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Giant Magnetoresistance in FeMn/NiCoFe/Cu/NiCoFe Spin Valve Prepared by Opposed Target Magnetron Sputtering

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Abstract. The giant magnetoresistance (GMR) effect in FeMn/NiCoFe/Cu/NiCoFe spin valve prepared by dc opposed target magnetron sputtering is reported. The spin valve thin films are characterized by Scanning Electron Microscopy (SEM), Vibrating Sample Magnetometer (VSM) and magnetoresistance ratio measurements. All measurements are performed in room temperature. The inserted 45 mm thickness FeMn layer to the NiCoFe/Cu/NiCoFe system can increase the GMR ratio up to 32.5%. The coercive field to be increased is compared with different FeMn layer thickness. Furthermore, the coercive field (*Hc*) decreases with increasing FeMn layer thickness. Magnitude of coercive field is 0.1 T, 0.09 T and 0.08 T for FeMn layer thickness is 30 nm, 45 nm and 60 nm, respectively. The FeMn layer is used to lock the magnetization in the ferromagnetic layer through the exchange anisotropy. This paper will describe the development of a GMR spin valve and its magnetic properties.

Introduction

Due to both a continuous basic interest and still strongly increasing industrial applications, GMR phenomenon still attracted great attention of researchers, and that it becomes a large area of applied research at this time. Its application is already visible in the form of improved memory and sensor devices. This interesting research area, called the "spintronics". Development of spintronic device was triggered by the discovery of GMR which provides the device with lower power consumption [1]. Some devices that work based on the phenomenon of GMR have been and are being developed such as magnetic field sensors [2, 3], non-volatile memory [4, 5], and magnetic recording on the hard disk drive [6].

GMR with spin valve structure has been widely used in magnetic recording devices and magnetic field sensors with high sensitivity [7]. The basic structure of a GMR spin valve consists of antiferromagnetic pinning layers, two ferromagnetic layers separated by a non-magnetic spacer layer. This basic spin valve structure is referred to as a simple spin valve. Antiferromagnetic layer is used to lock direction the magnetization in the ferromagnetic layer through exchange anisotropy, which occurs across the interface antiferromagnetic/ferromagnetic. FeMn material has been used experimentally as antiferromagnetic layer, because FeMn has a large surface resistivity (ρ_{FeMn} = 95 μΩ cm) [8].

The resistance of spin-valve is smallest when the magnetizations of the two ferromagnetic layers are parallel and largest when the magnetizations are antiparallel. The antiparallel alignment is achieved by making the two layers respond differently to an external magnetic field; an antiferromagnet in contact with one of the layers is used to effectively ‘pin’ the magnetization in this layer through an effect called exchange bias [9].

The GMR spin valve thin film is usually prepared using the sputtering, electrodeposition or molecular beam epitaxy (MBE). But so far, not many researchers who reported the manufacture of thin film of GMR spin valve by dc-opposed target magnetron sputtering (dc-OTMS). There are several advantages dc-OTMS method, among others: the resulting film has a high quality of homogeneity within a large area, reducing re-sputtering process, because electrons with high energies which strike substrate causing re-sputtering, is compensated again by impact-induced secondary emission, high ionization efficiency and self-discharge that continually able to be maintained under a certain pressure [10,11]. In addition, the dc-OTMS method operational costs are cheaper and simpler in comparison with the MBE method.

In this work, we studied the giant magnetoresistance effect in FeMn/NiCoFe/Cu/NiCoFe thin film. The purpose of this study was investigated the effect of antiferromagnetic layer thickness on magnetic properties of spin valve FeMn/NiCoFe/Cu/NiCoFe thin film.

Experimental

Thin films of FeMn/NiCoFe/Cu/NiCoFe were grown on Si (100) substrate by dc opposed target magnetron sputtering (OTMS) method. Sputtering target is NiCoFe as ferromagnetic material, Cu as nonmagnetic spacer, and FeMn as antiferromagnetic. Each of these targets is made by solid reaction. Molar composition of the NiCoFe target is Ni: Co: Fe = 60:30:10, while the molar composition of FeMn is Fe: Mn = 50:50.

Samples of the FeMn/NiCoFe/Cu/NiCoFe were deposited in several thicknesses of FeMn layers. Other deposition parameters are fixed. These parameters are: flow rate of Argon gas is 100 sccm, the growth pressure is 0.52 torr, dc voltage is 600 volt, and the temperature is 100^0C. The FeMn layer thickness is varied; 30, 45, and 60 nm, while the thickness of Cu and NiCoFe made fixed at 47.5 nm and 14.4 nm, respectively. Thin film of a GMR spin valve is optimized from the research that has been done previously [11,12] The samples were characterized by using SEM (Scanning Electron Microscope) type JEOL JSM-6360 LA, vibrating sample magnetometer (VSM), and magnetoresistance measurements were made by using a linear four-point probe method with current-perpendicular to-plane.

