The Growth of Thin Films and Study of Magnetotransport Properties of Co_2XSi (X=Fe,Ti) Heusler alloys for Spintronic applications

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Abstract

The potential of electronic circuits for performance increases, further miniaturisation and energy efficiency is becoming increasingly limited, spintronics devices can address these issues and create advanced devices in the future. Heusler alloys are the best material for applications in spintronics due to their versatile properties. The field of spin injection and detection has gained attention over the past few years since the Datta-Das transistor proposal. The control and manipulation of the electron spin in semiconductors is the fundamental part of spintronics. By controlling the orientation and magnitude of magnetic moments inside the semiconductor channel, researchers can manipulate the spin orientation of electrons, enabling functionalities such as spin filtering, spin manipulation, and spin torque generation. Controlling the spin polarization direction or population is crucial to the application of spintronics to realize it as a switching device. Similar to its charge analog, where the amount of charge or width of the channel is controlled by an externally applied field for switching, in spintronics too, a control knob is required for operation and efficient detection of spin in the device.The thesis addresses the growth of Heusler alloy and studies the structural, magnetic, and transport properties with growth temperatures. The creation and manipulation of spin polarization in semiconductors have been studied utilizing Hanle devices.

We have grown thin films of Co_2XSi (X=Ti,Fe) Heusler alloy on silicon substrate at different substrate temperatures (T_s) by electron beam evaporator under a high vacuum. The structural, magnetic, and electric characterizations were carried out and found a strong correlation between the properties and the growth temperatures of the samples. The crystallinity and magnetic moment were both significantly improved with increasing growth temperatures from room temperature (RT) to 400 °C. The temperature-dependent longitudinal resistivity demonstrated different scattering phenomena like weak localization, electron-magnon, electron-electron, and electron-phonon interactions. A decrease in residual resistivity (109 to 49 μΩ-cm) and an increase in residual resistivity ratio (1.2 to 1.39) indicate an enhancement of the crystallinity and structural order of CTS films. Heusler alloys have been considered Weyl semimetals due to the presence of time-reversal symmetry breaking, and one can get the idea of spin polarization of conduction current. We have studied the anomalous Hall effect of the Co_2TiSi Heusler alloy. A dominant role of intrinsic scattering is identified for the anomalous

Hall resistivity. These AHE studies provide a platform for further investigations of exotic properties in Co_2TiSi and other Co2-based Heusler materials. We have studied the spin transport properties (spin injection, spin accumulation, and detection of spin polarisation) of the Co_2XSi/SiO_2/n-Si heterostructure by measuring the Hanle signal. The density of states and band structure have also been calculated to check the half metallicity of CTS and CFS. To measure the spin injection and detection, we fabricated Hanle device where we used post-annealed film and native SiO_2 as a tunnel barrier. A large Hanle signal at room temperature confirmed the injection and accumulation of spin polarized carriers in semiconductor. The measured spin diffusion length and spin life time in these heterostructures are quite impressive at room temperature. So, it is possible to fabricate room temperature spintronic devices using ordered Co_2XSi and n-Si together, making them excellent candidates. The current-voltage electrical transport characteristics of Co_2XSi/SiO_2/n-Si heterostructures have been investigated in the presence of zero and non-zero magnetic fields. The interesting observation is that the heterostructures also behave like spin valves at all temperatures, although this is prominent at low temperatures. The magnetic field dependent junction magnetoresistance (JMR) value is found to be 1085 % and 130 % at 10 K and 300 K. We explained the origin of JMR by spin injection theory and analyzed the effect of growth substrate temperature. The JMR value for our heterostructure saturates at a much lower external magnetic field as compared to reported other heterostructures, thus making it a better choice for a magnetic diode in spintronics.

Keywords: **Spintronics, Heusler alloy, Magnetic diode, Junction Magnetoresistance, Three-terminal Hanle device, Spin injection, Anomalous Hall Effect.**