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STRUCTURAL, MAGNETIC AND MICROWAVE PROPERTIES OF BISMUTH FERRITE CERAMIC WITH YTTRIUM SUBSTITUTION PREPARED VIA MODIFIED THERMAL TREATMENT METHOD

RAHIMAH BINTI MUSTAPA ZAHARI

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

December 2021

DEDICATION

In appreciation of their love, doa', sacrifice, encouragement, advice, help, and support, this thesis is dedicated to my beloved family. They are my parent, my husband, my daughter, my son and my siblings.

Maznah Binti Mohamed Noor
Mustapa Zahari Bin Mohamad Yusof

MD Farid Bin MD Asni
Nur Fatihah Binti MD Farid
Muhammad Al-Fatih Bin MD Farid

Muhammad Fauzi Bin Mustapa Zahari
Roslina Binti Mustapa Zahari
Muhammad Alif Bin Mustapa Zahari

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

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RAHIMAH BINTI MUSTAPA ZAHARI

December 2021

Chair : Professor Abdul Halim Bin Shaari, PhD
Faculty : Science

Bismuth ferrite ($BiFeO_3$ or BFO) with a perovskite structure is one of the multiferroic materials that shows simultaneous coexistence of antiferromagnetic and ferroelectric properties at room temperature, with antiferromagnetic Néel temperature, T_N ~370 °C and ferroelectric Curie temperature, T_C ~820–850 °C. Based on previous reports, bulk BFO suffers from high impurity phase due to the difficulty in synthesizing single-phase polycrystalline BFO because of the narrow range stability of temperature region, and weak magnetism. Although BFO materials have been extensively studied in the past few years, there are only few reports on Yttrium (Y) substitution at the Fe-site of BFO system. This thesis reports the effect of Y substitution on the structural, magnetic, and microwave properties of BFO. Also, the effect of different prepared temperatures was studied. Y-substituted bismuth ferrites ($BiFe_{1-x}Y_xO_3$ with x = 0.0, 0.1, 0.2, 0.3, 0.4 and 0.5) ceramics were synthesized via modified thermal treatment method. Three series of samples (or sample batches) were synthesized via modified thermal treatment method. The samples were calcined at 550 °C and sintered at three different temperatures. Batch-1 samples, Batch-2 samples and Batch-3 samples were sintered at 600 °C, 650 °C and 700 °C, respectively. The structural, magnetic and microwave properties of $BiFe_{1-x}Y_xO_3$ samples were characterized by X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), vibrating-sample magnetometer (VSM), and microwave network analyzer (MNA).

The XRD analysis showed that the BFO sample was matched to rhombohedral structure with R3c space group. A structural transition has been found to occur with increasing Y concentration. For Batch-1 samples, the structural transition has occurred from rhombohedral R3c (x = 0.0) to orthorhombic Pnma (x = 0.1-0.5). For Batch-2 and Batch-3 samples, the structural transition has occurred from rhombohedral R3c (x = 0.0-0.1) to orthorhombic Pnma (x = 0.2-0.4), and finally to cubic Fm-3m (x = 0.5), respectively.

FESEM analysis showed clear grain boundaries with well-defined grain structures of BFO. Also, FESEM analysis revealed that Y substitution has decreased the grain sizes of BFO sample. For Batch-1, Batch-2 and Batch-3 samples, the grain sizes decreased from 165 nm to 38 nm; 201 nm to 56 nm and 354 nm to 90 nm, respectively. The highest value of grain size of about 354 nm was observed in the pure BFO sample from Batch-3. In general, the grain sizes of all the samples were increased with increasing sintering temperatures.

The magnetic analysis showed that sample x = 0.2 in each sample batches indicated the enhancement of saturation magnetization, M_s. The M_s value at x = 0.2 from Batch-1 and also from Batch-2 was 0.17 emu/g, meanwhile the M_s value at x = 0.2 from Batch-3 was 3.95 emu/g. The highest remnant magnetization, M_r value of about 1.21 emu/g was observed for sample x = 0.2 from Batch-3. Pure BFO sample from Batch-1 had the highest coercive force, H_c value of 146.08 Oe. The magnetic behavior of BFO samples changed from weak-ferromagnetic to antiferromagnetic with the increase of sintering temperatures. Also, with the increase of sintering temperatures, the hysteresis loops for samples x = 0.1, 0.2, 0.3, 0.4, and 0.5 became larger and the saturation magnetization increased.

The microwave properties of all the samples were measured by the MNA at the frequency range between 8 and 12 GHz (X-band). For the one-port method, both the magnitude and phase of the reflection coefficient is good because of the metal-backed termination at end of the sample which will give stronger combined reflection at the front face of the sample. The minimum reflection loss, RL_{min} of -8.60 dB at 10.54 GHz was observed for sample x = 0.1 from Batch-2 and -5.25 dB at 9.90 GHz for sample x = 0.0 from Batch-3. The 3 mm thick sample of the pure BFO which was sintered at 600 °C indicated the lowest RL of -19 dB at 8 GHz which is much higher compared to the pure BFO sample measured at the thickness of 1 mm. The RL_{min} reflects the microwave absorption properties of the prepared samples. Therefore, the results suggest that the microwave absorption properties of all the samples can be manipulated by changing the amount of yttrium substitution into BFO compound and the thickness of the samples. Also, the results suggest that sample x = 0.2 as the potential ferromagnetic applications which possess a high value of M_s making it suitable for the fast processing and higher data storage magnetoelectric random-access memories (MERAM) devices.

