Materials grown in the AKR group

AKR group has extensive activities in the area of materials growth . Almost all the materials used by the group are grown in house using the facilities available in the group. This involve various methods to grow nanowires and nanoparticles as well as growth of epitaxial thin film using pulsed laser deposition and chemically grown nano and microcrystals of organic materials. In this activity the group has strong collaboration with and participation of the group of Dr.Barnali Ghosh (Saha) . The materials grown encompass a large class of materials like metal nanowires, binary and complex oxide films, nanoparticles and nanowires, Charge transfer complex nanowires and microcrystals and elemental semiconductor (Si and Ge) nanowires. As a special capability of the group the nano wires grown are integrated with nanolithgography for making measurements at the level of single nanowire.

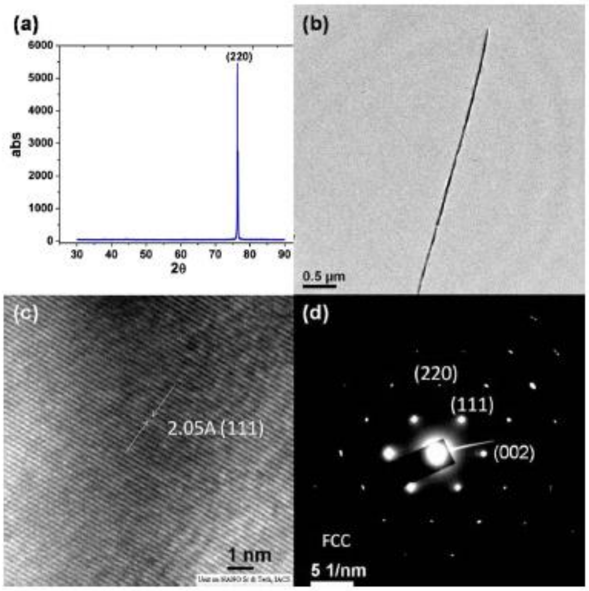
The nanoparticles are mostly grown by sol-gel or chemical solution deposition techniques or by a Laser ablation method.. The nanowires of metal are grown by electro deposition within an anodized alumina(AAO) nanoporous templates down to a diameter of 15nm. The oxide nanowires are grown by chemical methods within pores of the AAO template or by Hydrothermal method in an Autoclave. Some of the oxide nanowires are also grown by PLD. Elemental nanowires are grown by Vapour phase method in a multizone furnace on to a cold substrate with a suitable carrier gas. Charge Transfer Complex nanowires are grown by vapour phase as well as by solution method.

Pulsed Laser Deposition (PLD) using an excimer laser (KrF) is used to grow epitaxial films and multilyares on single crystalline substrates like Sapphire (Al_2O_3), TiO_2, NGO, LAO and STO. Often a RHHED gun equipped chamber is used to grow films on a terraced substrate.

Materials grown by AKR group (along with BG group)

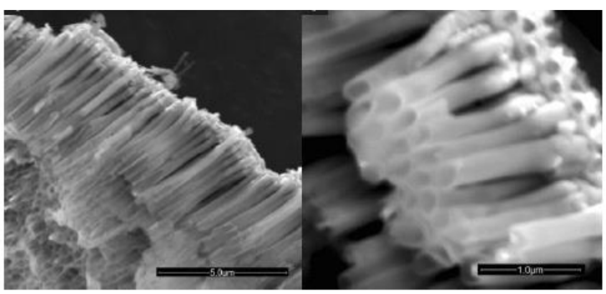
1. *Nanoparticles of ZnO, Manganites, Titanates , Nickelates, Cobaltates, Gold and Silver.*
2. *Nanowires of FCC metals, Zn, ZnO,WO_3, Manganites and Nickelates and TiO_2.*
3. *Nanowires of Si and Ge*
4. *Nanowires of TTF-TCNQ and Cu-TCNQ*
5. *Epitaxial films and multilayers of Oxides like ZnO, Manganites, Titanates and Nickelates on single crystalline substrates.*
6. *Nanostructured films of different materials.*

<u>Library of images of the materials grown in the group</u>



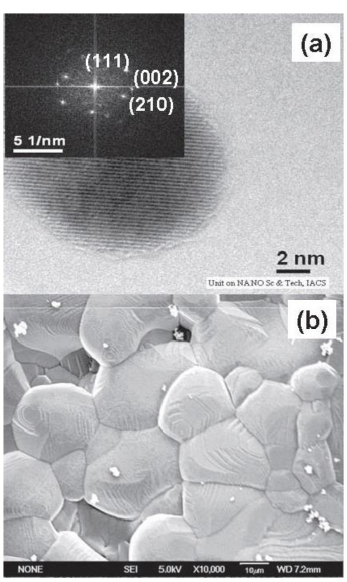
FCC metal nanowires grown by electrode position in AAO templates. _ _(a) XRD pattern of 55 nm diameter nanowire arrays, (b) TEM image of a 55 nm diameter nanowire, (c) HRTEM image of the lattice planes in a 55 nm diameter nanowire, and (d) the electron diffraction pattern of a 55 nm diameter nanowire.

