UNIVERSITI PUTRA MALAYSIA

MAGNETIC PROPERTIES OF RF MAGNETRON SPUTTERED Co-Ag-Cu GRANULAR THIN FILMS

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FSAS 2000 9

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By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Science and Environmental Studies
Universiti Putra Malaysia

June 2000

DEDICATION

Special Dedication is due to:

Dr. Joshua Otor Akol (Deputy Vice Chancellor Upper Nile University)

My Late Father, Mother,Brothers and Sisters

My Wife and my Sons

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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KABSAHI KHATIR KABASHI

June 2000

Chairman: Professor Abdul Halim Shaari, Ph. D.

Faculty: Science and Environmental Studies

The observation of the magnetoresistance (MR) effect in granular films, where the magnetic particles are embedded in a non-magnetic matrix, has stimulated remarkable interest because of its potential technological applications as magnetic sensors in the magnetic storage technology, and also due to interest in fundamental scientific research. The granular films can present MR effect even larger than in multilayers The MR effect was a large decrease in electrical resistivity that occurs when the magnetization of two layered or granular samples was aligned by an external magnetic field. In

surface morphology was smooth and homogeneous and there was a little contamination on these surfaces as indicated through SEM, which may be attributed to the oil spots and fingerprints throughout the deposition process and preparation for various measurements. The chemical composition and the element percentage for each series were determined by EDX.

The structure of the samples was characterized by XRD. The peaks of fcc (111), (200), (220), and (311) related to the Ag were detected and a set of fcc (111) and (220) peaks related to the Co were defected as well, indicating the formation of small fcc Co particles in Ag. The XRD measurements also detected the peak of fcc (111) related to the Cu and Co. However, the other peaks of fcc Cu (+Co) (200) and fcc Cu (+Co) (220) were not detected. Ag (111) peak shifts to higher angles ($2\theta > 38.11$) for the samples of $Co_{0.53}Ag_{0.47}$, $Co_{0.23}Cu_{0.77}$, and $Co_{0.32}Ag_{0.14}Cu_{0.54}$, while for the $Co_{0.26}Ag_{0.19}Cu_{0.55}$ and $Co_{0.30}Ag_{0.46}Cu_{0.24}$ samples the peak shifts to lower angles ($2\theta < 38.11$).

The as-deposited samples measurements at room temperature displayed a maximum value of 1.26% MR obtained by the $Co_{0.32}Ag_{0.14}Cu_{0.54}$ film when the deposition time was 80 minutes. The remaining samples of $Co_{0.23}Cu_{0.77}$, $Co_{0.26}Ag_{0.19}Cu_{0.55}$, $Co_{0.30}Ag_{0.46}Cu_{0.24}$, and $Co_{0.55}Ag_{0.47}$ have shown the values of 0.13%, 0.24%, 0.36%, and 0.84% MR respectively for the deposition time of 90 minutes. Post-annealing increased the MR for all the samples at room temperature and at low temperatures. The measurements of annealed samples at room temperature exhibited the values of 1.75%, 1.28%, 0.52%, 0.31%, and 0. $Co_{0.32}Ag_{0.14}Cu_{0.54}$, $Co_{0.53}Ag_{0.47}$, $Co_{0.30}Ag_{0.46}Cu_{0.24}$, $Co_{0.26}Ag_{0.19}Cu_{0.55}$, and $Co_{0.23}Cu_{0.77}$ respectively of the samples deposited for 90 minutes. The increase in the MR due to annealing process may be related to the reducing of the degree of structural disorder, enlarging the particle size and increasing of the interparticle separation, which may affect to the effect of phonon behavior on the resistivity of the film.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KAJIAN MAGNETORINTANGAN SAPUT TIPIS GRANULAR

Oleh

KABASHI KHATIR KABASHI

Jun 2000

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Pencerapan kesan magnetorintangan dalam filem granular dimana bahan magnet telah dibentuk oleh zarah magnet yang dibenamkan didalam bahan bukan magnet, telah merangsang aktiviti yang tinggi disebabkan oleh potensi kegunaan teknologinya sebagai sensor magnet dalam teknologi pengstoran magnet, dan juga keistimewaan dalam penyelidikan saintifik asasnya. Filem granular boleh memperolehi kesan magnetorintangan yang lebih besar dari filem multilapisan. Tetapi, magnetorintangan adalah satu peningkatan yang besar dalam rintangan elektrik dimana ia berlaku bila keadaan magnet bagi dua lapisan atau granular sampel telah disusun oleh satu medan magnet luaran.

