Annealing induced changes at Co/GaAs (001) interface

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1. Introduction

Among the various types of interfaces ferromagnetic metal/semiconductor interface is of great importance due to its central and critical role in Spintronic devices. Cobalt widely used in Giant magneto resistance based system [1], has a high spin polarization of the carrier at the fermi level and could therefore be a good candidate for spin injection applications. Concerning the Co/GaAs interface, there exist a number of studies in the literature due to various growth morphologies exhibited by this system under different conditions [2-4]. Apart from this, Co/GaAs system also shows some interesting structural properties upon annealing [5-6]. Even though Co/GaAs interfaces have been studies for long time, still there are some issues, which are not fully resolved.

In our earlier published study [7], we have discussed the Structural, magnetic and transport properties of Co/GaAs thin films as a function of annealing temperature. It has been observed by XRD measurements that the interaction of Co with GaAs starts at 100°C with formation of Co_2GaAs phase at the interface. At annealing temperature 400°C and 500°C it has been exhibited that the reaction is complete with formation of Co_2GaAs phase at the interface. Corresponding, magnetization and resistivity measurements show lowering of magnetization and resistivity. In the present attempt we have tried to investigate the electronic properties of Co/GaAs interface using photoemission spectroscopy technique, so the change in magnetic transport and structural properties can be correlate with the same

2. Experimental

The Co (400Å) thin film deposited on clean GaAs (001) substrate by ion beam sputtering technique. After deposition, samples were quickly transferred to the experimental chamber of a PES workstation installed on the toroidal grating monochromator (TGM) beamline on Indus-1 synchrotron radiation source. The details of this beamline are described elsewhere [8]. The experimental station is equipped with an angle-integrated spectrometer having 180º hemispherical electron energy analyzer (Omicron EA 125). All the measurements reported here were carried out at different photon energies (from 50 eV to 160 eV), using 50 eV pass energy giving a constant resolution of ~0.65 eV. Energy calibration of the spectrometer was done using known core levels of standard samples such as Au, Ag and Pt. The sample was properly grounded in order to avoid any charging effect. The depth profiling of the sample was done out using Ar^+ ion gun attached at oblique incidence, with the argon ion energy and ion beam current kept at 1 KeV and 1μA.

Since photon flux at the sample is of the order of 5×10^{10} photons/s/mrad/0.1 bandwidth, measurements can be performed in a short time as compared to a laboratory source. During the time of measurement, we do not observe any appreciable change in beam current, which is of importance in the present analysis, since the intensity of the photoemission peaks is directly proportional to the beam current. The PES measurements were carried out in a pressure better than 5 X 10^{-10} Torr. All the measurements were carried out at room temperature.

3. Results and discussion

Figure 1 shows the Valence Band photoemission spectra of Co/GaAs interface of as deposited as well as 400° C annealed sample. The VB spectra recorded after different successive sputtering interval to reach the interface region. The spectrum recorded at 60 eV photon energy i.e. the required photon energy to excite photoelectron from 3p-4s (M_{III}) core level. The VB spectra of as deposited sample shows well defined Co-3d density of states at 1.17 eV photon energy and satellite peak of Co at 5.8 eV photon energy. The observed results are consistent with previously reported ones [9]. However, a VB spectrum of 400° C annealed samples shows reduction in Co-3d density of states, as well as B.E. shifts towards lower B.E. side by 0.19 eV. In addition, the satellite peak position remains invariant with annealing, and a new shoulder appeared in the spectrum at B.E. position 8.5 eV. The reduction in Co-3d density of states with annealing can be understood in terms of transfer of charge carrier from Co-3d density of states to empty GaAs density of states with formation of Co_2GaAs phase as also revealed by our XRD measurements on this temperature.

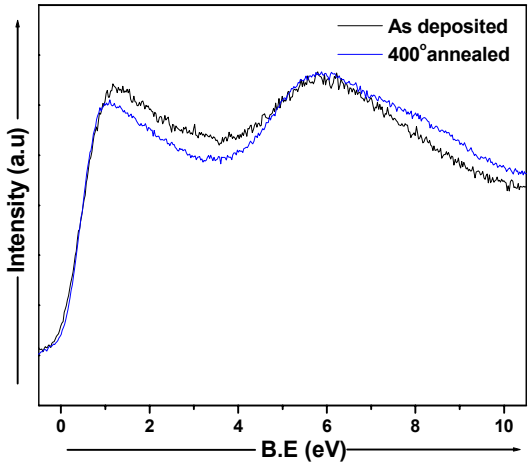

Figure 1 Valence band spectra of as deposited and 400° C annealed Co/GaAs interface recorded at 60 eV photon energy.

4. Conclusions

The PES technique has been employed to investigate the interaction of Co with GaAs substrate at Co/GaAs interface. The VB spectrum shows modifications in Co-3d density of states in 400° C annealed sample as compared to as deposited sample. The satellite peak position remains unchanged with annealing, while a new shoulder appears in the spectrum. The observed results are discussed and interpreted in terms of formation of Co_2GaAs phase at the interface, which modifies the electronic structure of Co/GaAs interface.

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