Ref. **(2009) "Low temperature electrical Transport in ferromagnetic Ni Nanowires". .**PHYSICAL REVIEW B **79**, 205417



Cu nanotube grown by electro-deposition in rotating electric field. .

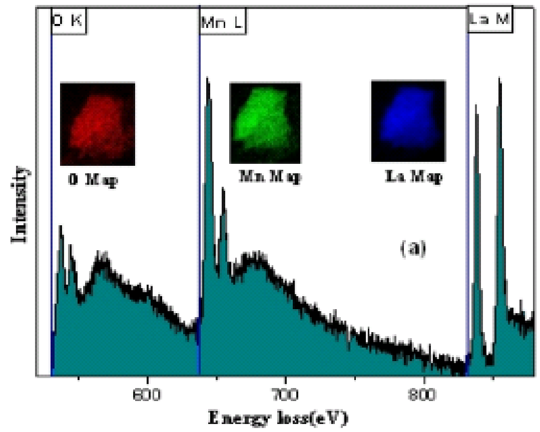
Ref. **(2008)** "**A novel method of synthesis of dense arrays of aligned single crystalline copper nanotubes using electrodeposition in presence of a rotating electric field"** Advanced . Mater. **20,** 149



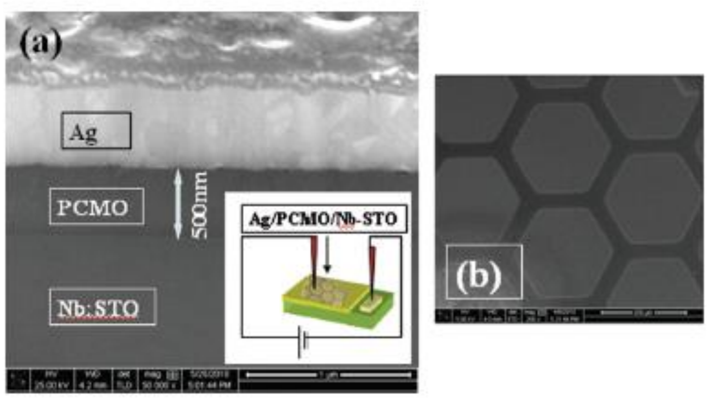
Solution grown complex oxides nanocrystals

(a) TEM image of LCMO ($La_{0.67}Mn_{0.33}O_3$) single nanoparticles size 15nm with the inset showing the selective area electron diffraction. (b) SEM image of LCMO microcrystals with average grain size exceeding 15µm. .

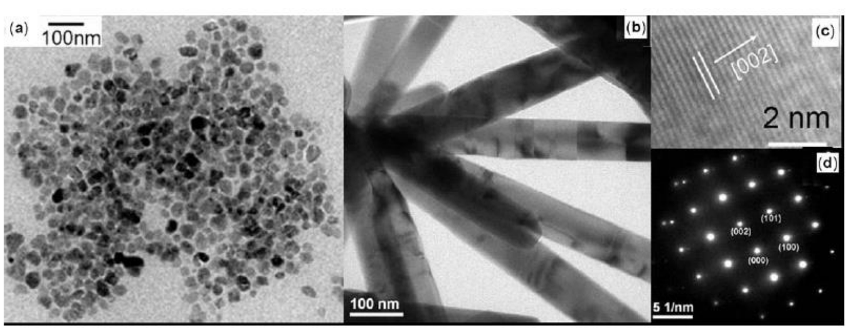
Ref: **(2010) "Effect of size reduction on the ferromagnetism of the manganite $La_{1-x}Ca_xMnO_3$ (x=0.33)".** New Journal of Physics **12** 123026



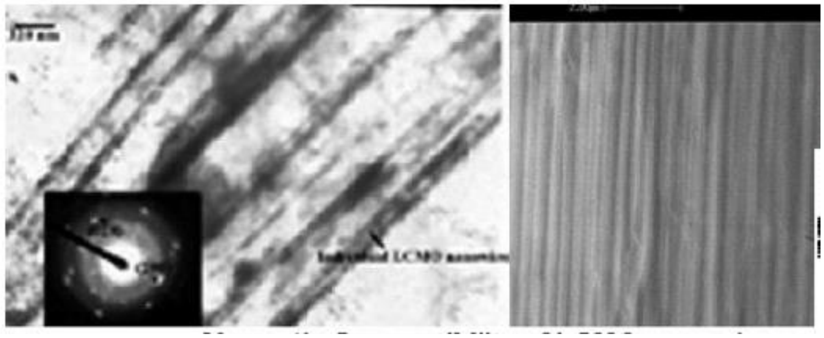
Solution grown complex oxides nanocrystals-elemental anaysis
(a) The EELS spectra of nanocrystals (size ~40nm) of LaMnO3+δ in the energy range 500–1000 eV showing the K lines of O, the L lines of Mn and the M lines of La. The insets show the energy filtered transmission electron microscope (EFTEM) elemental maps. The red, green and blue colors represent the distribution of elements O, Mn and La, respectively within the nanocrystal.
Ref: **(2014) "Effect of size reduction on the structural and magnetic order in $LaMnO_{3+\delta}$ ($\delta \approx 0.03$) nanocrystals: a neutron diffraction study"** J. Phys.: Condens. Matter **26,** 025603



