

LIST OF FIGURES

- Figure 1.1** Schematic illustrations of geometrical spin frustrated system; (a) Square lattice unfrustrated (b) Triangular lattice frustrated system (c) Tetrahedron lattice frustrated structure.
- Figure 1.2** Delafossite crystal structure: (a) Hexagonal structure and (b) Rhombohedral Structure
- Figure 1.3** Crystal structure of Delafossite CuCrO_2
- Figure 1.4** Crystal structure of crednerite CuMnO_2 with the monoclinic unit cell.
- Figure 1.5** Schematic diagram of isosceles triangular lattice layer with the nearest-neighbor and the next-nearestneighbor exchange interactions, J_1 and J_2 .
- Figure 1.6** Different processes for the exchange coupling of the neighboring Mn^{3+} ions in the MnO_6 octahedra (a) Direct overlap of the t_{2g} orbitals (b) antiferromagnetic t_{2g} - t_{2g} superexchange via oxygen (c) antiferromagnetic t_{2g} - e_g superexchange via oxygen the Jahn-Teller distortion makes the distance between these two Mn ions long.
- Figure 1.7** Schematic diagram of multiferroic materials which combine the properties of ferroelectrics and magnets.
- Figure 1.8** Time-reversal and spatial-inversion symmetry in ferroics.
- Figure 1.9** Depending upon the mechanism of origin of the ferroelectricity, type-I multiferroics have been divided in (a) Multiferroic perovskites (b) Ferroelectricity due to lone pairs (c) Ferroelectricity due to charge ordering and (d) Geometrically frustrated Ferroelectricity.
- Figure 1.10** Different types of spin structures relevant for type-II multiferroics. (a) Sinusoidal spin wave, in which spins point along one direction but vary in magnitude. This structure is centrosymmetric and consequently not ferroelectric. (b) The cycloidal spiral with the wave vector $Q = Q_x$ and spins rotating in the (x,z)-plane. It is in this case where one finds nonzero polarization, $P_z \neq 0$. (c) In a so-called “proper screw” the spins rotate in a plane perpendicular to Q . Here the inversion symmetry is broken, but most often it does not produce polarization, although in certain cases it might.
- Figure 1.11** Geometric configurations of (a) Cycloidal (b) Sinusoidal (c) Screw type of magnetic structure.
- Figure 1.12** Schematic illustrations of types of spiral magnetic structures on a 1D array of magnetic moments $S(r)$. Inversion symmetry breaking by (a)

collinear (b) noncollinear magnetic order and possible polarization direction. (d) proper-screw, (e) cycloidal, (f) longitudinal-conical, and (g) transverse-conical magnetic structure. The magnitudes of macroscopic polarization obtained from the spincurrent model or inverse DM model.

Figure 1.13 (a) Ising spin chain chain with nearest-neighbour ferromagnetic and next-nearest neighbour antiferromagnetic coupling has the up-up-down-down ($\uparrow\uparrow\downarrow\downarrow$) ground state (b) Ferroelectricity in charge ordered systems (c) Polarization induced by charge ordering and the ($\uparrow\uparrow\downarrow\downarrow$) type spin ordering in perovskite YniO_3 .

Figure 1.14 Effects of the antisymmetric Dzyaloshinskii–Moriya interaction.

Figure 1.15 The cluster model with two transition metal ions M1 and M2 with oxygen atom between them. Electric dipole induction through hybridization of p-d orbital

Figure 1.16 Schematic diagram of various spin configuration (a) Paramagnetic (b) Ferromagnetic (c) Antiferromagnetic (d) Ferrimagnetic (e) Spin Glass and (f) Griffith phase.

Figure 1.17 (a) Free energy $F(M)$ of a ferromagnet (b) Magnetization as a function of Temperature.

Figure 1.18 Schematic diagram of the spin configuration of an FM-AFM bilayer (a) at different stages (i)-(v) of an exchange biased hysteresis loop (b).

Figure 1.19 Schematic view of the angles and vectors used in the Meiklejohn and Bean model.

Figure 1.20 Schematic diagram of angles involved in an exchange bias system. AFM and FM anisotropy axes are assumed collinear and that the AFM sublattice magnetization M_{AFM} has two opposite directions.

Figure 1.21 Schematic illustration of a diluted ferromagnet in which magnetic ions are missing at some lattice sites. A region in which all the magnetic ion sites are occupied is outlined.

Figure 1.22 ESR spectra for $x = 0.125$ for $205 \ll T \ll 253$ with the magnetic field applied within the easy ac plane. Upper inset: Evolution of the spectra towards T_C . Lower inset: T dependence of the FMR intensity.

