OPTIMIZATION CONDITION OF GIANT MAGNETORESISTANCE IN GRANULAR THIN FILMS FOR APPLICATION AS MAGNETIC SENSORS

By

KABASHI KHATIR KABASHI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

June 2004

DEDICATION

This study is dedicated to my beloved family:

My Wife

Rogiah Omer

My Sons

Shihabuddin

Sharafuddin

Shamsuddin

and

Shaa'uddin

For Great Sacrifice and Support

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

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Chairman: Professor Abdul Halim Shaari, Ph.D.

Faculty: Science and Environmental Studies

The discovery of giant magnetoresistance *(GMR)* in multilayer systems and subsequently in granular films has stimulated worldwide research activities, due to both its fundamental significance and its potential application to magnetic sensors for fields ranging from 1 T up to 10 T. For granular films, however, there exists evidence that interface scattering plays a dominant role in magnetoresistance. The GMR is believed to be relating to the features of magnetic granules such as size, shape, and distribution. Concerning the effect of the feature of magnetic particle, most of the experimental work has focused on the post-deposition annealing, which is believed to promote grain growth or phase segregation. The need for new and improved optical and electronic

devices has stimulated the study of CoNiAg, CoFeAg, and CoNiCu thin solid films with controlled composition and specific properties in this project. Therefore, a comprehensive investigations of the microstructure, structural, and magnetoresistance properties for the as deposited and annealed samples were performed via scanning electron microscopy (SEM), atomic force microscopy (AFM), energy disperssive spectroscopy (EDS), x-ray diffractometry (XRD), and four point probe techniques. The measurements were achieved at low and room temperatures in the presence of applied magnetic field of ~1.1 T. In response to these investigations, SEM micrographs have revealed that the surfaces of the films are smooth, uniform, and homogeneity with the presence of some impurities occurred after annealing, whereas AFM images showed that both the grain diameter and the RMS roughness were increased after annealing. EDS has determined the average chemical composition for each system, which shows fine dispersion of Co particles into Ag and Cu matrices in comparison with Fe and Ni particles. XRD spectrum has shown fcc structure for all as deposited and annealed samples with the respective peaks of (111), and (200) corresponding to the Ag plane in addition to the unknown peak related to the impurities appeared at 400 ˚C and 500 ˚C for CoNiAg system. For CoFeAg samples the broadened diffraction peaks roughly corresponded to the Ag (111), Ag (200), and Ag (220) reflections were detected due to the phase separation, whereas in the CoNiCu system two diffraction peaks corresponding to the (111), and (200) related to Cu plane in addition to the unknown peak at ~36 ˚ have been

observed in all series. The intensities and positions of these peaks for all series vary upon increasing the magnetic content and annealing temperature, indicating that the lattice parameter decreases with increasing magnetic content. For the best MR effect in these three systems, MR value at 100 K, increases from 0.75% in the as deposited samples to 1.45% in the annealed samples for CoNiAg system, for which the optimum annealing temperature, deposition time, and Co content were 400 ˚C, 120 minutes and 16 at.% respectively. The MR ratios of 3.37% and 31.34% at 100 K, were obtained respectively in the as deposited and annealed samples of CoFeAg system for deposition time of 120 minutes, hence an optimum annealing temperature was located at 400 ˚C for optimum Co content of 12 at.%. While for CoNiCu system, the MR value increases from 0.41% for as deposited samples to 5.09% for annealed samples at 400 ˚C. The optimum deposition time, annealing temperature, and Co content that provides the highest MR values are 120 minutes, 400 ˚C, and 17 at.% respectively. Measurements at 300 K also show MR values but lower than at 100 K for all series. Among these systems, CoFeAg is the best, which shows the highest MR, while still under precise deposition conditions and proper thermal treatment, the other two systems may promise to show large MR effect.

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

KEADAAN PENGOPTIMUMAN BAGI MAGNETORINTANGAN GERGASI DALAM BUTIRAN FILEM TIPIS UNTUK APILIKASI SENSOR MAGNET

Oleh

KABASHI KHATIR KABASHI

Jun 2004

Pengerusi: Profesor Abdul Halim Shaari, Ph.D.

Fakulti: Sains dan Pengajian Alam Sekitar

Penemuan magnetorintangan gergasi (GMR) dalam sistem multilapisan dan seterusnya dalam filem butiran telah meningkatkan aktiviti penyelidikan diperingkat global, disebabkan pentingnya asas dan potensi applikasinya pada sensor magnet bagi julat medan daripada 1 T ke 10 T. Walaubagaimana pun, bagi filem butiran, terdapat bukti menunjukkan bahawa serakan permukaan memainkan peranan yang besar dalam magnetorintangan. GMR dipercayai mempunyai kaitan seperti saiz, bentuk dan taburan. Menitik beratkan kesan berkaitan dengan partikel magnet, kebanyakan kerja eksperimen telah memfokus pada sepuhlindap pasca-mendapan, yang dipercayai menyebabkan pertumbuhan butiran atau segregasi fasa. Keperluan, peralatan optik dan

