UNIVERSITI PUTRA MALAYSIA

STUDIES ON GIANT AND COLOSSAL MAGNETORESISTANCE OF ALLOY AND CERAMIC PREPARED BY RF MAGNETRON SPUTTERING AND PULSED LASER ABLATION TECHNIQUES

LIM KEAN PAH

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By

LIM KEAN PAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philisophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfiment of the requirements for the degree of Doctor of Philosophy

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November 2002

Chairman : Professor Abdul Halim Shaari, Ph.D.

Faculty : Science and Enviromental Studies

Magnetic thin films based on the giant magnetoresistance (GMR) and colossal magnetoresistance (CMR) effects are currently being used as head sensor in the magnetic data storage technology. With the technological revolution in the magnetic recording world of last decades, a need of better and more sensitive magnetoresistance material arises for head sensing. In the first part of this work, a series of Ag-Fe-Co granular films with different composition and thickness had been fabricated onto microscope glass slides using RF magnetron sputtering system. The crystalline analysis show that the as-deposited films consist of <111> and <200> silver texture. Negative GMR values have been obtained and no tendency to saturate at any temperature has been observed. The experimental results show that the GMR value is governed by the composition, microstructure, thickness and temperature. Under an optimum condition, formation of the right shape and size of magnetic cluster in the matrix will cause rapid increase of the GMR value. In this work, the optimum conditions for the highest GMR value of 7.6% measured at room

temperature is obtained for the $Ag_{87.0}Fe_{9.5}Co_{3.5}$ deposited for 60 minutes. In the second part of the work, Pulsed Laser Deposition (PLD) system had been assembled to fabricate ceramic films. Surface studies of the laser irradiated targets show that low fluence of laser causes the periodic structure such as ripples, ridges and cone. However, high fluence of laser will cause the exfoliational and hydrodynamic sputtering process. In this work, bulk and thin films of $La_{0.67}Ca_{0.33}MnO_3$ (LCMO), $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) and $La_{0.67}Ba_{0.33}MnO_3$ (LBMO) had been prepared. Scanning electron microscope micrograph shows that the films consist of wide range of small particles size distribution and they are in spherical shape. The XRD shows that the as-deposited film is in amorphous state and later transfers to polycrystalline state when heat-treatment is applied. Curie temperature, Tc of the films is slightly lower than that of bulk due to the existing amorphous or antiferromagnetic phases at the grain boundaries (GBs). However, the resistances show a huge increase due to the existence of the insulating GBs region. Overall, negative CMR had been obtained for bulk and film samples. The CMR value of polycrystalline films increases with decreasing temperature at low applied magnetic field. This behaviour, which is known as Low Field Magnetoresistance (LFMR), is expected to be due to the polarization of electrons in the magnetically disordered regions near the grain boundaries.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KAJIAN TENTANG MAGNETORINTANGAN GERGASI DAN RAKSAKSA BAGI ALOI DAN CERAMIK YANG DISEDIAKAN MELALUI PERCIKAN MAGNETRON RF DAN TEKNIK MENDAPAN PULSE LASER

Oleh

LIM KEAN PAH

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Pengerusi : Profesor Abdul Halim Shaari, Ph.D.

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Saput nipis magnet yang berdasarkan kesan magnetorintangan gergasi (MRG) dan magnetorintangan raksaksa (MRR) kini telah diguna sebagai kepala sensor dalam teknologi data simpanan bermagnet. Dengan revolusi teknologi dalam dunia pengrekodan bermagnet pada dekat yang lepas, keperluan bahan magnetorintangan yang lebih baik dan peka diperlukan bagi kepala sensor. Dalam bahagian pertama kerja ini, satu siri saput granular Ag-Fe-Co telah disediakan di atas slid kaca mikroskop pada ketebalan dan komposisi yang berbeza dengan menggunakan sistem percikan magnetron RF. Pencirian hablur menunjukkan bahawa saput nipis baru mendap mengandungi tekstur perak <111> dan <200>. Nilai negatif MRG telah didapati dan tiada kesan untuk menjadi tepu dilihat pada mana-mana suhu. Keputusan eksperimen menunjukkan bahawa nilar MRG dikuasai oleh komposisi, mikrostruktur, ketebalan dan suhu. Di bawah keadaan optimum, pembentukan rupa bentuk dan saiz butiran yang betul di dalam saput akan menyebabkan nilai MRG bertambah secara mendadak. Dalam kerja ini, keadaan optimum untuk mendapat