Results and Discussion

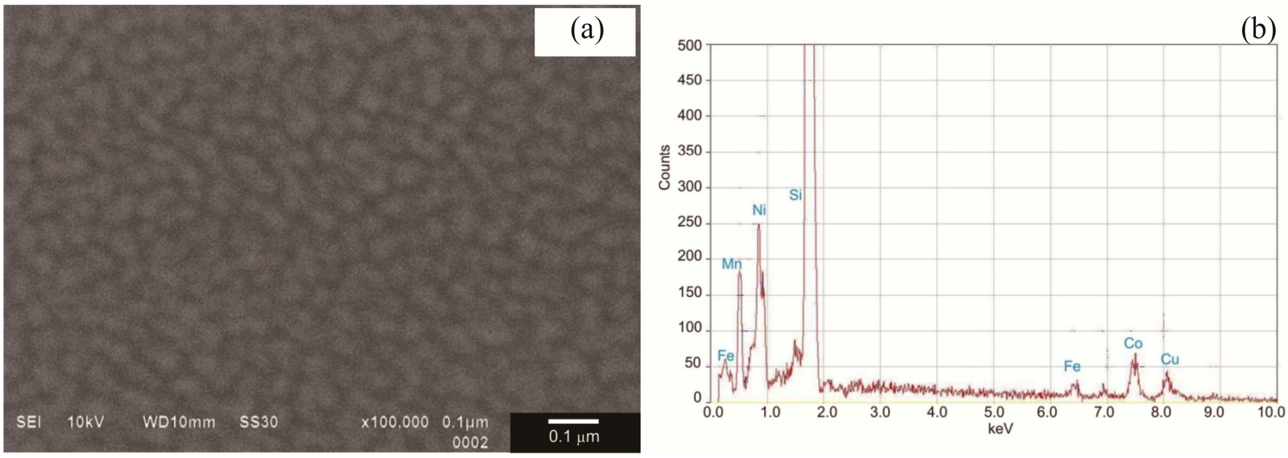

Fig. 1. (a). SEM image of FeMn/NiCoFe/Cu/NiCoFe thin film with 100,000 times magnification and FeMn layer thickness of 45nm. (b). EDX spectrum of FeMn/NiCoFe/Cu/NiCoFe thin film at 45 nm of FeMn layer thickness.

GMR spin valve thin film of FeMn/NiCoFe/Cu/NiCoFe has successfully grown using dc Opposed Targets Magnetron Sputtering methods onto silicon substrate. This can be evidenced by the SEM and EDX results in Fig. 1(a) and Fig. 1(b).

In Fig. 1(a) shows that a thin layer of the spin valve GMR FeMn/NiCoFe/Cu/NiCoFe have a homogeneous surface morphology. Growth of a thin film with sputtering method has a microstructure which corresponds to a growth temperature of the melting point of the sputtering target material. In the structure zone model of Thornton [13], this growth is located in zone I ($0<Ts/Tm<0.2$, Ts is the growth temperature, Tm is the melting point) which is growing in this zone produces grain-shaped structure rods are relatively homogeneous throughout the thickness of the film. Meanwhile, the peaks of intensity in Fig. 1(b) correspond to Ni, Co, Cu, Mn and Fe, indicating that the FeMn/NiCoFe/Cu/NiCoFe thin film were successfully deposition on Si substrate.

The FeMn/NiCoFe/Cu/NiCoFe thin films are exhibit giant magnetoresistance effect with a maximum GMR ratio of 32.5% at 45 nm of FeMn layer thickness as shown in Fig. 2. GMR ratio of the system NiCoFe/Cu/NiCoFe of 24.4% has been obtained previously [12]. The inserted of the FeMn layer to the system NiCoFe/Cu/NiCoFe, GMR ratio can increase up to 32.5%.