Dalam kajian ini, telah diperhatikan bahawa morforlogi permukaan adalah rata dan homogen dan juga terdapat sedikit pencemaran berlaku pada permukaan yang dapat diperhatikan dari imbasan elektron mikroskop (SEM), dimana ia mungkin disebabkan oleh kesan minyak dan cap jari dalam seluruh proses pemendapan dan juga penyediaan bagi pengukuran yang berbeza. Komposisi bahan kimia dan peratusan bahan bagi setiap siri telah ditentukan oleh analisis penyebaran sinaran-X (EDX).

Struktur bagı sampel telah dianalisiskan oleh pembelauan sinaran-X (XRD) Puncak fcc (111), (200), (220) dan (311) yang berkaitan dengan bahan Ag telah dıkesan dan satu set puncak fcc(111) dan (220) yang menunjukkan bahan Co telah terhasil, termasuk pembentukan hablur fcc (111) Co yang kecil dalam Ag Pengukuran XRD juga dapat kesan puncak fcc (111) yang berkaitan dengan Cu dan Co Manakala, puncak laın seperti fcc Cu (+Co)(200) dan fcc Cu (+Co)(220) tıdak dapat dikesan

Puncak Ag (111) beralih ke sudut yang lebih tinggi (2θ>38 11) bagı sampel $Co_{0\,53}Ag_{0\,47}$, $Co_{0\,23}Cu_{0\,77}$ dan $Co_{0\,32}Ag_{0\,14}Cu_{0\,54}$ manakala bagi sampel $Co_{0\,26}Ag_{0\,19}Cu_{0\,55}$ dan $Co_{0\,30}Ag_{0\,46}Cu_{0\,24}$ ia beralih ke sudut yang lebih rendah (2θ<38 11)

Pengukuran sampel baru dipercik dalam suhu bilik menunjukkan satu nilai maksımum iaitu 1 26% bagi filem $Co_{0\,32}Ag_{0\,14}Cu_{0\,54}$ yang dipercik selama 80 mınıt Bagi sampel lain iaitu $Co_{0\,23}Cu_{0\,77}$, $Co_{0\,26}Ag_{0\,19}Cu_{0\,55}$, $Co_{0\,3}$

dan $Co_{0\,53}Ag_{0\,47}$ memberi nilai 0 13%, 0 24%, 0 36% dan 0 84% MR bagi pecikan masa selama 90 minit Pemanasan selepas penyediaan menambah nılai MR bagı semua sampel pada suhu bilik dan suhu rendah Pengukuran bagi sampel, yang telah sepuhlindap, pada suhu bilik memberi nilai MR sebanyak 1 75%, 1 28%, 0 52%, 0 31% dan 0.16% bagi sampel $Co_{0\,32}Ag_{0\,14}Cu_{0\,54}$, $Co_{0\,53}Ag_{0\,47}$, $Co_{0\,30}Ag_{0\,46}Cu_{0\,24}$, Co_{0}

90 minit Penambahan dalam nilai MR yang disebabkan oleh proses sepuhlindapan mungkin dihubungkaitkan dengan darjah ketidaksusunan struktur, pembesaran saiz hablur dan penambahan jarak antara hablur,

merangsang kesan kelakuan fonon dalam kerintangan bagi filem

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor Professor Dr. Abdul Halim Shaari for his guidance, encouragement and supervision on this study. Also I am grateful to Dr. Zainul Abidin Hassan and Associate Professor Dr. W Mahmood Mat Yunus Members of the Supervisory Committee for their valuable discussions on this manuscript.

My sincere gratitude goes to the Sudan Government, particularly the Upper Nile University, for financial support.

The completion of this study would not have been possible without help from a large number of my colleagues and friends. I am particularly grateful to Adam Ibrahim, Osman Abdelghani, Mamour Choul, and Mohammed Ahmed Sulieman, for supporting and helping me in many ways.

I want to express my deep appreciation of my colleague K. P.
worked with me on much of the research reported in this study. My thanks also due to (Thin Film Group), S. F. Koh and S. O. Yu. My most sincere thanks are due to Dr.
(Superconductors Group) for their assistance in operating most of the laboratory equipment's and computer programmes. I am also grateful to Ms. Azela, Mr.
and Ms. Aminah, Faculty of Veterinary (UPM) for SEM analysis.

