Ghimire, "Investigation of opto-electronic phenomena in nanostructured ZnO with electric double layer gate", Completed.
2. Ravindra Singh Bisht, "Investigation of metal-insulator transition in 3d and 5d transition Metal Oxides", Ongoing.
3. Shaili Seth, "Investigation of transport properties in Germanium Nanowires", Ongoing.
4. Vibhuti Narayan Rai, "Electrical Transport and Phase Transitions in nanowires of Charge transfer complex nanowire CuTCNQ", Ongoing.
5. Subhamita Sengupta, "Physical Properties of interface of Ferroelectric and Ferromagnetic films", Ongoing.

Projects of M.Sc./ M.Tech./ B.Tech./ Post B.Sc. students

1. Sumit Kumar Singh, IIT/Kharagpur, "Fabrication and Photoconductivity of Si Nanowires fabricated on SOI wafers", Completed.

Post Doctoral Research Scientists

1. Pabitra Mandal
2. Jashashree Ray

Teaching activities at the Centre

1. 1st semester. PH 191 Basic Laboratory-I I.PhD Year 1, 9, Dr. Soumen Mondal
2. 3rd semester , PH 391 Methods of Experimental Physics , IPHD Year 2, 7, Dr. Barnali Ghosh, Dr.Kalyan Mandal and others

Publications in Journals

1. Sudeshna Samanta, Deepika Saini, Achintya Singha, Kaustuv Das, Prabhakar R. Bandaru, Apparao M. Rao, and **Arup Kumar Raychaudhuri;** *Photoresponse of a Single Y Junction Carbon Nanotube;* ACS Applied Materials and Interfaces; 2016; **8**; 19024.
2. Rabaya Basori, Manoranjan Kumar and **Arup K. Raychaudhuri;** *Sustained Resistive Switching in a Single Cu:7,7,8,8-tetracyanoquinodimethane Nanowire: A Promising Material for Resistive Random Access Memory;* Scientific Reports; 2016; **6;** 26764.
3. Aveek Bid and **A.K Raychaudhuri;** *Structural instability and phase co-existence driven non-Gaussian resistance fluctuations in metal nanowires at low temperatures;* 2016; Nanotechnology; **27;** 455701.
4. Rajesh Kumar Neogy, Rajib Nath, **A.K. Raychaudhuri;** *Thermal transport enhancement in gold nanofluid containing network like structure;* Materials Chemistry and Physics; 2017; **186;** 478.
5. Rishi Ram Ghimire, **A.K. Raychaudhuri;** *High performance thin film transistor (flex-TFT) with textured nanostructure ZnO film channel fabricated by exploiting electric double layer gate insulator;* Appl. Phys. Lett.; 2017; **110;** 052105.
6. Samt K Ray, Ajit K Katiyar and **A. K Raychaudhuri;** *One-dimensional Si/Ge nanowires and their heterostructures for multifunctional applications - a review;* Nanotechnology; 2017; **28;** 092001.
7. Shaili Sett, K Das and **A K Raychaudhuri;** *Weak localization and the approach to metal–insulator transition in single crystalline germanium nanowires;* J. Phys.: Condens. Matter.; 2017; **29;** 115301.
8. Soumen Dhara and **A. K. Raychaudhuri;** *Enhancement in red emission at room temperature from europium doped ZnO nanowires by 1,10 phenanthroline-europium interface induced resonant excitations;* AIP Advances; 2017; **7;** 025306.
9. Ravindra Singh Bisht, Sudeshna Samanta and **A. K. Raychaudhuri;** *Phase coexistence near the metal-insulator transition in a compressively strained $NdNiO_3$ film grown on $LaAlO_3$: Scanning tunneling, noise, and*

impedance spectroscopy studies; Physical Review B; 2017; **95;** 115147.

10. Shaili Sett, K. Das, and **A. K. Raychaudhuri;** *Investigation of factors affecting electrical contacts on single germanium nanowires;* Journal of Applied Physics; 2017; **121;** 124503.

Lectures Delivered

1. Metal Insulator Transition Revisited; Cornell University; May 2016 -1.
2. An investigation on certain emerging aspects of Metal-Insulator Transition in thin oxide films; SNBNCBS International Conference; January 2017-1.
3. Experimenting with Single nanowires: A new paradigm to do materials science; University of Southern Florida, USA; June 2016 -1.
4. Experimenting with Single nanowires: Physics and Applications; IGCAR, Kalpakkam; August 2016-1.
5. Synthesis of Charge transfer complex nanowires and its application in ultra-sensitive electronic devices; 12th IUPAC Conference, Changsha, China; October 2016-1.
6. Experimenting with single nanowires: Physics and application issues; International Workshop on Advanced Materials and Nanotechnology, Hanoi, Vietnam; November 2016-1.
7. A lonely nanowire and its broad vision; Annual Day Lecture, UGC-DAE Consortium of Research; December 2016.
8. Experimenting with single nanowires: A new paradigm of doing nanoscience and technology; International Conference on Emerging Trends in Nanomaterials Science & Technology, NIT, Dimapur; January 2017-1.
9. Photodetectors Switches and Nanowires: A single nanowire Paradigm; Nano India 2017, IIT,Delhi; March 2017-1.
10. Endless surprises of Metal Insulator Transition: Physics and Application Potentials; IIT, Kharagpur; March 2017-3.