electronik yang terkini dan diperbaharui telah mengalakkan kajian saput nipis pepejal CoNiAg, CoFeAg, dan CoNiCu dengan pengawalan komposisi dan sifat khusus dalam projek ini. Kajian komprehensif pada mikrostruktur, struktur dan sifat magnetorintangan selepas sampel dimendak dan sepuhlindap dikaji dengan kaedah mikroskopi elektron pengimbasan (SEM), mikroskopi daya atomik (AFM), spektroskopi penyerakan tenaga (EDS), difraktometer sinaran-x (XRD) dan penduga empat titik. Pengukuran dibuat pada suhu rendah dan suhu bilik dalam ~1.1 T medan magnet. Dalam kajian ini, didapati, mikrograf SEM menunjukkan permukaan filem adalah licin, seragam dan homogen dengan sedikit ketidaktulinan wujud selepas di sepuhlindap, dimana imej-imej AFM menunjukkan bahawa diameter butiran dan kekasaran RMS meningkat selepas proses sepuhlindap. EDS telah menentukan purata komposisi kimia bagi setiap sistem, yang menunjukkan serakkan sempurna zarah Co kepada matrik Ag dan Cu dibandingkan dengan zarah Fe dan Ni. Spectrum XRD menunjukkan struktur fcc bagi semua selepas sampel di mendak dan di sepuhlindap dengan puncak masing-masing (111) dan (200) sepadanan pada satah Ag dan puncak yang tidak diketahui berkaitan dengan ketidaktulinan wujud pada 400 ˚C dan 500 ˚C bagi sistem CoNiAg. Bagi sampel CoFeAg, pelebaran puncak serakan secara kasar bersamaan dengan serakan Ag (111), Ag (200), dan Ag (220) telah dikesan berasaskan pada pemisahan fasa, manakala dalam sistem CoNiCu dua puncak serakan bersamaan dengan (111) dan (200) berkaitan dengan satah Cu dalam penambahan pada puncak yang tidak

diketahui pada ~36 ˚ didapati bagi semua siri. Keamatan dan posisi puncak ini bagi semua siri berubah bergantung peningkatan kandungan magnet dan suhu sepuhlindap, menunjukkan parameter kekisi menurun dengan peningkatan kandungan magnet. Bagi kesan MR terbaik dalam ketiga-tiga sistem ini, nilai MR pada 100 K meningkat dari 0.75% bagi sampel dimendak kepada 1.45% bagi sampel di sepuhlindap bagi sistem CoNiAg, masing-masing bagi suhu sepuhlindap optimum, masa mendakan dan kandungan Co adalah 400 ˚C, 120 minit dan 16 at.%. Nisbah MR 3.37% dan 31.34% pada 100 K, masing-masing diperolehi dalam sampel yang telah dimendak dan sepuhlindap bagi sistem CoFeAg untuk masa dimendak 120 minit, dan demikian suhu sepuhlindap optimum anneal pada 400 ˚C bagi kandungan Co optimum pada 12 at.%. Manakala bagi sistem CoNiCu, nilai MR meningkat dari 0.41% bagi sampel dimendak kepada 5.09% bagi sampel yang sepuhlindap pada 400 ˚C. Masa mendakan optimum, suhu sepuhlindap dan kandungan Co yang memberikan nilai MR yang tinggi adalah masing-masing 120 minit, 400 ˚C dan 17 at.%. Pengukuran pada 300 K juga menunjukkan nilai MR tetapi rendah pada 100 K bagi semua siri. Diantara sistem ini, CoFeAg yang tebaik, yang menunjukkan MR tertinggi tetapi masih dibawah keadaan posisi tepat dan rawatan terma yang baik, manakala dua sistem yang lain akan memberikan kesan MR yang besar.

ACKNOWLEDGEMENTS

My deepest gratitude goes to my supervisor, **Professor Dr. Abdul Halim bin Shaari,** for his constant support, encouragement, and guidance, to whom, I am owed. I have really learned many technical things from him. I will definitely benefit from this training throughout my research career. I am also very grateful to Associate Professor Dr. Hishamuddin Zainuddin and Associate Professor Dr. Zainal Abidin Talib for serving on my supervisory committee. Many discussions with them were both fruitful and enjoyable.

In preparing, writing, and editing this thesis, the continuing support and interest of many of my colleagues within as well as outside Universiti Putra Malaysia (UPM) have been most helpful and stimulating. In particular my former and current lab mates, Dr. K. P. Lim, Dr. Abdullah Chik, Dr. Imad Hammadneh, Dr. Iftetan A. Taha, A. Agail, M. M. Dihom, R. Shaiboub, Walter C., Mohd Faisel, Azman. A., Hazar A. S., Zohra A. G., Nor Janna A., Mass. A., Sharmiwati M. S., and Huda Abdullah, for making our Laboratory (Superconductors and Thin Films) more comfortable and attractive. I would also like to thank UPM for providing a nice working environment, which makes an undertaking such as this possible. My gratitude extended to the staff at Scanning Electron Microscopy Unit, Faculty of Veterinary, UPM for providing their equipments in analyzing the microstructure of the samples as well as the

staff at Department of Physics, Faculty of Science and Environmental Studies, UPM for kind cooperation. Special thank goes to Sudanese Students Community at UPM and Universiti Kebangsaan Malaysia (UKM) for moral support.

The financial support was fully provided by the Ministry of Science, Technology, and Environment, of Malaysia through intensified research in priority area **(IRPA), Vote No:** ***[09-02-04-0148]***, and partially by the Ministry of High Education and Scientific Research, of Sudan upon which this study was completed, to whom I acknowledge with gratitude.

Finally, I am indebted to my family whose exemplary patience and moral support have sustained me to the completion of this work.

I certify that an Examination Committee met on 22nd June 2004 to conduct the final examination of Kabashi Khatir Kabashi on his Doctor of Philosophy thesis entitled "Optimization Condition of Giant Magnetoresistance in Granular Thin Films for Application as Magnetic Sensors" 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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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory 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.

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KABASHI KHATIR KABASHI

Date**:**

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