ABSTRACT

Index No. : 37/16/Phys/24

Title of the Thesis: ***Experimental Investigation of Magnetic and Dielectric Properties of Metal Oxides.***

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Metal-oxides are drawing considerable attention of researcher and have been applied in diverse fields of applications because of their various properties, such as dielectrics, magnetism, superconductivity, etc. By suitable doping, their electronic and magnetic properties can be tailored and made them suitable for required applications such as smart sensor, energy and data storage, etc. Furthermore, nanostructured metal oxides such as nanoparticles and thin films are known to exhibit exotic properties compared to the bulk materials, which make them indispensable tools in modern nanotechnology. The key to its applications demands the fundamental understanding of structural, electronic, dielectric, and magnetic properties.

The exchange bias (EB) phenomenon has generated a growing interest in the scientific community due to its potential technological value. Several investigations on this phenomenon have been performed in different systems such as ferromagnetic (FM) films on antiferromagnetic (AFM) single crystals and thin films, thin AFM-FM bilayer, multi-layered, core-shell structure of AFM oxide nanoparticles, mixed-valent perovskites, etc. A large number of applications of such materials in advanced magneto-electronic devices like hard disk drive, magnetic sensors, magneto resistive RAM have gained much attention of researchers in recent days. In addition, there is the growing need of increasing the storage capacity of the magnetic material within a small volume as well as cost-effectiveness. In this thesis work, therefore, we have concentrated on materials like nickel oxide (NiO) granular film, Zn doped NiO ($Ni_{1-x}Zn_xO$) ($0 \leq x \leq 0.05$) film and Sr doped $NdCoO_3$ polycrystalline nanoparticles to investigate the EB phenomena. Structural and morphological characterization of the above samples are performed by using XRD, FESEM, AFM, etc

Significant exchange bias effect has been identified in the granular nickel oxide (NiO) and granular Zn doped nickel oxide ($Ni_{1-x}Zn_xO$) films. For NiO film, thermal variation of zero field cooled magnetization (ZFC) measured in 500 Oe shows a broad peak around 156 K. Below 25 K, both the field cooled (FC) and ZFC magnetization display a significant rise indicating the existence of a ferromagnetic (FM) component, which is suggested due to the uncompensated (UC) spins residing at the grain boundaries. The systematic shift in the magnetic hysteresis loops is observed when the sample is field cooled. This shift is the manifestation of exchange bias effect. Training effect is also observed at 6 K which could be analysed by a recursive formula in the framework of spin configurationally relaxation model.

For Zn doped nickel oxide ($Ni_{1-x}Zn_xO$) film, magnetization measurement reveals the blocked state of $Ni_{0.95}Zn_{0.05}O$ below 155 K. On the other hand, the uncompensated spin is inferred for $Ni_{0.97}Zn_{0.03}O$ from the low temperature up turn of the magnetization. The systematic shift of the magnetic hysteresis loop of $Ni_{1-x}Zn_xO$ film is measured in field cooled mode. This is the fingerprint of exchange bias effect which is found to depend strongly on x. It should be mentioned that the pinning mechanism at the interface between antiferromagnetic core and shell consisting of uncompensated spins leads to the EB effect in both the granular NiO and $Ni_{1-x}Zn_xO$ film.

In case of $Nd_{0.78}Sr_{0.22}CoO_3$ nanoparticles, the measurement of DC magnetization in the range 1.6 K to 300 K reveals the disordered magnetic phase (below 36 K), which is substantiated by the magnetic memory effect. A significant upturn in the ZFC magnetization below 4.5 K, signature of a dominant ferromagnetic (FM) component, is observed here. This FM component may be attributed to the uncompensated (UC) spins at the surface of $Nd_{0.78}Sr_{0.22}CoO_3$ nanoparticles. The presence of the interface of these two magnetic components with significantly different anisotropy results the exchange bias effect.

In addition, Aluminium doped ZnO (AZO) and $Ni_{1-x}Zn_xO$ (with $0 \leq x \leq 0.05$) nanoparticles are synthesized by chemical precipitation method in order to investigate the effect of doping on the dielectric and transport properties of metal oxides. Prepared samples are characterized by XRD, SEM and TEM. Ac conductivity, dielectric constant and dielectric loss of $Zn_{1-x}Al_xO$ ($0 \leq x \leq 0.1$) are investigated as a function of frequency (ω) and doping concentration (x) at room temperature. In case of $Ni_{1-x}Zn_xO$, regular increase of the optical band gap with increase in doping concentration (x) is observed which is consistent with the variation of particle size. It is observed that the dielectric constant (ε_r) increases gradually with x at high frequency (2 MHz). The dc conductivity (σ_{dc}) is found to decrease with Zn doping at room temperature which may be attributed to the reduction of oxygen vacancy. The temperature dependence of dielectric properties for x= 0.00, 0.05 are also investigated as a function of frequency. Cross over of dc conductivity of $Ni_{0.95}Zn_{0.05}O$ to that of NiO observed around ~ 365 K indicates the lowering of activation energy of conductivity for x = 0.05 with increase in temperature. Enhancement of dielectric constant accompanied with lowering dielectric loss due to Zn doping makes $Ni_{0.95}Zn_{0.05}O$ a potential candidate for high frequency device as well as for the further miniaturization of microelectronics components in near future.

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