I acknowledge the contribution of Mr Rosdi Ibrahim (SIRIM) for semiquantitative analysis Also my appreciation due to Mr L. M Hong and Ms S L Tze (Chemistry Dept, UPM) for XRD analysis Thanks are due to Mr Razak Harun and to the Phys Dept (UPM) for providing a platform to complete this study

Also I want to acknowledge the valuable contributions of Dr Ali Eltahir and Mr Abbaker Ali (Khartoum University) and Mr Sallah Saed ministry of higher education (Sudan), Mohammed Hammad, Abdel Aziz Eisa, Mohammed Hassan and all friends in UPM

Finally, this study could not be completed without the constant help and understanding of my wife Rugia Omer

I certify that an Examination Committee met on 29 June, 2000 to conduct the final examination of Kabashi Khatir Kabashi on his Master of Science thesis entitled "Magnetic Properties of RF Magnetron Sputtered Co-Ag-Cu Granular Thin Films" 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 was submitted to the Senate of Universiti Putra Malaysia and was accepted as fulfilment of the requirements for the degree of Master of Science

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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

KABASHI KHATIR KABASHI

Date 6/7/2000

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LIST OF ABBREVIATIONS AND GLOSSARY OF TERMS

Abbrev/Gloss	Description
α, β, γ	Phase designations
θ	Bragg diffraction angle
$\rho\uparrow$	Spin-up density
$\rho\downarrow$	Spin-down density
ρ_F	Ferromagnetic resistivity
ρ_N	Non ferromagnetic resistivity
$\rho_{\parallel}$	Parallel resistivity
ρ_T	Transverse resistivity
ρ_b	Bulk resistivity
ρ_0	Resistivity due to impurity
ρ_H	Resistivity at applied magnetic field H
ρ_m	Magnetic resistivity
$\Delta\rho$	Resistivity variation
ρ_{tot}	Total resistivity
σ	Conductivity
$\wedge_S$	Interface spin-scattering length

λ_1	Mean free path of sputtered atoms
AMR	Anisotropic magnetoresistance
AP	Antiparallel
AF	Antiferromagnetic
a	Radius of sphere
APCVD	Atmospheric pressure chemical vapor deposition
at%	Atomic percent
B	Magnetic induction
CIP	Current in plane
CPP	Current perpendicular to the plane
CMR	Colossal magnetoresistance
CVD	Chemical Vapor Deposition
d	Lattice spacing
DC	Direct Current
e	Charge of electron
EDX	Energy Dispersive X-ray
F	Ferromagnetic
$\vec{F}$	Force
GMR	Giant Magnetoresistance
$\vec{H}$	Magnetic field strength
HBT	Hetrojunction bipolar transition
HEMET	High electron mobility transistor

LSI	Large Scale Integration
L_{SF}	Spin-diffusion length
MBE	Molecular beam epitaxy
MESFET	Metal semiconductor field effect transistor
MOCVD	Metalorganic chemical vapor deposition
MR	Magnetoresistance
OMR	Ordinary magnetoresistance
PVD	Physical Vapor Deposition
PECVD	Plasma Enhanced chemical vapor deposition
R_0	Resistance at zero field
R_H	Resistance at applied magnetic field
RF	Radio Frequency
R_{max}	Maximum resistivity
SAW	Surface acoustic wave
SEM	Scanning Electron Microscopy
T	Tesla
T_c	Crystallization temperature
T_{ept}	Epitaxial temperature
T_s	Substrate temperature
TMR	Tunneling magnetoresistance
T_A	Annealing temperature
t_F	Ferromagnetic thickness
t_N	Non ferromagnetic thickness (normal thickness).

v	Velocity of electron
V_{scat}	Scattering potential
V_{cl}	Cluster volume fractions
V_c	Corrosion potential (unit cell volume)
W	Watt
XRD	X-Ray Diffraction

CHAPTER I

INTRODUCTION

Thin film is a deposition of atoms to form thin layer on a substrate, their thickness is typically less than several microns The formation of thin films on a substrate by deposition is basically a phase change phenomenon involving nucleation and growth with the constraint of the substrate There are important variables that should be controlled in a deposition process (Glang, 1970, Poate, et al, 1978 and Smith, 1995) such as

a) Vacuum pressure

b) Deposition rate

c) Substrate material (structure)

d) Substrate temperature

e) Deposition atmosphere

The thin film process comprises of three elementary stages includes

a) Production of the appropriate atomic, molecular, or ionic species

b) Transport of the species to the substrate through a medium

c) Condensation on the substrate, either directly or through a chemical reaction to form a solid film

The starting materials in the form of gas, liquid, or solid are decomposed into various fragments of neutral or ions in the form of atoms, molecules, clusters or powders, by the external powers (Suzui, et al, 1998)

The crystalline properties of the deposited films are controlled by the selection of the substrate materials and the substrate temperature

The amorphous thin films are prepared on a glass and /or ceramic substrate at substrate temperature below the crystallization temperatures of the thin films Polycrystalline films are prepared on a glass and/ or ceramic substrates at the substrate temperatures above the crystallization temperature Single crystalline films are prepared on a single crystal substrate due to the epitaxial growth process and, in general, they are epitaxially grown on a single crystal substrate at the substrate temperature above the epitaxial temperature Table 1 lists the basic process of the deposition of the thin films