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GIANT MAGNETORESISTANCE OF SILVER NICKEL IRON GRANDULAR MAGNETIC THIN FILMS PREPARED BY RF MAGNETRON SPUTTERING SYSTEM

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By

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LIST OF SYMBOLS

GMR	Giant Magnetoresistance
SEM	Surface electron microscope
XRD	X-ray diffraction
EDX	Energy dispersive X-ray
SAW	Surface acoustic wave
VCR	Video recorder cassette
OMR	Ordinary Magnetoresistance
AMR	Anisotropic Magnetoresistance
CMR	Colossal Magnetoresistance
TMR	Tunneling Magnetoresistance
Ni	Nickel
Ag	Silver
Fe	Iron
PVD	Physical vapour deposition
CVD	Chemical vapour deposition
W	Tungsten
Mo	Molybdenum
Ta	Tantalum
Torr	Pressure unit
KrF	Krypton Fluoride

MBE	Molecular beam epitaxy
ARE	Activated reactive evapouration
S	Sputter yield
DC	Direct current
He	Helium
NE	Neon
Ar	Argon
O_2	Oxygen
RF,rf	radio frequency
N_2	Nitrogen
m_e	mass of electron
e	charge of electron
v_e	Velocity of electron
H,B	Magnetic field
E	Electric field
Å	Angstrom
K	Kelvin
°C	Degree Celsius
G	Gauss
T	Tesla
MR	Magnetoresistance

ρ_{max}, ρ_o	Resistivity
R	Resistance
M	Magnetic layer
NM	non-magnetic layer
CIP	Current parallel to the plane of the film layer
CPP	Current perpendicular to the plane of the film layer
l_{sf}	spin diffusion length
t_N	Thickness of non magnetic film
σ	Conductivity
c	Magnetic entities concentration
λ_s, λ_m, λ_{nm}	Mean free paths for the interfaces, granules and matrix
p_o, p_s	The ratio of the spin-dependent potentials to spin-independent potentials for the granules and for the interfaces
a_o	Lattice constant of the granules
V_α	The volume of the granules
$f(V_\alpha)$	Distribution function for the size of the granules
m_α (V_α)	The cosine of the angle the magnetic moment of the αth granule makes with respect to the external field
r_o	radian of the magnetic granule
V_o	volume of the magnetic granule
M	magnetization
MRAM	magnetoresistance random access memory

T_s	substrate temperature
T_c	crystallization temperature
T_{epi}	epitaxial temperature
mbar	pressure unit
a_{ni}	the sputtering area of the iron foil
a_{Ag}	the sputtering area of the silver disc
a_{total}	total sputtering area
Ni_{EDX}	the percentage of nickel element in the sample
Ni_{target}	the ratio of the surface area of nickel in the target
fcc	face centered cubic

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

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July, 1998

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Faculty : Science and Environmental Studies

The discovery of giant magnetoresistance (GMR) in multilayer system and subsequently in granular films has stimulated world wide research activities, due to both its fundamental significance and its potential application to magnetic sensors and data storage. Hence, this work is carried out to investigate this phenomenon. The first part of the work is to find out the suitable parameter and condition for producing good quality films. Granular magnetic thin films of Ag-Ni-Fe have been prepared at different deposition rates and compositions using RF Magnetron Sputtering system. Subsequently, the surfaces of the thin films were examined using the scanning electron microscope (SEM) and energy dispersive X-ray (EDX) analysis, also in the SEM, was used to determine the composition of the films. The crystalline state of the films was determined by X-ray diffraction using CuK_α radiation in a 2θ powder diffractometer and the resistances of the films were measured using a four-point probe method to calculate the GMR effect. Lastly, the data obtained were analysed to investigate and understand the electrical transport mechanism in thin films. The result shows that the GMR effect is thickness, structure and composition dependent. The highest GMR value was obtained for the samples deposited for 60 minutes with 25% of magnetic entities embedded in the non-magnetic matrix. The microstructure analysis shows that the highest GMR value was obtained if the formation of <111> fcc Ag texture is dominant and small grain size was formed in the film. In conclusion, a good granular thin film with high GMR value of 3.73% at room temperature has been developed and this result meets the requirement in the magnetic sensors and data storage industry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
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MAGNETORINTANGAN GERGASI TERHADAP SAPUT TIPIS GRANULAR MAGNET Ag-Ni-Fe YANG DISEDIAKAN MELALUI SISTEM PERCIKAN MAGNETRON RF