Membership of Committees

External Committee

1. Member of Board , Science and Engineering Research Board
2. Chairman, Scientific Advisory Committee, UGC-DAE Consortium of Research, Indore
3. Member, Governing Board and Governing Council, UGC-DAE Consortium of Research, Indore
4. Convenor, Sectional committee VI- INSA;
5. Chairman, PAC of Physics , International Division (DST)
6. Programme Advisory Committee , Solar Energy Research Initiative (DST);
7. Programme Management Committee , SERIUS, Indo-US Science and Technology Forum;
8. Member Faculty Selection Committee at IISER and IIT's.
9. Member expert committee on different topics in DST
10. Member delegation to Indo-US Joint Commission on S&T.

Internal Committee

Nodal officer, Technical Research Centre, SNBNCBS

Patent/s submitted / granted

1. Ammonia Gas Sensor and A Method for Manufacturing The Same; Avisek Maity, Barnali Ghosh, A.K.Raychaudhuri; Submitted on 03/01/2017

Awards / Recognitions

1. J.C. Bose fellowship 2nd renewal

Fellow / Member of Professional Body

Fellow: Indian National Science Academy, New Delhi; Indian Academy of Sciences, Bangalore; National Academy of Sciences, Allahabad; Asia Pacific Academy of Materials;

Members: American Physical Society; Materials Society of India; Indian Physics Association; Indian Association of Physics Teachers; Instrumentation Society of India

Sponsored Projects

1. Unit for Nanoscience, Nanomission, March 2011-October 2016
2. Theme Unit of Excellence in Nanodevice ,Nanomission, Technology, October 2011-April 2017
3. J.C Bose Fellowship, SERB, June 2006- February 2020,
4. An investigation on certain emerging aspects of Metal-Insulator Transition in thin oxide films, SERB, March 2017-March 2020
5. Technical Research Centre at SNBNCBS, DST, January 2016-December 2020

Collaborations including publications (Sl. No. of paper/s listed in 'Publications in Journals' jointly published with collaborators)

National

1. Dr. Aveek Bid, IISC (Sl. No. 3)
2. Dr. Achintya Singha (Sl. No. 1)

International

1. Dr. Deepika Saini, Prof. Prabhakar R. Bandaru, Prof. Apparao M. Rao (Sl. No. 1)

Significant research output / development during last one year

General research areas and problems worked on

- Broad areas: Nanomaterials, and Nanolithography,. Physics of correlated oxides
- Specific problems investigated in 2016-17, include electronic and optoelectronic properties of Ge nanowires, Y-Jn CNT and Au functionalized ZnO nanowires, Fluctuations in metal nanowires, Phase -coexistence near metal-insulator transition in correlated oxides
- Research Keywords: Nanomaterials, Nanolithography, Correlated electron systems, Optoelectronics