PLD grown multilayers of manganites (PCMO) on Nb:STO single crystalline substrate.
(a) Cross-sectional SEM image of the PCMO/Nb:STO multilayer with Ag top electrode. The inset shows the schematic of the structure and probe placement during measurements Arrow indicates the current direction. (b) Ag top electrode of lateral dimension 200 μm deposited on PCMO/Nb:STO film by evaporation through metal musk.
(2011) " Voltage bias induced modification of all oxide $Pr_{0.5}Ca_{0.5}MnO_3$ /$SrTi_{0.95}$ Nb $_{05}O_3$ junctions" J. Appl. Phys. **109**, 083934

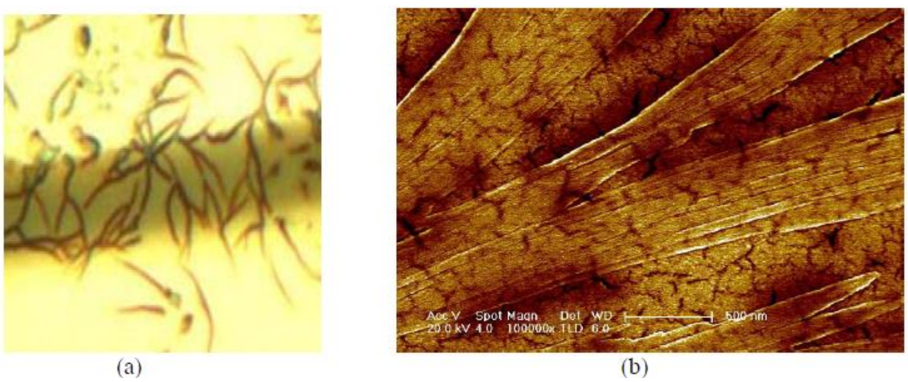


Growth of ZnO nanorods from solution using low temperature route (~80C) on nanoparticle seeded substrates. (a) TEM image of the seed nanoparticles taken on a grid from a suspension in ethanol, (b) TEM image of ZnO nanorods grown for 5 h, (c) lattice image of the nanorods. along [002] direction and (d) the indexed SAED pattern of the nanorods confirms the hexagonal symmetry of the single crystalline ZnO nanorods.
(2008) "Growth of compact arrays of optical quality single crystalline ZnO nanorods by low temperature method" Bulletin of Materials Science **31**, 283.



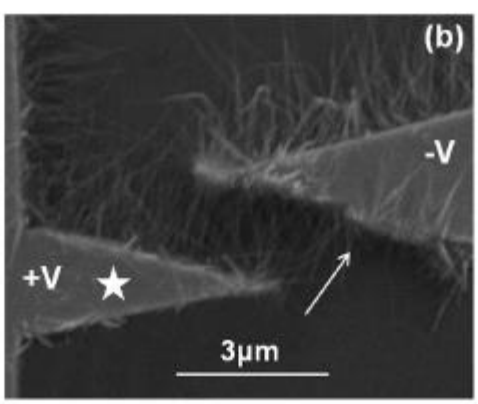
Growth of complex oxide nanowires in AAO templates. (a)Transmission electron micrograph of LCMO nanowires along with the selected area electron diffraction, (b) Scanning electron micrograph of LCMO nanowire array within AAO template.

Ref: : **(2005) "Fabrication of Nanowires of multicomponent oxides: Review of recent advances"** materials Science and Engineering **C 25,** 738-751



Vapour grown TTF:TCNQ nanowires.(a) Optical microscope image taken after co-evaporation of TTF and TCNQ on shadow masked SiO2 substrate. (b) SEM image of the same sample where bundles of parallel TTF TCNQ wires could be seen.

(2008) "Electric Field Directed Growth of Molecular Wires of Charge Transfer Molecules on Prefabricated Metal Electrodes",Mater. Res. Soc. Proc. **1058** , JJ0503



Vapour phase growth of charge transfer complex nanowire on to prefabricated electrodes.
SEM image of a Cu:TCNQ nanobridge array. The arrow indicates the direction of growth. The electrode from which growth starts is marked by star.

(2013) "**Large photoresponse of Cu:TCNQ nanowire arrays formed as aligned nanobridges".**
Appl. Phys. Lett. **102**, 061111