Oleh

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Pengerusi : Prof. Madya Abdul Halim Shaari (Ph. D.)
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Penemuan magnetorintangan gergasi (MRG) dalam sistem multilapisan dan seterusnya dalam saput tipis granular telah merangsang banyak aktiviti penyelidikan di seluruh dunia disebabkan oleh keistimewaan asas dan potensi penggunaannya pada sensor magnet dan pengstoran data. Justeru itu, kajian ini dilakukan untuk menyiasat fenomena tersebut. Bahagian pertama kajian ini adalah untuk mencari parameter dan keadaan yang sesuai untuk menghasilkan saput yang berkualiti. Saput tipis granular magnet Ag-Ni-Fe telah disediakan pada kadar mendapan dan komposisi yang berbeza dengan menggunakan sistem percikan magnetron RF. Seterusnya, permukaan saput tipis diperiksa dengan menggunakan mikroskop elektron pengimbasan (SEM) dan analisis penyebaran tenaga sinaran-X (EDX) yang terdapat dalam SEM telah digunakan untuk menentukan komposisi sampel. Keadaan kehabluran sampel pula ditentukan dengan kaedah pembelauan sinaran-x dengan menggunakan sinaran CuK_{α} dalam meter pembelauan serbuk 2θ dan rintangan bagi saput tipis pula diukur dengan menggunakan satu penduga empat titik untuk mengira kesan MRG. Akhir sekali, data yang didapati dianalisis untuk mengkaji dan memahami mekanisme pengaliran elektrik dalam saput tipis. Keputusan menunjukkan bahawa MRG mempunyai persandaran kepada ketebalan, struktur dan komposisi sampel. Nilai MRG yang tertinggi diperolehi pada sampel yang dipercik selama 60 minit dengan 25% bahan magnet dibenamkan dalam matrik bahan bukan magnet. Analisis mikrostruktur menunjukkan bahawa MRG yang paling tinggi diperolehi jika pembentukan tekstur <111> Ag adalah dominan dan butiran yang terbentuk dalam saput tipis adalah kecil. Kesimpulannya, saput tipis granular yang bermutu dengan nilai MRG yang tinggi, iaitu 3.73% pada suhu bilik telah diperolehi. Keputusan yang diperolehi juga menunjukkan bahawa saput tipis yang disediakan dapat memenuhi syarat dalam industri sensor magnet dan penyimpanan data.

CHAPTER I

GENERAL INTRODUCTION

Introduction

At present, various kinds of thin film materials are used for the production of the electronic devices including high precision resistor, surface acoustic wave (SAW) filters, optical disks, magnetic tapes, sensors, and active matrix for liquid crystal television. Recent progress of these thin film devices is the result of developments of Si-Large Scale Integration (LSI) technology including thin film growth process, microfabrication and analysis technology of both the surface and interface of the thin films (Wasa, 1992). The recent discovery of giant magnetoresistance (GMR) in multilayer and granular thin films has led to much current world wide interest in the effect (Wiggins, 1996; Yu, 1994), due to both its fundamental significance and its potential in a variety of applications such as magnetic sensor (Folkerts, 1994), video cassette recorder (VCR) application (Suzuki, 1994), data storage (Brown, 1994) and many more.

Basis of Work

With the technological revolution in the magnetic recording world of the last decades, a need of better magnetoresistance material arises for large storage capacities and magnetoresistance sensor for information carrying and processing.

The evolution of storage technologies has influenced the thin film field. The data are now introduced into a system on a magnetic support with a much higher transfer rate. The operating speed of the internal memory increased with the use of matrices in which the ferrite cores were replaced by thin ferromagnetic films. This tendency shifted again in 1970 when the progress made in miniaturizing the active components led to semiconductor internal memories with bipolar or metal oxide semiconductor (MOS) technologies. Finally, external memories still preserve their classical structure but the introduction of thin film heads and media has led to a spectacular increase in recording performance (Ciureanu, 1990).

The search for better and more sensitive material for magnetic sensing was done for these last few decades. Hence, this work is carried out to search for a good magnetic granular thin film, which has high magnetoresistance value.

Objective of Work

The recent discovery of giant magnetoresistance (GMR) in multilayer system and subsequently in granular films has stimulated world wide research activities, due to both its fundamental significance and its potential application to magnetic sensor. It has generally been agreed that in both multilayer system and granular films the GMR arises from spin-dependent scattering occurring either at the surface of or within the magnetic entity (Badia, 1997; Yu, 1994; Greaves, 1994).

The magnitude of the GMR which had been observed has been found to be a sensitive function of both the size and the concentration of the ferromagnetic particles in the alloy (Badia, 1997; Yu, 1995).

So far, much attention has been paid to this problem both experimentally and theoretically, but it is still far from being understood. Most of the experimental work has focused on as-deposition and post-deposition annealing, which can produce good film for study (Badia, 1997; Yu, 1994).

In this research, the aims of work are as follows:

1. To find out the suitable parameters and conditions for producing good quality films.
2. To investigate the effects of composition and thickness on the magnetic properties of the magnetic thin films

3. To investigate the surface morphology and structure of the films
4. To set-up a simple four point probe system for the measurement of the magnetoresistance effect

Thesis Content

A general outline of the current status of the research work on magnetic thin films and its application has been given in this chapter. A thorough literature review is given in chapter II. Subsequently, basic theories of thin films, sputtering and magnetoresistance effect are discussed in chapter III. The following chapter (chapter IV) mainly deals with the methodology of the project. The experimental results are discussed in chapter V. Conclusions and suggestions are given in chapter VI.

CHAPTER II

LITERATURE REVIEW

Introduction

Giant magnetoresistance (GMR) has been discovered first in Fe/Cr multilayers by Baibich in 1988 (Baibich, 1988; Kobayashi, 1994; Chaiken, 1993) and subsequently in many other multilayers, such as Ni-Fe/Cu (Nakatani, 1992), CoFe/Cu (Kanai, 1993), Co/Cu (Rupp, 1993; Kobayashi, 1994), etc., in which antiferromagnetically coupled layers are separated by non-magnetic interlayers. Recently, GMR has also been found in magnetic granular thin films, such as NiFeAg (Badia, 1997; Greaves, 1994; Wiggins, 1996), CoCu (Jackson, 1996; Yu, 1995), CoAg (Zhang, 1997; Tsoukatos, 1993), etc., and this has provided a promising application in the magnetic record industry.

In Chang's (1996) paper, he proposed that magnetoresistance effect can be roughly classified by their origin into several categories namely, ordinary magnetoresistance (OMR), anisotropic magnetoresistance (AMR), giant