GW 07

CHARACTERISTICS OF COBALT-DOPED ZINC OXIDE THIN FILMS PREPARED BY PULSED LASER DEPOSITION

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Spintronics is a rapidly expanding research area because of recent developments in the physics of spin-dependent phenomena in spintronic materials and their potentially exciting new applications. Diluted magnetic semiconductors (DMS) has been extensively studied for use as spintronic materials. Recently, from several predictions of the possibility of room temperature ferromagnetism, the transition-metal-doped ZnO has attracted considerable attention [1]. In this paper, several physical properties of Co-doped ZnO films are reported.

$Zn_{1-x}Co_xO$ and $Zn_{0.99-x}Co_xAl_{0.01}O$ thin films were grown on sapphire (0001) using pulsed laser deposition. The solubility limit of Co ions in ZnO films was determined to be ~50 mol%, which is quite higher than the previously observed values [1]. The films has *c*-axis preferred orientation up to $x = 0.4$, whereas the films with $x > 0.4$ exhibit (102) peaks besides (002) basal plane peaks. We found from magnetization measurements that most of the $Zn_{1-x}Co_xO$ and $Zn_{0.99-x}Co_xAl_{0.01}O$ films are paramagnetic. Only some films grown at a high temperature (≥ 700 °C) in a low oxygen ambient pressure ($\leq 10^{-3}$ torr) exhibited ferromagnetism at room temperature, as clearly shown in figure 1. We attributed the ferromagnetism observed in these films to the presence of Co microclusters, which was revealed by high-power x-ray diffraction as shown in figure 2. The formation of the Co microclusters in $Zn_{1-x}Co_xO$ films can be understood from Ellingham phase diagram according to the corresponding growth conditions. As Co content is increased, both the carrier concentration and the electrical conductivity of these films decrease exponentially. Photoluminescence (PL) spectrum for $Zn_{0.98}Co_{0.02}O$ showed two PL bands having peaks at 410 and 540 nm. The PL peak at 540 nm shifts to the lower energy side as Co content is increased.

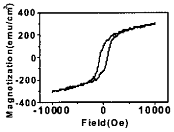

Figure 1 Hysteresis curve at 300 K for $Zn_{0.75}Co_{0.25}O$.

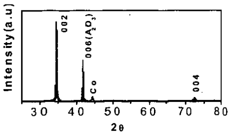

Figure 2 XRD pattern at 300 K for $Zn_{0.75}Co_{0.25}O$.

[1] K. Ueda *et al.*, Appl. Phys. Lett. **79**, 988 (2001); Z. Jin *et al.*, ibid. **78**, 3824 (2001).

GW 08

THREE ROUTES TO INCREASE THE OUTPUT CURRENT OF THE SPIN-VALVE TRANSISTOR

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Introduction

The spin-valve transistor (SVT) is a three terminal device in which hot electrons are emitted over a Schottky barrier, they cross a metallic spin valve and are collected with energy and momentum selection. While SVTs with high relative magnetic response (above 300% at room temperature) have been made, the absolute value of the output (collector) current (I_C) is still low (I_C = 10nA at I_E = 2mA [1]). Although this is sufficient to study spin-dependent hot-electron transport across magnetic layers, it is certainly a disadvantage for practical applications. We will present three routes to increase the collector current by enhancing the transfer ratio ($\alpha = I_C/I_E$).

Results

Supported by TEM studies it is shown that the quality of the buffer layer and the subsequent growth of the spin valve can be used to enhance α.

The spin dependent behavior of the SVT is mainly caused by the bulk properties of the magnetic layers in the base. The transfer ratio decays exponentially with base layer thickness, whereas the relative collector current change (MC) increases with magnetic layer thickness. An optimum base layer thickness can thus be found for maximum change in collector current.

Table 1 shows five types of SVTs that only differ in the choice of emitter and collector Schottky barrier material. An enhancement in α is found when the Schottky barrier height difference ($\Delta\phi_B$) between the emitter and collector is enlarged. A smaller $\Delta\phi_B$ results in the same α when a Si/Au emitter replaces the Si/Pt emitter. The largest α is found for a Si/Au/NiFe/Au/Co/Cu/Si SVT and its magnetic response is shown in figure 1.

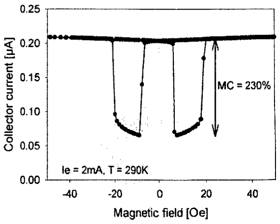

Figure 1. Magnetic response of a Si/Au/NiFe/Au/Co/Cu/Si spin-valve transistor.

	Pt/S.V./Pt	Pt/S.V./Au	Pt/S.V./Cu	Au/S.V./Au	Au/S.V./Cu
$\Delta\phi_B$	0.020 eV	0.052 eV	0.270 eV	0.005 eV	0.126 eV
α	1.0×10^{-6}	7.4×10^{-6}	106.0×10^{-6}	9.5×10^{-6}	117.5×10^{-6}
MC	213%	260%	218%	204%	230%

Table 1. Five types of SVTs. S.V. stands for a NiFe (3nm)/Au/Co(3nm) spin valve.

[1] R. Jansen, O.M.J. van 't Erve, S.D. Kim, R. Vlutters, P.S. Anil Kumar and J.C. Lodder, **"The spin-valve transistor: Fabrication, characterization and physics"**, J. Appl. Phys. Vol. 89, 7431 (2001).

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