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Electric properties of magnetic/nonmagnetic p-n junction diode

Sungjung Joo[1], H. Kim[1], K. Jung[1], Y. Kim[1], K. Park[1], J. Hong[1,3], K. Rhie*[1,3], B. C. Lee[2], K. Shin[3], J. Choi[4], and S. Cho[4]

[1]Department of Physics, Korea Universtiy, Chung-nam, Korea
[2]Department of Physics, Inha Universtiy, Incheon, Korea
[3]KIST, Seongbuk-gu, Seoul, Korea
[4]Department of Physics, Ulsan University, Ulsan, Korea

*Corresponding author: krhie@kist.re.kr, Phone: +82 42 821 6632, Fax: +82 42 822 6272

Recently, magnetic p-n junction diode have been proposed theoretically [1], which consists of non-magnetic semiconductor on one side and magnetic semiconductor exhibiting the giant spin-splitting on the other side. New kinds of phenomena can be expected in this device including giant magnetoresistance, spin-voltaic and spin-valve effect resulting from the spin-polarized current in the presence ofan external magnetic field.

In this study, we fabricated magnetic/nonmagnetic p-n junction diodes as a basic step for magnetic bipolar transistor. P-type layer (GaMnAs) has been grown by Molecular Beam Epitaxy (MBE) on n-type GaAs substrate. For optimization of the composition of the GaMnAs layer, samples with different content of Mn (4% and 8%) were grown. The devices have been patterned at shown in Fig. 1 (a) by means of optical lithography and wet etching technique. The electrode was made by the deposition of In/Au on n-type GaAs and Au on p-type GaMnAs using electron beam evaporation. To make it Ohmic behavior, the samples wereannealed at 600℃ for 15 minute.

In order to investigate electro-magnetic properties of our device, the current-voltage (I-V) characteristics were measured for various range of temperature (2~300K) and external magnetic field (0~9T). As shown in Fig. 1(b) the dramatic dependence of the conductance on external magnetic field observed when the bias is forward. We believe these behaviors are attributed to the giant magnetoresistance effect of the magnetic p-n junction proposed theoretically by Zutic and Fabian [1]. Therefore, in this study we experimentally verified one of the theoretical predictions of the magnetic p-n junction diode.

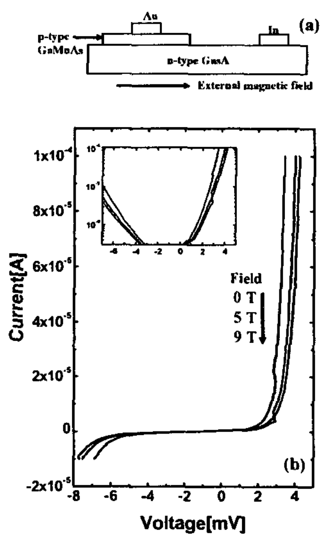

Fig. 1. (a) Schematic structure of a magnetic / nonmagnetic p-n junction diode. (b) I-V characteristics at 50K for various external magnetic field. The inset shows I-V curve in log scale.

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Mössbauer study of spin direction in spin sprayed ferrite films

M. Tada*[1], J. Morita[1], T. Nakagawa[1], N. Matsushita[2] and M. Abe[1]

[1] Department of Physical Electronics, Tokyo Institute of Technology, 2-12-1, Ookayama, Meguro, Tokyo, 152-8552, Japan
[2] Materials and Structures Laboratory, Tokyo Institute of Technology, 4259 Nagatsuta, Midori, Yokohama 226-8503, Japan

*Corresponding author: tada.m.ab@m.titech.ac.jp, Phone: +81 3 5734 2394, Fax: +81 3 5734 2906

Spin sprayed NiZnferrite films exhibit high permeability even in GHz range, far exceeding Snoek's limit for bulk samples.
To explain this phenomenon, we proposed a model in which the spontaneous magnetization is limited to in film plane due to demagnetizing field.
This paper reports magnetization direction for spin sprayed ferrite films measured by ^{57}Fe Mössbauer effect.
As shown in Fig. 1, the Mössbauer spectrum for (100) orientated magnetite film was fitted by two sets of hyper fine patterns and obtained intensity ratio $I_4 : I_5$ was 1:1.8.
The ratio for (111) orientated calculated from NiZn ferrite film (Fig. 2) was 1:3.2. Since both of the intensity ratio are differ from that for, and thus Θ for (100) orientated magnetite film and (111) orientated NiZn ferrite film was calculated to be 38° and 19°. Since easy axis for magnetite and NiZn ferrite is [111], the angle of easy axis in (100) and (111) orientated ferrite films making with film plane were calculated geometrically as 35° and 20° which are in good agreement with those for calculated from intensity ratio $I_4 : I_5$ in Mössbauer spectra.
Those results indicate that the spin direction in spin sprayed ferrite films lies along easy axes of [111] directions, which is possible reason for mismatch in predicted and measuredcomplex permeability for spin sprayed ferrite films.

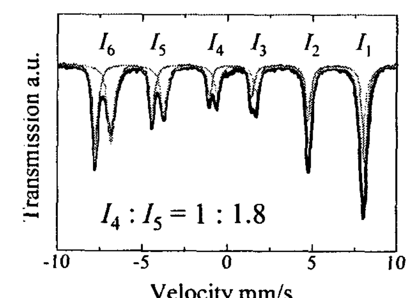

Fig. 1. ^{57}Fe Mössbauer spectrum for (100) orientated magnetite film.

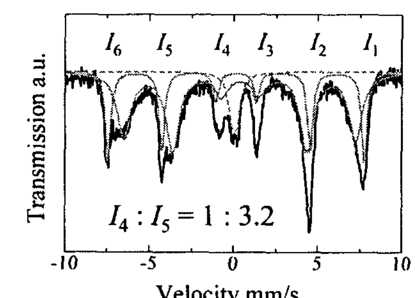

Fig. 2. ^{57}Fe Mössbauer spectrum for (111) orientated NiZn ferrite film.

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[1] M. Abe, M. Tada, N. Matsushita, Y. Shimada, J. Appl. Phys, **99**, art. no. 08M907 (2006).