LIST OF FIGURES

Fig. 1.1: (a) Schematic of a Cooper pair, (b) Schematic of cooper pair at Fermi surface.

Fig. 1.2: Schematic showing the crystal structure of YBa$_2$Cu$_3$O$_6$ and YBa$_2$Cu$_3$O$_7$.

Fig. 1.3: (a) Ideal perovskite unit cell showing the oxygen octahedron, (b) Undistorted oxygen octahedron around Mn$^{4+}$ ion and distorted Octahedron around a Mn$^{3+}$ ion. The distortion causes $ab$-plane contraction (shown by inward arrows) of the Mn-O bond length and along $c$-axis elongation of Mn-O bond length (shown by outward arrows) (c) The distortion yielding long and short Mn-O bonds in ac-plane.

Fig. 1.4: A schematic diagram of paramagnetic effect of Cooper pair in the presence of exchange field.

Fig. 1.5: Schematic diagram of basic principle of molecular beam epitaxy

Fig. 1.6: Schematic behavior of the superconducting order parameter near the superconductor-normal metal interface. Superconducting order parameter and coherence length in normal are $\psi_N \sim \exp\left(-x/\xi_N\right)$ and coherence length is $\xi_N = \sqrt{\frac{\hbar D}{kT}}$. Here $D$ is the diffusion coefficient of charge carriers and $T$ is temperature.

Fig. 1.7: Schematic behavior of the superconducting order parameter near the superconductor-ferromagnetic metal interface.

Fig. 1.8: Schematic behavior of the superconducting order parameter in SC/FM/SC trilayers in 0 phase and $\pi$- phase.

Fig. 1.9: Schematic diagram of FM and AFM coupling in FM/SC/FM trilayers.

Fig. 2.1 Schematic diagram of DC magnetron sputtering system

Fig. 2.2: Photograph of DC sputtering system.
Fig. 2.3: Photograph of the PLD system.

Fig. 2.4: Schematic diagram of the PLD system.

Fig. 2.5: Schematic diagram showing how strain affects XRD peaks. (a) Shows relaxed film, (b) Film with uniform strain and (c) Film with non uniform strain.

Fig. 2.6: Geometry for specular reflectivity.

Fig. 2.7: Schematics of the polarized neutron reflectometer.

Fig. 2.8: Block diagram of a typical SEM setup.

Fig. 2.9: Interaction of incident electron beam with sample surface.

Fig. 2.10: Photograph of SEM (model: Tescan VEGA MV2300T/40).

Fig. 2.11: Schematic diagram of linear two probe and four probe measurements.

Fig. 2.12: Schematic diagram of temperature control system in MPMS5.

Fig. 2.13: Schematic diagram of measurement unit in MPMS5.

Fig. 3.1: XRR measurements on Co film, open circles and solid line are measured and fitted data, respectively. Inset shows two layer model used for the fitting.

Fig. 3.2: SEM images of the sputter deposited Co films annealed at different temperatures (under a vacuum of $5 \times 10^{-6}$ mbar for 1 h).

Fig. 3.3 The normalized magnetic moment ($m/m_{2kOe}$) versus applied field ($H$) hysteresis loop recorded at 300 K for Co-films annealed at different temperatures $T_{an}$.

Fig. 3.4: Variation in $H_C$ (10 K and 300 K) for Co-films annealed at different temperatures $T_{an}$.

Fig. 3.5: $H_C$ variation with temperature for Co films as deposited (open circles) and Annealed at 700 °C (closed circles).

Fig. 3.6: SEM images of Ni films of different thicknesses deposited by sputtering.
Fig. 3.7: The normalized magnetic moment (m/m₀) versus applied field (H) hysteresis loop recorded at 300 K for Ni-films of different thickness. The full hysteresis loop for 20000 Å Ni films is shown in inset.

Fig. 3.8: \( H_C \) and \( S \) plotted with different thickness of sputtered deposited Ni.

Fig. 3.9: Magnetic moment (m) with temperature (T) is measured in ZFC and FC mode at 100 Oe and 1000 Oe for 300 Å Gd film.

Fig. 3.10: Magnetic moment (m) with applied magnetic field (H) at different temperature for Gd film (300 Å) deposited by sputtering.

Fig. 3.11: Variation in \( H_C \) with temperature for Gd film (300 Å) deposited by sputtering.

Fig. 3.12: Superconducting transition transport electrical resistance with temperature in Nb film.

Fig. 3.13: Superconducting transition magnetic moment with temperature in Nb film.

Fig. 3.14: XRD patterns are recorded for all films of NbN (50nm) deposited at different sputtering power from 54 W to 135W.

Fig. 3.15: A temperature dependent resistance is measurement from 4.2 K to 300 K. Inset the superconducting transition.

Fig. 3.16: XRD patterns are recorded for all films of NbN (500 Å) deposited at different substrate temperature \( T_{\text{Sub.}} \) from room temperature to 800 °C.