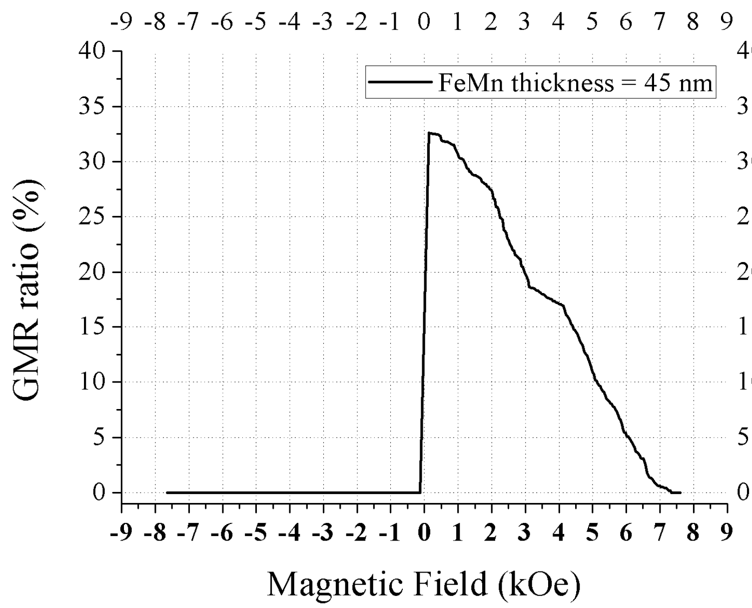

Fig.2. GMR ratio of spin valve FeMn/NiCoFe/Cu/NiCoFe at 45 nm FeMn layer thickness.

Hysteresis curve of spin valve FeMn/NiCoFe/Cu/NiCoFe are shown in Fig. 3. Seen in Fig. 3, the FeMn/NiCoFe/Cu/NiCoFe spin valve has soft ferromagnetic properties. However, the saturation magnetization occurs in a large magnetic field about 0.85 T. It is related to the direction of the magnetic field parallel to the sample.

When antiferromagnetic FeMn layers are inserted to the system NiCoFe/Cu/NiCoFe, the coercive field to be increased compared with no FeMn layer, as shown in Fig 3. Furthermore, the coercive field decreases with increasing FeMn layer thickness, t_{FeMn}. Magnitude of coercive field is obtained, which are 0.1 T, 0.09 T and 0.08 T for FeMn layer thickness is; 30 nm, 45 nm and 60 nm, respectively.

Exchange interaction at the interface of the ferromagnetic layer with antiferromagnetic layer produces some interesting magnetic properties, such as the shift of the hysteresis loop and the addition of coercive field [14]. Experimental results show the addition of antiferromagnetic layer, coercive field decreased with increasing antiferromagnetic layer thickness. Meanwhile, a shift in the hysteresis loop associated with the exchange bias field is inversely proportional to the thick layer of antiferromagnetic [15].

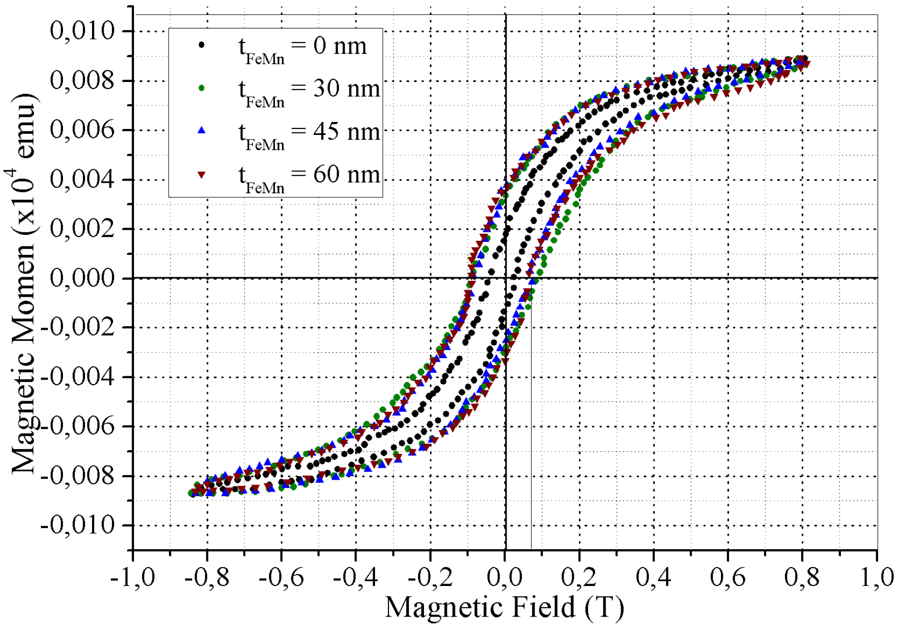

Fig. 3. Hysteresis curve of spin valve FeMn/NiCoFe/Cu/NiCoFe at different FeMn layer thickness.

Conclusions

We have been growth GMR spin valve FeMn/NiCoFe/Cu/NiCoFe onto Si substrates by opposed target magnetron sputtering method. Insert of FeMn layer in NiCoFe/Cu/NiCoFe system can increase GMR ratio and the coercive field. Furthermore, FeMn layer thickness affects the coercive field, where the coercive field decreases as the thickness of FeMn layer increased.

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