List of Figures:

1.1 Schematic of different type of interfaces (a) An ideal interface, (b) Interface with mixing of components (upper panel) and roughness (lower panel) and (c) Interface alloy layer of two primary components, A and B in a binary system.

1.2 XRR profile of (a) an infinitely thick Si layer and (b) from Ge layer [Ge Si (substrate) /Ge(200 Å)].

1.3 (a) Un polarized and (b) polarized neutron reflectometry from a Ni-Al multilayer [Si (substrate) /[Al(25Å)/Ni(50Å)]×10].

1.4 Flux across area ‘A’ due to particle flux J(x).

1.5 (a) Reduction in Bragg peak intensity due to diffusion (inset shows interface alloy layer formation due to diffusion) (b) diffusion at atomic level.

2.1 Classification of thin film deposition methods.

2.2 Schematic of Sputtering.

2.3 Schematic showing the magnetic field and target assembly in a RF magnetron sputtering set up.

2.4 Sputter Yield/ Deposition rate as a function of sputter gas pressure (Ar).

2.5 Cross-sectional schematic view of the D.C./RF magnetron sputtering system layout.

2.6 Photograph of the sputtering unit at SSPD, BARC during deposition.

2.7 XRR profile of Ni(380Å)/Si.

2.8 (a) XRR profile (b) XRD profile of the Ni film [Ni(222Å)/Si] deposited on Si substrate.

2.9 XRR of Si/Cu (405Å)/Ti (286Å).

2.10 XRR of Si/[Cu(56Å)/Ti(76Å)]×5.

2.11 XRR profile of Ge films with varying sputter power (a) with 20W (b) with 50W.

2.12 XRR profile of a Ni-Ge bilayer [Si/[Ni(93Å)/Ge(215Å)]].
2.13 PNR profile of a Ni-Ge multilayer \{ Si (substrate) /[Ni_{100Å} / Ge_{200Å}] × 4\}............46

3.1 Geometry of specular and off-specular (diffuse) reflectivity (b) wave function at the interface.................................................................50

3.2 Effect of roughness on specular reflectivity from Si substrate with \( \sigma = 0 \) Å (solid line) and \( \sigma = 10 \) Å (dashed line). Inset (a) shows image of rough interface with Gaussian profile of height. The standard deviation of the Gaussian function describing the roughness represents the root mean square roughness, \( \sigma \).............................54

3.3 Diagram of a multilayer stack containing \( N \) layers, where the refractive index, thickness, propagation angle, and interface roughness parameter of the \( i^{th} \) layer are \( n_i \), \( d_i \), \( \theta_i \) and \( \sigma_i \), respectively.................................................................56

3.4 Schematic, representation of the scattering geometry, for polarized neutron reflectivity measurements, used in the present thesis.................................................................60

3.5 Simulated (a) un-polarized and (b) polarized neutron reflectivity pattern for Ni/Al multilayer........................................................................62

3.6 (a) Schematic of Polarized Neutron Reflectometer at Dhruva reactor...............64
3.6 (b) Photograph of the Polarized Neutron Reflectometer at Dhruva reactor.........65

3.7 Steps involved in working of GA. (I is the number of iteration).........................70

3.8 Schematic of alloy layer formation in a bilayer................................................73

4.1 Polarized Neutron Reflectivities, \( R^+ \) (solid circles) and \( R^- \) (open circles) for as deposited (a) and sample annealed at 160°C for 1hr (b), 4hr (c) and 8hr (d) along with fits (solid lines) to the data .................................................................80
4.2 Nuclear scattering length density (SLD) profiles (a) for as deposited sample and sample annealed at 160°C for (b) 1hr, (c) 4hrs, (d) 8hrs, and (e)-(h) show the corresponding magnetization (M) depth profiles.........................................................81

4.3 Nuclear scattering length density (SLD) depth (a) and magnetization (M) depth (b) profiles across Ni on Al (Ni/Al) and Al on Ni (Al/Ni) interfaces of the Ni-Al bilayer..........................................................82

4.4 (a) X-ray reflectivity (XRR) data from the as-deposited sample and sample annealed at 160°C for 8 hrs. (b) Electron scattering length density (SLD) profile of the sample which gave best fit to XRR data (Fig. (a)). (c) represents the Electron SLD profile across Ni/Al and Al/Ni interfaces of a Ni-Al bilayer..........................................................85

4.5 Variation of magnetization (M) of Ni layer (a) and diffusion length (b) as a function of annealing time. Inset of (b) shows the X-ray reflectivity (XRR) data across first order Bragg peak for as-deposited sample and sample annealed at 160°C for different times..............................................................................................................................................86

