RECENT RESEARCH ACTIVITIES IN AKR GROUP

General area of research:

Experimental Condensed Matter Physics, Materials Physics,

Nanosciences and Nanotechnology

Current areas of interest :

The following research areas are currently being pursued in the group of AKR. His group activities involve extensive materials synthesis using different routes , their characterization and then using them in variety of physical experiments that span basic physics as well as applied physics. AKR group has a strong interaction with the research group of Dr. Barnali Ghosh. AKR group is also involved in technology development through the Technical Research Centre (TRC) Project of the centre . Currently his group activities are broadly involved in the following main themes:

(a) Physics and Technology with single nanowire devices.
(b) Investigation of the Physics of Metal insulator transition in correlated oxide films and oxide interfaces including such interfaces like that between Ferroelectric-Ferromagnetic materials.
(c) Development and innovation of Oxide based Thin film Transistors with novel gates and on flexible substrates.
(d) Utilization of plasma as a tool to engineer materials.

With the group of Dr. Barnali Ghosh and Dr. Manik Pradhan, AKR is also involved in development of breathe analysis as a tool for disease detection. This activity is a part of the TRC project

(a) Physics and Technology with Single nanowire devices.

Nanowires (with diameters < 50nm or so) often show interesting physical properties that are not seen in their bulk counter part. The focus of the research in this area is to understand the properties of nanowires through experiments on single nanowires and harness these properties for application. Activities in this area involves growth of nanowires such as semiconducting nanowires like Ge and Si using a vapour phase method using Au nanoparticle as catalyst. , growth of molecular materials nanowires such as Cu:TCNQ from vapours of TCNQ , metal nanowires using templates by electrochemical route . After synthesis the nanowires are integrated into single nanowires devices using nanolithography tools such as Electron Beam Lithography and Focused Ion Beam lithography so tat electrical and opt-electrical measurements can be made on them. The physical experiments on single nanowires are done to probe physics of phenomenon like localization, metal – insulator transition, charge ordering, Ferro and Anti-ferromagnetic transition, Optical detection and Charge Density wave transition etc. These activities led to discovery of ultra sensitive photodetectors realizable in a single nanowire.

Some of the recent publications in this area are:

Rabaya Basori, K. Das, Prashant Kumar, K.S.Narayan and A. K. Raychaudhuri
"Single CuTCNQ charge transfer complex nanowire as ultra high responsivity photo-detector"
OPTICS EXPRESS 22 , 4944 (2014) .

Subarna Datta, Sudeshna Samanta, Barnali Ghosh and A. K. Raychaudhuri
"Low-Frequency Resistance Fluctuations in a single nanowire (diameter _ 45nm) of a complex oxide and its relation to magnetic transitions and phase separation" Applied Physics Letters 105, 073117 (2014)

K. Das, S. Mukherjee, S. Manna, S. K. Ray , A .K .Raychaudhuri
"Single Si nanowire (diameter ≤ 100nm) based polarization sensitive near-infrared photodetector with ultra-high responsivity." RSC- Nanoscale 6 , 1123 (2014)

Sudeshna Samanta, Deepika Saini, Achintya Singha, Kaustuv Das, Prabhakar R. Bandaru, Apparao M. Rao, and A.K Raychaudhuri
*"Photoresponse of a Single Y-Junction Carbon Nanotube",*ACS Applied Materials and Interfaces 8 , 19024 (2016)

Rabaya Basori, Manoranjan Kumar & Arup K. Raychaudhuri
"Sustained Resistive Switching in a Single Cu:7,7,8,8tetracyanoquinodimethane Nanowire"
Scientific Reports 6 26764 (2016)

Aveek Bid and A.K Raychaudhuri
"Structural instability and phase co-existence driven non-Gaussian resistance fluctuations in metal nanowires at low temperatures" Nanotechnology 27, 455701 (2016)

.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 29 115301 (2017)

Shaili Sett, K. Das, and A. K. Raychaudhuri
"Investigation of factors affecting electrical contacts on single germanium nanowires"
JOURNAL OF APPLIED PHYSICS 121, 124503 (2017)

(b) Investigation of the Physics of Metal insulator transition in correlated oxide films and oxide interfaces including such interfaces like that between Ferroelectric-Ferromagnetic materials.

