PD02

A Mössbauer Study of a Ge-Fe Thin Film

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Ge based diluted magnetic semiconductors (DMSs) have received much attention, mainly due to the prediction of a high Curie temperature fromtheory based on the Zener model [1]. A series of recent experiments show some evidence of ferromagnetic ordering at room temperature in well-characterized thin films of amorphous Ge-Cr [2], Ge-Mn [3], and Ge-Fe [4]. This might be due to the incorporation ofa large amount of the transition metals without forming second phases. Potentially, this has significant practical importance in spintronics, although some more work needs to be carried out in the future. In addition to the practical importance of these new materials, interesting magnetic properties were also observed. One example is a $Ge_{48.2}Fe_{51.8}$ (in at.%) thin film prepared by thermal co-evaporation onto oxidized Si substrates held at room temperature, which is the sample of current interest. Magnetic measurements indicate that this thin film shows a superparamagnetic state above 160 K which was predicted from the fitting of a room temperature M-H loop with the Langevin function [5]. Although the prediction appeared confident, the fitting being reasonably good, it would be better to have additional evidence for this behavior. Mössbauer spectroscopy was used in this work in order to further check the superparamagnetic behavior in the $Ge_{48.2}Fe_{51.8}$ thin film and also to obtain other magnetic information. The results for the Mössbauer spectra taken at room temperature confirm the superparamagnetic behavior. The isomer-shift values indicate that the Fe atom in the amorphous phase is in the high-spin Fe^{3+} charge state. Some magnetic parameters estimated from the Mössbauer spectraare summarized in the Table 1 below.

Table 1. *The quadrupole splitting (ΔEQ), isomer shift (δ), and relative absorption area estimated from the Mössbauer spectra which are composed of two sub-spectra A and B.*

Temp. (K)	Sub-spectrum A			Sub-spectrum B		
	ΔE_Q (mm/s)	δ (mm/s)	Area (%)	ΔE_Q (mm/s)	δ (mm/s)	Area (%)
200	0.407	0.319	~75	0.685	0.330	~25
RT	0.494	0.300	~75	0.515	0.155	~25

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PD03

Magnetism in Si1-xMnx Diluted Magnetic Semiconductors

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We investigated the epitaxial growth and magnetic characterization of $Si_{1-x}Mn_x$ ($0 \leq x \leq 0.05$) semiconductors that were grown on Si (100) substrates at 200℃ by using MBE. The substrate was heated to 1100℃ for 30 minutes, and then cooled slowly with the maximum rate is at 1℃ per second to substrate temperature prior to the deposition process in oder to remove native Si oxide. Average growth rate was ~15 Å/ min and final film thickness was around 100 nm. Microstructure of $Si_{1-x}Mn_x$ magnetic semiconductors was examined by observing X-ray diffraction and transmission electron microscope (TEM) show that the thin films were single crystals without and secondary phases. $Si_{1-x}Mn_x$ thin films have p-type major carriers with hole density is 5.1×10^{19} ~ 5.9×10^{20} cm^{-3}. Temperature dependence of electrical resistivity and Hall analysis show that the $Si_{1-x}Mn_x$ thin films have semiconductor characteristics. The magnetization at 300K was 50 emu/cc for Mn 5.0 at% and 33 emu/cc for Mn 3.6 at%, respectively. Hysteresis loops at 300 K for Mn 3.6 at% and 5.0 at% with high magnetization value indicate that the thin films behave similar to ferromagnetic. However, magnetization versus temperature the separation between zero-field cooled (ZFC) and field-cooled (FC) show the nature of super paramagnetsm in $Si_{1-x}Mn_x$ due to the fluctuation of Mn concentration in Si matrix.

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