UNIVERSITI PUTRA MALAYSIA

PREPARATION AND CHARACTERIZATION OF Sr-YIG AND YIG-PVA COMPOSITE

Mohd Shamsul Ezzad Shafie

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BY

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FACULTY OF SCIENCE
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Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfilment of the requirement for the degree of the Master of Science

August 2008

DEDICATION

I would like to dedicate this thesis to:

- My family members

'Shafie Bin Awang, Norizah Bt Mat, Mohd Shamsul Rizal and Siti Norhazlina'

For teaching me these words,

"Hidup adalah segugus pengalaman
yang mengajar kita menafsir
dan mengenal untung nasib
antara kebahagiaan
atau takdir yang rapuh
kita pasti terpalit warnanya"

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in Fulfilment of the requirement for the degree of Master of Science

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Mohd Shamsul Ezzad Shafie

August 2008

Chairman : Associate Professor Dr. Mansor Hashim, PhD

Faculty : Science

This thesis deals with the subject of magnetic properties utilizing iron garnet materials. The main purpose of this project is to prepare of $Y_{3.0-X}Sr_XFe_5O_{12}$ and develop of YIG-PVA composite films. In addition, other properties including Q-factor, microstructure and XRD had also been studied. For powder preparation, seven garnet powder samples were prepared which are $Y_{3.0-X}Sr_XFe_5O_{12}$ (x = 0 to 2.5), in the interest of 0.5 value. From the results, the highest permeability obtained at sample $Y_{3.0}Fe_5O_{12}$ (YIG) which is 1.58. The lowest loss factor is 7.41, which is obtained from sample $Y_{1.5}Sr_{1.5}Fe_5O_{12}$. From the XRD characterization, the peak changing from 32.31° to 32.89°, indicating the transition from YIG to Strontium based iron garnet. From the SEM analysis, the $Y_{2.0}Sr_1Fe_5O_{12}$ has the largest grain size while Y3S0 exhibit smallest grain size. As a conclusion, this sample can be utilized for high frequencies applications. Considering the best microstructure, highest permeability, lower LF, the best sample is YIG. It was chosen as filler in preparation polymer composite. For polymer composite preparation, the composites consisted of polyvinyl alcohol (PVA) and YIG were prepared by casting technique. YIG (1 wt%) and YIG (5 wt%) prepared as filler in polyvinyl alcohol (PVA) as polymer composite. Both YIG exhibit similar XRD patterns to standard YIG sample including extra peak for PVA at 40˚. Compared to YIG (1 wt%), the YIG (5 wt%) was more effective to improve the magnetic properties of the composites because of its network structure. In conclusion, a certain high level of filler content was proven to be necessary for the promotion of magnetic properties in oriented composite.

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

PENYEDIAAN DAN PENCIRIAN Sr-YIG DAN YIG-PVA KOMPOSIT

Oleh

Mohd Shamsul Ezzad Shafie

Ogos 2008

Pengerusi : Professor Madya Dr. Mansor Hashim, PhD

Fakulti : Sains

Thesis ini menjuruskan penyelidikan berkaitan bahan magnetik menggunakan bahan garnet sebagai asasnya. Tujuan sebenar penyelidikan ini adalah untuk menyediakan $Y_{3.0-X}Sr_XFe_5O_{12}$ dan menghasilkan polimer komposit YIG-PVA. Sebagai tambahan, ciri-ciri lain seperti faktor-Q, mikrostruktur dan XRD juga telah dikaji. Untuk penyediaan hablur, tujuh kumpulan serbuk bahan garnet telah disediakan secara formula, iaitu $Y_{3-x}Sr_x Fe_5O_{12}$, (x = 0 sehingga 2.5, dalam perbezaan nilai 0.5). Daripada penyelidikan, ketelapan tertinggi diperolehi dari sampel $Y_{3.0}Fe_5O_{12}$ (YIG) iaitu 1.58. Faktor kehilangan terendah adalah 7.41, dimana diperoleh daripada sampel $Y_{1.5}Sr_{1.5}Fe_5O_{12}$. Daripada pencirian XRD, puncak berubah daripada 32.31° ke 32.89°, menunjukkan peralihan daripada YIG kepada Strontium berasaskan garnet. Daripada analisa SEM, $Y_{2.0}Sr_1Fe_5O_{12}$ mempunyai saiz butiran terbesar manakala YIG mempamerkan saiz butiran terkecil. Sebagai kesimpulan, sampel ini boleh digunakan untuk applikasi frekuensi peringkat tinggi. Dengan mempertimbangkan mikrostruktur terbaik,

ketelapan tertinggi, LF terendah, sampel terbaik adalah YIG. Ia telah dipilih sebagai bahan isian dalam penyediaan polimer komposit. Untuk penyediaan polimer komposit, komposit yang terdiri oleh polyvinyl alcohol (PVA) dan YIG telah disediakan menggunakan kaedah tebaran daripada campuran YIG dan PVA. Daripada analisa SEM, $Y_{2.0}Sr_1Fe_5O_{12}$ mempunyai saiz butiran terbesar manakala YIG mempamerkan saiz butiran terkecil. Sampel ini boleh digunakan untuk aplikasi frekuensi tinggi. Dengan mempertimbangkan butiran terbaik, ketelapan tertinggi, factor kehilangan yang lebih rendah, sampel terbaik adalah sampel YIG dan ia dipilih sebagai bahan isian dalam penyediaan polimer komposit. . YIG (1 wt%) dan YIG (5 wt%) disediakan sebagai bahan isian di dalam polyvinyl alcohol (PVA) sebagai polimer komposit. Kedua-dua mempamerkan bentuk XRD yang serupa dengan piawai sampel YIG termasuk puncak tambahan untuk PVA pada 40˚. Dibandingkan dengan YIG (1 wt%), YIG (5 wt%) adalah lebih efektif untuk meningkatkan bahan magnetik komposit kerana struktur jaringannya. Kesimpulannya, paras kandungan bahan isian tertentu telah dibuktikan perlu untuk menggalakkan peningkatan magnetik dalam orientasi komposit.