Fig. 3.17: Superconducting transition in films of NbN (500 Å) deposited at different substrate temperature \( T_{\text{Sub.}} \) from room temperature to 800 °C.

Fig. 3.18: (a): Specular X-ray reflectivity measurements from as-deposited multilayer (open circles) and sample annealed at 100°C (open squares) and 150°C (open triangles). (b) shows the normalized SLD profiles at interfaces extracted from fit to XRR data.
Fig 3.19: (a): M(H) hysteresis curves (open circles) and magnetoresistance (open triangles) as function of applied magnetic field for [Fe(50 Å)/Au(100 Å)]\textsubscript{10} multilayer after annealing at 100 °C for one hours. (b): MR vs H for as-deposited (b) and sample annealed at 100 °C (c) and 150 °C (d).

Fig.3.20: \( M(H) \) hysteresis curves for [Fe(50 Å)/Au(50 Å)]\textsubscript{10} multilayer sample at 5 K (open triangles) and 300 K (open circles). (b): variation of \( M_r/M_s \) ratio with thickness of Fe (closed circles) and Au (closed triangles) layers. (c): MR vs \( H \) plot for [Fe(50 Å)/Au(50 Å)]\textsubscript{10}. (d): variation of MR with thickness of Fe (closed circles) and Au (closed triangles) layer.

Fig. 3.21: XRR measurement on Nb/Ni bilayers

Fig. 3.22: magnetic moment measured with temperature in ZFC mode at 50 Oe for Nb/Ni bilayers. Inset show the superconducting transition in transport measurements.

Fig. 3.23: The m-H hysteresis loops for the Nb/Ni bilayers were recorded at 10 K (> \( T_{SC} \)) and at 5.5 K (< \( T_{SC} \)).

Fig. 3.24: Two step V-I curves of Nb/Ni bilayer at different temperatures.

Fig. 3.25: Magnetic moment (m) with temperature (T) is measured in ZFC and FC mode at 100 Oe for bilayers of Nb/Gd.

Fig. 3.26: Magnetic moment (m) with applied field measured at 10 K for bilayers of Nb/Gd.

Fig. 3.27: Superconducting transition in transport electrical resistance measured with increasing temperature from 4.5 K to 10 K for Nb Film and bilayer of Nb/Gd.
**Fig. 3.28:** Schematic diagram of nucleation of domain wall superconductivity in the Nb layer of Nb/Gd bilayer where ferromagnetic Gd layer have magnetic domains with domain walls.

**Fig. 3.29:** Field dependent superconducting transition in bilayer of Nb/Gd.

**Fig. 3.30:** History dependent resistances versus temperature (R-T) curves are recorded with same field (400 Oe) in two different magnetic domains structures.

**Fig. 3.31:** History dependent Voltage -current (V-I) curves are recorded with same field (400 Oe) in two different magnetic domains structures.

**Fig. 3.32:** Resistance versus temperature plot of a NbN/NbO/Co trilayer and NbN film measured at applied current of 200 μA. Inset shows magnetization hysteresis curve measured at 10 K showing ferromagnetic nature of the film.

**Fig. 3.33:** Temperature dependence of resistance of NbN/NbO/Co trilayers measured at different probe currents.

**Fig. 3.34:** Schematically diagram of production of vortex and anti vortex in NbN due to stray field of Cobalt layer.

**Fig. 4.1:** XRD pattern on LSMO film deposited at 1.0 mbar oxygen pressure. Inset shows the enlarged view of (111) doublets of STO and LSMO fitted to lines corresponding to the X-ray source used.

**Fig 4.2:** (111) peaks of STO/LSMO samples deposited under different P_{O2}. Arrow shows the peak position.

**Fig. 4.3:** FC and ZFC $m$ (normalized by $m(T=5 \text{ K})$) vs $T$ data in 100 Oe field. $T_{FM}$ is marked by an arrow.

**Fig. 4.4:** $m(T)$ normalized by field cooled moment at 5K vs $T / T_{FM}$ for different films.
Fig. 4.5: $m - H$ loops measured at 5K for different values of $P_{O_2}$.

Fig.4.6: XRD pattern of 500Å LSMO thin films on a) STO(100), b) MgO(100) and c) YBCO substrates.

Fig. 4.7: ZFC and FC $m$ vs $T$ in a field of 100 Oe. $T_{FM}$ is marked by arrow.

Fig. 4.8: $m - H$ loops measured at 100 K for different LSMO films on different substrates.

Fig. 4.9: $H_C$ vs $T$ in LSMO films deposited on different substrates.

Fig.4.10: XRR patterns of LSMO films with different thickness on MgO (100) substrates.

Fig.4.11: XRD pattern of LSMO films with different thickness on a) MgO(100) and b) STO(100) substrates.