Figure 1.23 . (a) $\ln \rho$ versus $(1/T)^{0.25}$ from VRH model, the barrier energy parameter T_0 is calculated from the slope of the curve. (b) The localization length in the localized wave function

- Figure 1.24** (a) $\ln \rho$ versus $(1/T)$ from Arrhenius model. (b) The activation energy and the band gap between valence and conduction bands.
- Figure 2.1** Schematic diagram of X-ray diffraction
- Figure 2.2** SQUID detection schematic.
- Figure 2.3** 2ω detection principle
- Figure 2.4** Block diagram showing the principle of UV-VIS spectrometer.
- Figure 2.5** Schematic diagram of X-ray photoemission spectroscopy.
- Figure 2.6** Schematic diagram of test circuit for measuring resistivity with the four-point probe method.
- Figure 3.1** Block diagram of solid state reaction technique to synthesize Fe doped CuMnO_2 .
- Figure 3.2** Rietveld refinement of synchrotron X-ray powder diffraction data of CuMnO_2 at room temperature.
- Figure 3.3** Rietveld refinement of synchrotron X-ray powder diffraction data of $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$ at room temperature.
- Figure 3.4** Rietveld refinement of neutron powder diffraction data of $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$ at room temperature.
- Figure 3.5** Rietveld refinement of neutron powder diffraction data of $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$ at 6K.
- Figure 3.6** XPS core level spectra of Cu_{2p} , blue dots for CuMnO_2 and red dots for $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$.
- Figure 3.7** XPS core level spectra of Mn_{2p} , blue dots for CuMnO_2 and red dots for $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$.
- Figure 3.8** XPS core level spectra of Fe_{2p} for $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$.
- Figure 3.9** XPS core level spectra of O_{1s} , blue dots for CuMnO_2 and red dots for $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$.
- Figure 3.10** Valance-band XPS spectra of CuMnO_2 and $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$.
- Figure 3.11** Variation of resistivity versus temperature for $\text{CuMn}_{1-x}\text{Fe}_x\text{O}_2$ (where $x = 0, 0.05$). Inset variation of $\ln \rho$ vs. $1000/T$ for ($x = 0$ and 0.05) samples.

- Figure 3.12** Absorption spectra of CuMnO_2 and $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$. Inset: optical and gap from UV-Visible spectroscopic measurement of CuMnO_2 and $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$.
- Figure 3.13** Magnetization curve $M(H)$ of CuMnO_2 at 5 K.
- Figure 3.14** Magnetization curve $M(H)$ of $\text{CuMn}_{0.95}\text{Fe}_{0.05}\text{O}_2$ at 5 K.
- Figure 4.1** Rietveld refinement of the X-ray diffraction pattern of CuMnO_2 . Refinement has been made with the $C2/m$ space group.
- Figure 4.2** Magnetization of CuMnO_2 as a function of temperature at different field.
- Figure 4.3** Inverse susceptibility of CuMnO_2 as a function of temperature at different field. The solid line shows the Curie-Weiss fitting. Shaded region represents the Griffith Phase region.
- Figure 4.4** Plot of χ_{dc}^{-1} as a function of $(T/T_N-1)(1-\lambda)$ to estimate the value of λ . Inset: χ'^{-1} as a function of $(T/T_N-1)(1-\lambda)$
- Figure 4.5** Variation of χ' as a function of temperature. Upper Panel: Plotted at different magnetic field. Lower Panel: Plotted at different frequencies. Inset Upper panel: χ'^{-1} as a function of temperature and linear region of χ'^{-1} as a function of frequency at different temperature. TG indicates the onset of the Griffith like phase.
- Figure 4.6** Variation of χ'' as a function of temperature. Upper Panel: Plotted at different magnetic field. Lower Panel: Plotted at different frequencies. Inset Lower panel: χ'' as a function of temperature at different frequencies. TG indicates the onset of the Griffith like phase.
- Figure 5.1** Rietveld refinement profiles of Synchrotron X-ray diffraction data of the CuCrO_2 sample. The red circles represent the observed data while solid line through circles is the calculated profile, vertical ticks below curves represent allowed Bragg-reflections for the wurtzite phase. The difference pattern is given below the vertical ticks.
- Figure 5.2** Rietveld refinement profiles of Synchrotron X-ray diffraction data of the $\text{CuCr}_{0.95}\text{Mn}_{0.05}\text{O}_2$ sample
- Figure 5.3** Figure 2: The pyroelectric current with temperature, in presence of poling electric field 400 kV/m, magnetic fields 3T and 5T respectively for CuCrO_2 and $\text{CuCr}_{0.95}\text{Mn}_{0.05}\text{O}_2$ (a and c) respectively. Electric in presence of poling electric field 400 kV/m, magnetic fields 3T and 5T respectively for CuCrO_2 and $\text{CuCr}_{0.95}\text{Mn}_{0.05}\text{O}_2$ (b and d).

- Figure 5.4** Temperature dependence of ZFC and FC magnetization $M(T)$ for CuCrO_2 and $\text{CuCr}_{0.95}\text{Mn}_{0.05}\text{O}_2$ at different magnetic fields.
- Figure 5.5** Isothermal $M(H)$ curves for CuCrO_2 and $\text{CuCr}_{0.95}\text{Mn}_{0.05}\text{O}_2$ at 5K.
- Figure 5.6** Real and imaginary part of AC susceptibility for CuCrO_2 as a function of temperature.
- Figure 5.7** Real part of ac susceptibility with temperature for CuCrO_2 at different dc magnetic field.
- Figure 5.8** Variation of imaginary part of ac susceptibility with frequency at different temperatures. Inset (a) The imaginary part of the magnetic susceptibility scaled to peak amplitude and frequency for CuCrO_2 at 32K and 34K. (b) Cole-Cole plot of the susceptibility data at different frequencies for $T = 32$ K.
- Figure 5.9** Real and imaginary part of AC susceptibility for $\text{CuCr}_{0.95}\text{Mn}_{0.05}\text{O}_2$ as a function of temperature with different frequency.