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I certify that an Examination Committee met on 1 August 2008 to conduct the final examination of Mohd Shamsul Ezzad Shafie on his Master of Science thesis entitled "Preparation and characterization of Sr-YIG and YIG-PVA Composite" in accordance with Universiti Putra Malaysia (Higher Degree) Act 1980 and Universiti Putra 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 has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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Date: 9 April 2009

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.

MOHD SHAMSUL EZZAD SHAFIE

Date:

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol

Greek Symbol

μ	permeability of ferrite core	
μ_i	initial permeability	
μ'	real part of permeability	
μ''	imaginary part of permeability	
μ_o	permeability of free space	
μ_r	relative permeability of material	
μ_B	The Avogadro or Loschmidt number	
$\tan \delta$	loss tangent	
$\tan \delta_{tot}$	total loss tangent	
π	pi (22/7)	
γ	gyromagnetic ratio	
τ	relaxation time	s
θ	theta	^oC
ω	angular frequency	Hz
λ_S	average point of magnetostriction	m
α_x	directional cosines	
θ_B	Bragg's Angle	
λ	wavelength of electromagnetic wave	m
ε	subsequent path	
φ	phase difference	

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol

Other Symbol

D_o	outer diameter of film	meter
D_i	inner diameter of film	meter
t	thickness of film	meter
f	measured frequency	Hertz
f_r	resonance frequency	Hertz
H	magnetic field	Oersted or A/m
B	magnetic induction	Gauses or Teslas (werbers / m^2)
c	velocity of light in free space	m /s^2
R_s	series loss resistance	ohm
L_s	series inductance	Henry
$\Delta(2\theta)$	Difference in 2θ angles / Line Breadth	
XRD	X-Ray Diffraction	

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nine years of worldwide revolutionary developments in nanoscience, combining physics, chemistry, material science, theory and even biosciences, have brought us to another level of understanding. Nanotechnology becomes a key word of public interest, since even politician and economists realized the social power of nanotechnological development. Nanotechnology is called the technology of the next century, coming after microtechnology. Nanotechnology unfortunately also becomes a catchword for people with ambitions in science fiction.

Nanoparticles themselves had been around and studied long before the words were coined. For example, many of the beautiful colors of stained glass windows are result of the presence of small metal oxide clusters in the glass, having a size comparable to the wavelength of light. Particle of different sizes scatter different wavelength of light, imparting different colors to the glass. Small colloidal particles of silver are a part of the process of image formation in photography. Water at ambient temperature consists of clusters of hydrogen-bonded water molecules. Nanoparticles are generally considered to be a number of atoms or molecules bonded together with a radius of <100nm. A nanoparticles is 10^{-9} m or 10Å, so particles having a radius of about ≤1000Å can be considered to be nanoparticles.

1.2 Ferrites

The history of ferrites (magnetic oxides) and their applications have been known for several centuries ago. The loadstone (magnetite, Fe_3O_4), a natural non-metallic solid, may attract iron was first described in known Greek writings about 800 B.C. Much later, the first application of magnetite was as 'Lodestones' used by early navigators to locate magnetic North. That is the first scientific significance was appreciated, after the first technical magnetic material because it formed the first compass (Crangle, 1977). The first scientific study of magnetism named De Magnete was published by William Gilbert in 1600. Later, in 1819 Hans Christian Oersted observed that an electric current in a wire affected a magnetic compass needle.

Naturally occurring magnetite is a weak 'hard' ferrite. 'Hard' ferrites possess a magnetism which is essentially permanent. Originally manufactured in a few select shapes and sizes, primarily for inductor and antenna applications, 'soft' ferrite has proliferated into countless sizes and shapes for a multitude of uses. Furthermore, ferrites are used predominately in three areas of electronics: low level applications, power applications, and Electro-Magnetic Interference (EMI) suppression. The breadth of application of ferrites in electronic circuitry continues to grow. The wide range of possible geometries, the continuing improvements in material characteristics and their relative cost-effectiveness make ferrite components the choice for both conventional and innovative applications.

Basically, ferrites are ceramic materials, dark grey or black in appearance and very hard and brittle. Ferrites may be defined as magnetic materials composed of oxides containing ferric ions as the main constituent (the word ferrite comes from the Latin "ferrum" for iron) and classified as magnetic materials because they exhibit ferrimagnetic behavior. The ferrites, in powder or thin film forms, can be prepared by high-temperature solid-state reaction method, sol–gel method, coprecipitation, pulsed laser deposition, high-energy ball milling and hydrothermal technique.

A ferrite core is made by pressing a mixture of powders containing the constituent raw materials to obtain the required shape and then converting it into a ceramic component by sintering. The magnetic properties arise from interactions between metallic ions occupying particular positions relative to the oxygen ions in the crystal structure of the oxide. In the commercial ferrites, they can be divided into three important classes, with each one having a specific crystal structure, namely:

1. Soft ferrite with the garnet structure such as the microwave ferrites (e.g: YIG).
2. Soft ferrites with the cubic spinel structure such as NiZn-, MnZn-, and MgMnZn ferrites.
3. Hard ferrites with the magnetoplumbite (hexagonal) structure such as Ba and Sr hexaferrites.

Ferrites are widely used in transformer and inductors for telecommunications, power conversion and interference suppression. Much of the ferrite-related research took place after the 1950s, thanks to a technology expansion in the fields of radio,