Physics of Metal Insulator Transition (MIT) is one of the most well researched yet least understood area of physics for nearly half a century. Directly or indirectly it has its impact on a large class of problems in modern day condensed matter physics (like manganites , oxide superconductors etc.) and it is also one of the factors that affect different facets materials science.
One of the crucial issue that has not been sorted out is the nature of the transition region, particularly in the context of Mott insulators. It is now emerging from recent experiments on MI transition that there may actually be co-existence of varying proportions of metallic and insulating phases around the transition temperature region. This becomes even more involved if there is a structural transition associated with the MI transition region. *Our current investigation involves an in-depth study using both temporally or spatially resolved tools like: scanning tunneling microscopy (STM)/scanning tunneling spectroscopy (STS), 1/f and Jhonson Noise spectroscopy and Impedance spectroscopy. The investigation is done on very thin films of oxides grown by using LASER MBE.*
The group of AKR has now started working on the physics of interface of ferroelectric material like $BaTiO_3$ and ferromagnetic materials like $SrRuO_3$ and $La_{0.7}Sr_{0.3}MnO_3$. AKR group would like to investigate whether

the work function and the built-in potential at the interface of the two materials depend on the polarization of the ferroelectric material. This will then lead to an interesting interface whose electronic transparency can be controlled by the dielectric polarization. Challenges in this work stem from growing thin ferroelectric film that retains ferroelectric polarization down to few monolayer thickness of the film.

<u>Some of the recent publications in this area are:</u>

Sudeshna Samanta , A. K. Raychaudhuri, Xing Zhong and A. Gupta
"Dynamic phase coexistence and non-Gaussian resistance fluctuations in VO_2 *near the metal-insulator transition".*
PHYSICAL REVIEW B 92, 195125 (2015)

. Ravindra Singh Bisht, Sudeshna Samanta and A. K. Raychaudhuri
"Phase co-existence near metal-insulator transition in a compressively strained $NdNiO_3$ *grown on* $LaAlO_3$*: Scanning tunneling, noise and impedance spectroscopy studies"*
PHYSICAL REVIEW B 95, 115147 (2017)

(c) *Development and innovation of Oxide based Thin film Transistors with novel gates and on flexible substrates.*

Thin film transistor (TFT) is an important component of modern day electronics in particular in such application areas like display, sensors, photodetector etc. At present proposed design of many TFT uses oxides as channels of TFT. Oxides like ZnO, In-Ga-ZnO, SnO_2 etc. are some of the most researched materials. One of the problem of TFT with oxide channel is that it need very high operational bias often exceeding few tens of volt. The group of Prof. AKR uses a novel material (e.g, solid electrolyte) as a gate dielectric so that the TFT can be made to turn on at a very low bias often within a few hundreds of mV and can show very high ON/OFF current ratio. The novel gate was used to make a flexible TFT (with ZnO as channel) on a common polyimide material film like Kapton ® that can reach ON/OFF current ratio in excess of 10^7 , a threshold voltage of $\leq$ 1V and a sub-threshold voltage swing $\leq$ 75mV/dec signifying a sharp switching. The electrolyte gate dielectric has been used also to make gated photo-detector with enhanced performance (for UV detection) where a synergy has been built between the carriers generated by light and that induced by gate.