Fig.4.12: Non uniform strain with LSMO thickness on MgO(100) substrates.

Fig.4.13: $m$ vs $T$ for LSMO film of different thickness on MgO Substrate.

Fig. 4.14: $m - H$ loops measured at 5K for LSMO film with different thicknesses on a) STO(100) and b) MgO(100) substrates.

Fig. 4.15: Variation in $H_C$ with LSMO film thickness deposited on STO(100) and MgO(100) substrates.

Fig. 4.16: XRR pattern of LCMO film with on MgO (100) substrates.

Fig. 4.17: ZFC and FC $m$ vs $T$ of LCMO films on STO (100) and MgO (100) substrates.

Fig. 4.18: XRD pattern of YBCO films on MgO (100) and STO (100) substrates.

Fig. 4.19: XRR pattern of YBCO film with on MgO (100) substrates.

Fig. 4.20: Superconducting transition on YBCO film on STO (100) substrates.

Fig. 4.21: X-ray diffraction data from STO/YBCO bilayer on STO (100) substrate.

Fig. 4.22: X-ray reflectivity (XRR) pattern from STO/YBCO heterostructures. Inset show the corresponding thickness and roughness of each layer which gave best fit to XRR data.
Fig. 4.23: X-ray diffraction data from LCMO/STO/YBCO trilayer on STO (100) substrate.

Fig. 4.24: X-ray reflectivity (XRR) pattern from two heterostructures LCMO (300 Å)/STO (25 Å)/YBCO (300 Å) and LCMO (200 Å)/STO (50 Å)/YBCO (200 Å).

Fig. 4.25: FC Magnetization of LCMO (300 Å)/STO (25 Å)/YBCO (300 Å) trilayer in 300 Oe field showing the FM transition at around 130 K. Inset show ZFC showing $T_{\text{SC}} \sim 60$ K.

Fig. 4.26: (a) Polarized neutron reflectivity (PNR) measurements and their modeling. a, PNR (spin up, $R^+$ and spin down, $R^-$) data from the LCMO (300 Å)/STO (25 Å)/YBCO (300 Å) trilayer at 300 K and 10 K. Reflectivity data at different temperature are shifted by a factor of 20 for the sake of clarity. (b) Spin difference ($R^+ - R^-$) data at 300 K (upper panel) and 10 K (lower panel). (c) Nuclear scattering length density (SLD) depth profile extracted from fitting PNR data at 300 K as shown in a, b. (d) Magnetization ($M$) depth profile corresponding to PNR data shown in (a) and (b). Two magnetization models, with and without magnetic dead (MD) layer at LCMO/STO interface, at 10 K are depicted in d and the corresponding fits to PNR data are shown in b (lower panel).

Fig. 4.27: (a) PNR (spin up, $R^+$ and spin down, $R^-$) data from the LCMO (300 Å)/STO (25 Å)/YBCO (300 Å) sample at 10 K. upper panel show the spin difference ($R^+ - R^-$) data at 10 K. (b) shows the corresponding magnetization depth profiles which fitted PNR data at 10 K.

Fig. 4.28: Polarized neutron reflectivity (PNR) measurements and their modeling across superconducting transition temperature. (a) Spin difference ($R^+ - R^-$) data the LCMO (300 Å)/STO (25 Å)/YBCO (300 Å) sample at 100 K (upper panel) and 50 K (lower panel). (b) Magnetization ($M$) depth profile at 100 K (upper panel) and 50 K (lower panel)
corresponding to spin difference data shown in a. Two magnetization models at 100 K are depicted in the upper panel of (b) and the corresponding fits to PNR data are shown in upper panel of (a).

**Fig. 4.29:** Polarized neutron reflectivity (PNR) measurements and their modeling from the sample with double thickness of insulator layer. (a) Spin difference data from the LCMO (200 Å)/STO (50 Å)/YBCO (200 Å) trilayer at 300 K (upper panel) and 10 K (lower panel). (b) Nuclear scattering length density (NSLD) depth profile (upper panel) and magnetization depth profile (lower panel) extracted from fitting PNR data at 300 K and 10 K as shown in a. Two magnetization models at 10 K are depicted in the lower panel of (b) and the corresponding fits to PNR data are shown in lower panel of (a).

**Fig. 4.30:** Variation of magnetization (M) as a function of temperature for field cooled condition in a magnetic field of 300 Oe using SQUID (open circle) and PNR (open star) for LCMO (300 Å)/STO (25 Å)/YBCO (300 Å) trilayer.

**Fig. 4.31:** Fitting of magnetization depth profile of YBa$_2$Cu$_3$O$_{7-\delta}$ (300 Å)/SrTiO$_3$ (25 Å)/La$_{2/3}$Ca$_{1/3}$MnO$_3$ (300 Å) sample at 10 K obtained from PNR data using Eq. 4.1.