nilai MRG yang paling tinggi yang bernilai 7.6% diukur pada suhu bilik telah diperolehi bagi $Ag_{87.0}Fe_{9.5}Co_{3.5}$ yang dimendap selama 60 minit. Dalam bahagian kedua bagi kerja ini, sistem Mendapan Dedenyut Laser (MDL) telah dipasang untuk fabrikasi saput tipis seramik. Kajian permukaan bagi bahan yang disinar cahaya laser menunjukkan bahawa sinaran kuasa rendah laser menyebabkan struktur berkala seperti jurang, bukit dan kon. Manakala, sinaran laser yang tinggi akan menyebabkan process percikan "eksfoliasi" dan "hidrodinamik". Dalam kerja ini, pepejal dan saput nipis bagi $La_{0.67}Ca_{0.33}MnO_3$ (LCMO), $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) dan $La_{0.67}Ba_{0.33}MnO_3$ (LBMO) telah disediakan. Mikrograf pengimbasan mikroskop elektron menunjukkan bahawa saput menggandungi taburan butiran kecil yang berjulat besar dan berbentuk sfera. Data kritalografi menunjukkan bahawa saput baru mendap adalah dalam bentuk amorfus dan akan bertukar ke bentuk polihablur bila diberi rawatan haba. Suhu Curie, Tc bagi saput tipis adalah rendah sedikit berbanding dengan bahan pepejal disebabkan oleh wujudnya kawasan amorfus dan antiferromagnet di bahagian sempadan butiran (GBs). Walau bagaimanapun, satu peningkatan mendadak pada rintangan berlaku disebabkan oleh wujudnya bahagian penebat di GBs. Secara keseluruhan, MRR negatif telah diperolehi bagi sampel pepejal dan saput tipis. Magnitud MRR bagi saput tipis polihablur meningkat dengan penyusutan suhu pada keadaan medan magnet yang rendah. Tingkahlaku ini, dikenali sebagai magnetorintangan medan rendah (LFMR), adalah dijangkakan dan disebabkan oleh pengutuban elektron dalam bahagian kemagnetan yang tidak tersusun berdekatan dengan sempadan butiran.

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I certify that an Examination Committee met on 20th November 2002 to conduct the final examination of Lim Kean Pah on his Doctor of Philosophy thesis entitled "Studies on Giant and Colossal Magnetoresistance of Alloy and Ceramic Prepared by RF Magnetron Sputtering and Pulsed Laser Ablation Techniques" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

(Lim Kean Pah)

Date : 20/12/2002

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LIST OF ABREVIATIONS/NOTATIONS OF TERMS

DC	Direct current
RF	Radio frequency
S	Sputtering yield
YAG	Yttrium Aluminium Garnet
PLD	Pulsed Laser Deposition
L_s	Distance target to holder
LIPSS	laser-induced periodic surface structures
$\Delta L/L_o$	Thermal expansion
E	Young's modulus
T_m	Thermal shocks
T_{sub}	Substrate temperature
T_{cry}	Crystallization temperature
T_{epi}	Epitaxial temperature
MR	Magnetoresistance
OMR	Ordinary Magnetoresistance
AMR	Anisotropic Magnetoresistance
GMR	Giant Magnetoresistance
CMR	Colossal Magnetoresistance
TMR	Tunnelling Magnetoresistance
MBE	Molecular Beam Epitaxy
CIP	current parallel to the plane
CPP	current perpendicular to the plane