<u>Some of the recent publications in this area are:</u>

. Ravindra Singh Bisht, Rishi Ram Ghimire, and A. K. Raychaudhuri
"Control of Grain Boundary Depletion Layer and Capacitance in ZnO Thin Film by a Gate with Electric Double Layer Dielectric". J. Phys. Chem. C , 119 , 27813–27820 (2015)

Shahnewaz Mondal, Rishi Ram Ghimire and A. K. Raychaudhuri
"Mobility enhancement in Electric Double Layer gated n-ZnO UV photodetector by synergy of gate and illumination: A photo Hall study", Applied Physics Letters 106, 041102 (2015);

Rishi Ram Ghimire, Shahnewaz Mondal and A. K. Raychaudhuri
"Large enhancement of UV photo response of a nanostructured ZnO thin film using an electric double layer gate dielectric " , Journal of Applied Physics 117, 105705 (2015);

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. 110, 052105 (2017);

Patent applied in this area :
Rishi Ram Ghimire, Chandan Samanta, Barnali Ghosh, A.K.Raychaudhuri
FLEXIBLE THIN FILM TRANSISTOR USING ELECTRIC DOUNLE LAYER AS GATE DIELCTRIC AND A METHOD OF FABRICATING THEREOF.
Temp/E-1/15531/2017-KOL

(d) Utilization of plasma as a tool to engineer materials.

Plasma of different gases , created by an Inductively Coupled Source (ICP) can be used for Reactive Ion Etching (RIE). While the ICP-RIE can be used in nanolithography for pattern transfer through dry etching, AKR group uses the plasma for surface treatment of solids to engineer its properties (like surface roughnes) as well as for reactively cleaning surface that often may have a wrong phase. This is a versatile tool that can be used to engineer the surface of any materials to enhance the surface sensitive properties.

Some of the recent publications in this area are:
. Ajit K. Katiyar, S. Mukherjee, M. Zeeshan, Samit. K. Ray,,and A. K. Raychaudhuri
"Enhancement of Efficiency of a Solar Cell Fabricated on Black Si Made by Inductively Coupled Plasma−Reactive Ion Etching Process: A Case Study of a n-CdS/p-Si Heterojunction Cell"
ACS Appl. Mater. Interfaces, ,7, 23445–23453 (2015)

Some of the past areas worked on:

a) Low energy excitation in glasses (TLS) and physics of glassy state.

Representative publications :
(Raychaudhuri and Pohl, Phys. Rev. **B25**, 1310 (1982), Raychaudhuri and Hunklinger Z. Phys. **B57**, 113 (1984), Hunklinger and Raychaudhuri *PROGRESS IN LOW TEMPERATURE PHYSICS*. *Vol. IX* page 265 (1986)

b) High temperature superconductor.
Representative publications :

Rao,Ganguly,Raychaudhuri and Mohanram, Nature. **326,** 856 (1987), .Srikanth and Raychaudhuri **"**Phys.Rev. **B 45,** 383 (1991-II) , Srikanth and .Raychaudhuri ,Physica **C190,** 229 (1992)

c) Metal insulator transition in transition metal oxides.

Representative publications :
"Low temperature conductivity of Ta compensated sodium bronze near the metalinsulator transition" Phys.Rev. B 44, 8572 (1991-II)
"Quantum corrections to conductivity in a perovskite oxide : A low temperature study of La $Ni_{1-x} Co_x O_3$" Phys. Rev. B 46, 1309 (1992).

"Metal – Insulator Transition In perovskite oxides : Tunneling Experiments" Phys. Rev B 51, 7421 (1995)

"Metal-insulator transition in perovskite oxides: a low temperature perspective" Advances in Physics 44, 21 (1995)

d) Colossal Magnetoresistance (CMR) and Charge ordering in hole doped rare earth oxides.

***Representative publications* :**

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(1996) "Structure electron- transport properties and giant magnetoresistance of hole doped $LaMnO_3$ systems." Phys. Rev B 53, 3348

(1996) "Effect of particle size on the giant magnetoresistance of $La_{0.7}Ca_{0.3}MnO_3$" Appl. Phys. Letts. 68, 2291

(1996) "Magnetoresistance of the spin state transition compound $La_{1-x}Sr_xCoO_3$" Phys. Rev B 54, 16 044

(1999) " The density of states of hole-doped manganites : A scanning tunneling microscopy/spectroscopy study" , Phys. Rev. B 59 , 5368

(2000) "Collapse of charge ordering gap of $Nd_{0.5}Sr_{0.5}MnO_3$ in an applied magnetic field" J.Phys. Condens. Matter (letters) 12, L 101