ABSTRACT

The PhD research work presented in this thesis is motivated by remarkable structural and magnetic properties of epitaxial ferromagnetic layer on semiconductor or insulator heterostructures which are important for magneto-electronic device applications. This thesis reports findings of different epitaxial heterostructures, namely Fe/MgO/GaN(0001), $Ni_{20}Fe_{80}$/MgO(111), $Ni_{20}Fe_{80}$/Si(111), and $Ni_{20}Fe_{80}$/Au/Si(111) grown by Molecular Beam Epitaxy (MBE).

First experiment presents structural and magnetic investigation of fully epitaxial Fe/MgO/GaN heterostructure grown by molecular beam epitaxy. *In-situ* reflection high energy electron diffraction (RHEED) and *ex-situ* X-ray diffraction (XRD) measurements indicate epitaxial Fe(110) films on top of an epitaxial 2 nm MgO(111) tunnel barrier on GaN(0001). X-ray reflectivity (XRR) measurements confirm a roughness of approximately 0.3 nm and 0.7 nm for the MgO/GaN and the Fe/MgO interfaces, respectively. Results of *in-situ* magneto-optical Kerr effect (MOKE) measurements indicate that 1 nm thick Fe film shows signs of in-plane ferromagnetism at room temperature. Vibrating sample magnetometer (VSM) measurements determine the saturation magnetisation of the 5 nm thick film to be 1659 ± 100 emu/cm^3 and show that this system has a predominant uniaxial anisotropy contribution despite the presence of cyclic twinned crystals. We estimate the values of effective uniaxial (K_U^{eff}) and cubic (K_1^{eff}) anisotropy constants to be 11700 ± 170 erg cm^{-3} and - 3300 ± 700 erg cm^{-3} by fitting the angular dependence of the magnetising energy.

In the second experiment, first time epitaxial thin films of $Ni_{80}Fe_{20}$ (Permalloy, Py) are prepared using molecular beam epitaxy at room temperature on MgO(111) substrates. X-ray diffraction graphs confirm permalloy films of (111) phase having fcc structure. Phi scans at the Py (200) peak position show that the Py layer grown on MgO substrate is epitaxially oriented. Room temperature vibrating sample magnetometer measurements indicate increase in remanent and saturation magnetisation with the increase in thickness of magnetic layer. Magneto-optical Kerr effect measurements along various azimuthal angles showed dominant uniaxial anisotropy. Superconducting quantum interference device (SQUID) measurement of thinnest permalloy film 0.6 nm shows an out of plane anisotropy.

In the third experiment of this PhD research work, thin films of $Ni_{80}Fe_{20}$ are prepared using molecular beam epitaxy (MBE) at room temperature on HF etched Si(111) substrates with and without Au buffer layer. The x-ray diffraction measurement shows a good structural quality of films with Py(111) fcc phase. X-ray reflectivity measurements confirm relatively smooth interfaces with roughness of approximately 0.9 nm for the permalloy on silicon with Au buffer layer. We show that the soft magnetic properties are enhanced in the film deposited on buffer layer in comparison to the film deposited directly on Si(111). It was found from Vibrating sample magnetometer measurement that coercivity decreases and saturation magnetisation increases for the Py/Au/Si hetrostructure.