

## **Recent Research Activities**

**General area of research: Experimental Condensed Matter**

**Physics, Materials Physics and Nanosciences**

**Current areas of interest :**

- a) Nanoscience and nanotechnology particularly fabrication of single nanowires devices using nanolithography tools and physical experiments on single nanowires.
- b) Physics of correlated transition metal oxides particularly perovskite oxides ( like manganites that show colossal magnetoresistance) .
- c) Physics and applications of wide band gap semiconductor like ZnO.

**Some of the past areas worked on:**

- a) Low energy excitation in glasses and physics of glassy state.
- b) High temperature superconductor.
- c) Metal insulator transition in oxides.

**Present research problems that will be pursued by**

**AKR group in next 5 years:**

**Physics of size reduction:**

In recent years the group focused on the general areas of nanoscience and technology and particularly on measurements of single nanowires. A specific problem of size reduction is that it can

which affect cohesive energy and related properties like mechanical properties, melting point Debye temperatures etc . Our investigation is directed to understanding how the basic thermodynamic properties get affected by size reduction.

“Engineering” of properties of nanomaterials in a predetermined and controlled manner would need an understanding of ionic diffusion as well as creation and diffusion of defects. AKR group is trying to understand some of the basic issues involved in this process through controlled experiments on lithographically fabricated nanostructures.

Size reduction , in complex systems, can tune their ground state. In complex oxide nanowires and nanoparticles this can lead to very different transport and magnetic properties as compared to the bulk. Size reduction as in nanowires can also affect the noise and fluctuations significantly as the smaller size of the nanowires make them more prone to fluctuations. These noise can come from structural origin, electronic origin and also from spins which in

nanowires are aligned by shape anisotropy but are prone to creation of domain walls by thermal fluctuations.

**Single nanowires devices as ultra-sensitive detector of charge and radiation:**

Very recent work by the group has shown that certain types of nanowires when configured as a single nanowires device can act as ultra-sensitive detectors of photons which may open the path for single photon detection. The group is now trying to develop this type and reach sensitivity of single photon detector. A related , although not the same problem, is development of ultra-sensitive charge detectors. The group would like to embark on this challenging problem

**Physics of correlated oxides:**

AKR group has been working on correlated oxides like transition metal oxides for some time. In recent years it has investigated current driven resistance state transition in such oxides. In such materials , when the doping level is low it shows an insulating state that is ferromagnetic in character. The recent work in the group has

investigated the onset of metallic state in such ferromagnetic insulators on application of hydrostatic pressure. The AKR group is also investigating the “glassy electronic” state in such materials that freeze out the charge relaxation kinetically using measurement of charge and polarization fluctuation. A future endeavor will be to tune the glassy electronic state by pressure/strain and investigate whether it gives rise to a quantum phase transition.

### **Physics and application of wide band gap semiconductor ZnO:**

The AKR group has been active in this area since 2005. Currently it is working on Thin Film Transistor (TFT) made from ZnO and is investigating new effects that can enhance their response and hence the applicability as detectors . These TFT’s are made either from solution based deposition or as multilayered structure made by pulsed laser deposition. In recent years the group is investigating effect of polymer electrolyte gate on such ZnO-TFT. This type of gate creates an Electric-Double layer gate that can introduce large charge to the material that makes the channel in the TFT. Recently it has been discovered by our group that

illumination of UV light on such EDL-FET ZnO-TFT leads to new effects that include gate controllable persistent photo conductivity and a synergetic response of the TFT with both gate and illumination.

**Problems for new Ph.D students:**

The group is currently looking for 2 Ph.D students who are likely to work on the following areas:

- (a) Ultra-sensitive charge detector using single nanowires devices. This work will have several steps. In its first step, a suitable material which can be made into a nanowires and nanotube and act as sensitive charge detector need be identified. In the second step, using nanolithography one would create a test device. The device response will then be tested. We would like to achieve single electron detectibility at room temperature. The problem will have a combination of device fabrication challenges, physics and application potential.

- (b) Investigation of the Physics of slow relaxing electron and the glassy electronic state in disordered oxides with correlations. The work will evolve around fabrication of epitaxial thin films (ultra-thin) on atomically smooth terraced substrate using pulsed laser deposition and RHHED. The films will be then studied for charge relaxation using such techniques like measurement of charge and polarization fluctuations down to low temperatures. We also would like to image spatially the “glassy electronic “ state using such local probes as an UHV scanning tunnel microscope (STM). In the second step, the films will be grown on substrates that can be strained electronically and the effect of uniaxial - strain on the glassy state and how it evolves to a metallic state will studied. This project is more physics based but has challenges in thin film fabrication and analysis and also in precision measurements using an STM.

**Techniques used and developed for the research:**

✓ **Materials synthesis**

- a) Synthesis of materials particularly Nanomaterials by chemical routes.
- b) Vapour phase synthesis using pulsed laser deposition and magnetron sputtering.
- c) Nanolithography using a combination of optical lithography, e-beam lithography and focused ion beam lithography.

✓ **General materials characterization:**

The group uses a combination of materials characterization techniques that range from XRD, SEM, HRTEM, Raman, Infrared, UV-Visible spectroscopy, Scanning Probe Microscopy, DTA/TGA, Ellipsometry, DLS and such techniques as are necessary for the problem in hand.

✓ **Experimental Measurements:**

**In the group**

- Electrical Transport and magneto transport measurements down to 2K in 10T field.
- Dielectric measurements upto 10 MHz.
- Magnetic measurements using VSM.
- Optical conductivity measurements.
- Low temperature UHV Scanning Probe Microscopy
- 1/f noise spectroscopy
- Dynamic thermal and mechanical measurements.

**Out side national facilities**

- SQUID magnetometry
- Synchrotron radiation (Photon Factory, ESRF)
- Neutron diffraction (ILL, Druva)
- Measurements below 1K.