Interesting results obtained

1. We report an observation of phase coexistence near the metal-insulator transition (MIT) in a film of NdNiO3 grown on crystalline substrate LaAlO3. This was established through a combination of three techniques, namely, scanning tunneling spectroscopy, 1/f noise spectroscopy, and impedance spectroscopy experiments. The spatially resolved scanning tunneling spectroscopy showed that the two coexisting phases have different types of density of states (DOS) at the Fermi level. One phase showed a depleted DOS close to EF with a small yet finite correlation gap, while the other coexisting phase showed a metal-like DOS that had no depletion. The existence of the phase separation leads to a jump in the resistance fluctuation (as seen through 1/f noise spectroscopy) at the transition, and, notably, the fluctuation becomes non-Gaussian. This was corroborated by the impedance spectroscopy, which showed a broad hump in capacitance at the transition region as a signature of the existence of two phases. The phase separation starts well within the metallic phase much above the transition temperature and makes the sample electronically "inhomogeneous" in nanoscopic scale.
2. We study the low-temperature electronic transport properties of single germanium nanowires (NWs) with diameters down to 45 nm to investigate the weak localization (WL) behavior and approach to metal–insulator transition (MIT) within them. The NWs (single crystalline) we investigate lie on the metallic side of the MIT with an extrapolated zero temperature Conductivity $\sigma 0$ in the range 23 to 1790 (Ohm cm)−1 and show a temperature-dependent conductivity which below 30 K can be described by a 3D WL behavior. From the observed value of $\sigma 0$ and the value of the critical carrier concentration nc, it is observed that the approach to MIT can be described by the scaling equation $\sigma 0 \sim (n - nc)^{\nu}$ with $\nu \approx 0.6$, which is a value expected for an uncompensated system. The investigation establishes a NW size limit for the applicability of 3D scaling theories.
3. We investigated optical response in a single strand of a branched a Y-junction CNT composed of multiwalled CNTs. The experiment was performed by connecting a pair of branches while grounding the remaining one. Of the three branch combinations, only one combination is optically active which also shows a nonlinear semiconductor-like I–V curve, while the other two branch combinations are optically inactive and show linear ohmic I–V curves. The photoresponse includes a zero-bias photocurrent from the active branch combination. The photoresponse experiment allows us to understand the nature of internal connections in the Y-CNT. Analysis of data locates the region of photoactivity at the junction of only two branches and only the combination of these two branches (and not individual branches) exhibits photoresponse upon illumination. A model calculation based on back-to-back Schottky-type junctions at the branch connection explains the I–V data in the dark and shows that under illumination the barriers at the contacts become lowered due to the presence of photogenerated carriers.

Proposed research activities for the coming year

In the year to come we will investigate the metal insulator transition in correlated oxide films (preferably very thin within few unit cells) using such tools as low temperature measurements down to 0.3K, 1/f noise spectroscopy , Scanning Tunneling Microscopy as well as impedance spectroscopy.

We will also investigate single nanowire photo-detectors using vapor phase grown Ge nanowires and in particular, investigate their very large responsivity in the near IR region upto 1600nm. This work will also couple to investigation of weak localization phenomena in Ge nanowire through low temperature conductivity and magnetoresistance measurements.

In an attempt to understand the interface of ferroelectric and ferromagnetic materials, we will grow epitaxial films of $SrRuO_3$ (a FM material below 160K) and $La_{0.7}Sr_{0.3}MnO_3$ (a FM material below 300k) on $BaTiO_3$ (a Ferroelectric material below 350K). The challenge of making a sharp interface and growing film of proper stoichiometry will be addressed to.

We will also study functionalization of ZnO nanowires with Au nanoparticles and will explore whether their performance as a photo-detector can be extended to visible range of the spectrum.

We will also investigate likely occurrence of Bose –Einstein Condensation of Magnons in Gd nanostructured films.

We will also investigate whether current induced magnetization reversal can be observed in nanoconstrictions of few hundred nanometer in Gd nanowires, nanofabricated by nanolithography tools and will also explore whether this can be used for making measurements of anisotropy energy.

We will also would do deliverable specific research in TRC projects.

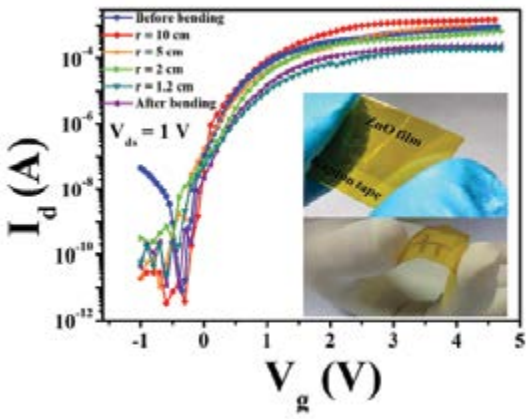

Fig.1: Flexible Thin Film Transistor High performance flexible thin film transistor (flex-TFT) with textured nanostructure ZnO film channel fabricated on Kapton using electric double layer gate insulator

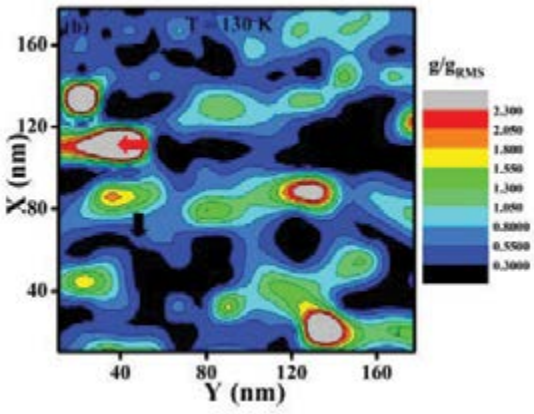

Fig.2: Nanoscopic phase separation on $NdNiO_3$ film grown on $LaAlO_3$ near MI transition Local tunneling conductance map at 130 K taken in UV The data are plotted as normalized conductance g /grms .. The red and black arrows show the highest and lowest g regions, respectively.