4.6 (a) and (b) show x-ray diffraction (XRD) pattern from as-deposited and annealed (at 150°C and 300°C) samples S1 and S2, respectively, (c),(d) shows SIMS profiles for as-deposited samples for S1 and S2 respectively, (e),(f) shows corresponding annealed profiles for SIMS at 300°C.................................................................................................................91

4.7 (a) and (b) show x-ray reflectivity (XRR) profile from as-deposited and annealed (at 150°C and 300°C) samples S1 and S2 respectively, (c) and (d) show corresponding electron scattering length density (ESLD) profiles from fits to the XRR data.................92

4.8 (a) and (b) show polarized neutron reflectivity (PNR) profiles R⁺ (red solid circles) and R⁻ (blue open circles) from as-deposited and annealed (at 150°C and 300°C) samples S1 and S2 respectively, (c) and (d) show corresponding nuclear scattering length density (NSLD) profiles for samples S1 and S2, respectively, (e) and (f) show magnetization depth profiles for samples S1 and S2, respectively..................................................95
4.9 Block diagrams for two bilayers in S1 and S2 for the as-deposited samples and after annealing the same at 300°C. Lengths of the coloured blocks are proportional to the thickness of the corresponding elements and the alloy layers (after annealing). The ‘virtual Kirkendall markers’ allows to compare the position of the interfaces before annealing and the growth of the alloy layers after annealing with the substrate-film interface as a fixed reference line.

4.10 X-ray diffraction (XRD) pattern for as-deposited and annealed (150°C, 200°C, 300°C) states for samples S1(a) and S2(b), respectively. Open triangles, solid triangles and solid squares mark the possible Bragg peaks for alloy phases.

4.11. Variation of alloy peak as a function of annealing temperatures (150°C, 200°C, 300°C) for samples, S1 (left panel) and S2 (right panel) respectively.

4.12. Height-difference correlation function (g(r), open circles) with the fit (solid lines) from samples, S1 and S2 for as deposited and annealed state obtained from AFM. (Inset shows corresponding 3-dimensional AFM images of size (2 μm × 2 μm)).

4.13 Spin ASYM [(R⁺ - R)/ (R⁺ + R)] function (closed circles) with fit (solid lines) at different temperature of annealing for S1 [(a)-(d)] and S2 [(e)-(h)].

4.14 Measured reflectivity profiles for spin up (R⁺) neutrons for as deposited and annealed state at 300°C for samples S1 (a) and S2 (b) respectively. Inset of (a) shows Bragg Peak intensity variation as a function of different annealing temperature for S1.

4.15 Arrhenius plot for growth of alloy phase in sample S1 and S2.

4.16 Variation of (a) crystallite size (b) alloy layer thickness (c) average magnetic moment of Ni atom in individual layers as a function of annealing temperature for S1 and S2. Lines drawn are just a guide to visualization.
5.1 Resistance measurement of the Ni-Ge multilayer at different stages of annealing by Four probe method. All the measurements were carried out on samples of same geometry........................................................................................................117

5.2 X-Ray diffraction of the sample for the (a) as deposit and (b) annealed stage at 250 °C for 4hr, Panel below shows the possible XRD Bragg peaks..............................................................118

5.3 Height-difference correlation function for the as deposited and annealed state at 250°C_4hr (Inset shows respective 3d-AFM image of the film surface (2×2µm²)).................................................................120

5.4 (a) PNR measurements from the as-deposited and annealed samples along with fits (solid lines) (b) Nuclear scattering length density (NSLD) and (c) magnetic scattering length density (MSLD) depth profile of a single Ni-Ge bilayer, that fits the PNR data shown in 2(a). (d) XRR profiles for as-deposited and annealed sample along with fits and (e) corresponding electron scattering length density (ESLD) profile of a single Ni-Ge bilayer........................................................................................................................................121

5.5 SQUID measurement profiles for the as deposited and sample annealed at 250 °C for 4h.............................................................................................................................................123

5.6 Variation in (a) layer thicknesses of Ni, Ge and the alloy layer and (b) resistance of the Ni-Ge multilayer sample at 300 K as a function of annealing time. (c) left panel show the schematic of interface before and after annealing the Ni/Ge multilayer sample. Right panel show the schematic of a parallel combination of resisters with Ni and Ge in alternating positions and considering only the Ni layers as resisters in the as deposited state........................................................................................................................................125

**List of Tables**

2.1 Sputtering parameters of deposited systems.............................................................................39
3.1 Specification of PNR instrument .................................................................................................66
4.1 Physical parameters obtained from XRR and PNR.................................................................84

11