Development and Application of Giant Magnetostrictive and Magnetoresistive Materials*

Abdul Halim Shaari, Elias Saion, Wan Daud W. Yusuf, Hishamuddin Zainuddin and Chow Sai Pew

Faculty of Science and Environmental Studies
Universiti Putra Malaysia
43400 UPM, Serdang, Selangor
Malaysia

E-mail of Corresponding Author: ahalim@fsas.upm.edu.my

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Introduction

This research work covers the growth, characterization and exploitation of magnetic granular thin films and bulk properties (Lim et al. Kean Pah, 1998). Magnetoresistance (MR) in ferromagnetic/noble metal heterogeneous materials has been widely studied since the discovery of giant magnetoresistance (GMR) in granular materials. Currently, GMR materials have been prepared and its properties have been studied. Another class of materials that have much higher MR values called the colossal magnetoresistive (CMR) materials is also being researched into. MR is defined as $\Delta R/R_{min} = [(R(B) - R_{min})/R_{min}]$ where R (B) is the resistance when the applied field is B. R_{min} is either the value of the resistance at saturation or else the value of the resistance in the highest applied field available.

Materials and Methods

GMR thin granular films of the following combinations: Co-Cu, Ag-Ni, Co-Ag-Cu, Ag-Fe, NiFe-Cu, NiCr-Ag, NiFe-Ag and Fe-Ag have been fabricated using R.F. Magnetron sputtering technique (Lim et al. Kean Pah, 1998, Kabashi, 2000) and Pulsed Laser Ablation Deposition (PLAD) (Jackson et al. 1996). The films were deposited on glass substrates at substrate temperature less than 400°C. In sputtering, the split target consisting of both ferromagnetic/noble metals matrix was stationary while the substrate rotated at off axis to the target. In the PLAD technique, the situation is reversed. Surface and crystallinity of the films were studied using SEM and XRD. The MR values were measured using a four-point probe technique. Bulk CMR materials of La-Ca-Mn-O (LCMO) system was synthesized using conventional mixed-oxide solid state sintering. The effect of Bi, Sn, Gd and Dy doping on Ca or La site were studied (Halim et al. 1998a, b, c).

The electrical resistance was measured in the temperature range of 20-300 K by a standard four- point technique using a constant current source of 24 mA. Ac susceptibility measurements were performed in then temperature range of 20-300K using an Ac susceptometer (Lake shore Cryotonics- Model 7000). Identification of phases was done using a Siemens XRD machine with Cu Kα radiation. SEM observed the microstructure of the samples. MR was measured between 77 K to room temperature in the applied dc field of 0-1Tesla, using a spring-loaded four-point probe

Results and Discussion

Observation of the surface of the films, prepared by sputtering, in the SEM showed negligible droplets. However, on the surface of the film prepared by PLAD, droplets were observed due to the splashing effect from the target during ablation. This effect could cause interfacing problem in the fabrication of multilayers. In the case of granular films, this effect is minimal. The as prepared granular films of Co-Cu, Ag-Ni, Ag-Fe, NiFe-Cu, NiFe-Ag and Fe-Ag are polycrystalline. However, NiCr-Ag films are amorphous when prepared. Hence further annealing was done to see the formation of polycrystalline structures. The best annealing temperature was around 350° C. The resistance of the films displayed conventional metallic behavior between room temperature and 20 K. However some of the films were found to be concave towards the temperature axis with a drop only 2.8% between room temperature and low temperature. This non-metallic behavior can be attributed to impurity scattering from defects within the lattice structure and grain boundaries. The room temperature GMR value for AgNi film is close to 4% (Lim et al. Kean Pah, 1998). In practical application this value is adequate, especially in the recording industry. The effect of post annealing lowers but saturates the GMR values. This will stabilize the output when it is incorporated into the system. The electrical resistance of LCMO materials in zero applied fields showed a semiconductor-metal transition at temperatures lower than room temperature (Halim. et al. 1998c). This transition may be Anderson-Mott transition, as discussed by Beltiz and Kirkpatrik. At about the same temperature, this material also exhibits ferromagnetic-paramagnetic transition. This phenomenon is explained using the double exchanged mechanism. Phase transition was also studied by doping LCMO with either magnetic or non-magnetic elements (Halim, et al. 1998a, b, c). Magnetic elements tend to destroy the ferromagnetism more than the non-magnetic elements (Koh et al. 2001)]. Thin films of LCMO fabricated via pulsed laser ablation method shows almost similar characteristic as that of the bulk.

Conclusions

i) Granular GMR films are easily prepared via sputtering of the split targets.

ii) Magnetic elements tend to destroy the ferromagnetism more than the non-magnetic elements and hence favors the super-exchange mechanism.

iii) Annealing helps to saturate the GMR values and hence solved the linearity problem if the films are to be incorporated into the detection, measuring or sensing system.

iv) Bulk CMR materials show exciting magnetic and transport behaviour, where at a particular temperature, this material exhibits Anderson-Mott transition as well as ferromagnetic-paramagnetic transition. These phenomena could be explained via double exchange mechanism.

Benefits from the study

These studies provide following information:

i) The effect of doping of non-magnetic element is less severe than magnetic doping.

ii) The room temperature GMR value for AgNi film is close to 4%. In practical application this value is adequate, especially in the recording industry.

iii) Colossal magnetoresistive thin films can be successfully fabricated by pulsed laser ablation method.

iv) These films having huge MR has good potential applications as sensor elements that can be incorporated into MEMS technology

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