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

CIRI-CIRI STRUKTUR, MAGNET DAN MIKROGELOMBANG SERAMIK BISMUT FERIT DENGAN PENGGANTIAN YTTRIUM DISINTESIS MELALUI KAEDAH RAWATAN SUHU YANG DIUBAHSUAI

Oleh

RAHIMAH BINTI MUSTAPA ZAHARI

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Bismut ferit ($BiFeO_3$ atau BFO) dengan struktur perovskit adalah salah satu bahan multiferoik yang menunjukkan kewujudan bersama serentak sifat-sifat antiferomagnet dan feroelektrik pada suhu bilik, dengan suhu Néel antiferomagnet, T_N ~ 370 °C dan suhu Curie feroelektrik, T_C ~ 820-850 °C. Berdasarkan kajian-kajian yang lalu, BFO pukal mengalami kerencatan oleh fasa bendasing yang tinggi menyebabkan kesukaran dalam sintesis fasa-tunggal BFO polihablur kerana kestabilan julat rantau suhu yang sempit, dan kemagnetan yang lemah. Walaupun bahan-bahan BFO telah dikaji dengan meluas dalam beberapa tahun kebelakangan ini, hanya terdapat sedikit laporan mengenai penggantian Ytrium (Y) di tapak-Fe sistem BFO. Tesis ini melaporkan kesan-kesan penggantian Y terhadap sifat-sifat struktur, magnet dan mikrogelombang BFO. Juga, kesan suhu penyediaan yang berbeza dikaji. Seramik Y-gantian bismut ferit ($BiFe_{1-x}Y_xO_3$ dengan x = 0.0, 0.1, 0.2, 0.3, 0.4 dan 0.5) disintesiskan melalui kaedah rawatan suhu yang diubahsuai. Tiga siri sampel (atau kelompok sampel) disintesiskan melalui kaedah rawatan suhu yang diubahsuai. Sampel-sampel itu dikalsinkan pada 550 °C dan disinterkan pada tiga suhu yang berbeza. Sampel kelompok-1, sampel kelompok-2 dan sampel kelompok-3 masing-masing disinterkan pada suhu 600 °C, 650 °C dan 700 °C. Sifat-sifat struktur, magnet dan mikrogelombang sampel $BiFe_{1-x}Y_xO_3$ dicirikan oleh pembelauan sinar-X (XRD), mikroskopi elektron pengimbasan pancaran medan (FESEM), magnetometer sampel-bergetar (VSM), dan penganalisis rangkaian mikrogelombang (MNA).

Analisis XRD menunjukkan bahawa sampel BFO dipadankan dengan struktur rombohedron dengan kumpulan ruang R3c. Peralihan struktur didapati berlaku dengan peningkatan kepekatan Y. Untuk sampel kelompok-1, peralihan struktur telah berlaku dari rombohedron R3c (x = 0.0) ke ortorombik Pnma (x = 0.1-0.5). Untuk sampel-sampel kelompok-2 dan kelompok-3, peralihan struktur telah berlaku masing-masing dari rombohedron R3c (x = 0.0-0.1) ke ortorombik Pnma (x = 0.2-0.4), dan akhirnya ke kubik Fm-3m (x = 0.5).

Analisis FESEM menunjukkan sempadan butiran yang jelas dengan struktur butiran BFO yang didefinisikan dengan baik. Juga, analisis FESEM mendedahkan bahawa penggantian Y telah mengecilkan saiz butiran sampel BFO. Untuk kelompok-1, kelompok-2 dan kelompok-3, saiz butiran masing-masing mengecil dari 165 nm ke 38 nm; 201 nm ke 90 nm; dan 354 nm ke 90 nm. Nilai tertinggi saiz butiran diperhatikan sekitar 354 nm dalam sampel BFO tulen daripada kelompok-3. Secara umumnya, saiz butiran untuk kesemua sampel meningkat dengan peningkatan suhu-suhu pensinteran.

Analisis magnet menunjukkan bahawa sampel x = 0.2 di dalam setiap kelompok sampel menandakan peningkatan pemagnetan tepu, M_s. Nilai M_s pada x = 0.2 daripada kelompok-1 dan juga daripada kelompok-2 adalah 0.17 emu/g, sementara nilai M_s pada x = 0.2 daripada kelompok-3 ialah 3.95 emu/g. Nilai tertinggi kemagnetan baki, M_r kira-kira 1.21 emu/g telah diperhatikan pada sampel x = 0.2 daripada kelompok-3. Sampel BFO tulen daripada kelompok-1 mempunyai nilai daya paksa, H_c yang tertinggi sebanyak 146.08 Oe. Perilaku magnet sampel-sampel BFO berubah daripada feromagnet lemah kepada antiferromagnet dengan peningkatan suhu-suhu pensinteran. Juga, dengan peningkatan suhu-suhu pensinteran, gelung histeresis untuk sampel-sampel x = 0.1 hingga 0.5 menjadi lebih besar dan pemagnetan tepu meningkat.

Sifat-sifat mikrogelombang kesemua sampel telah diukur oleh MNA pada julat frekuensi di antara 8 dan 12 GHz (jalur-X). Untuk kaedah satu-port, kedua-dua magnitud dan fasa pekali pantulan adalah bagus kerana penamatan berbelakang-logam dekat hujung sampel di mana ianya akan memberikan pantulan tergabung yang lebih kuat pada muka depan sampel tersebut. Kehilangan pantulan minimum, RL_{min} sebanyak -8.60 dB pada 10.54 GHz diperhatikan untuk sampel x = 0.1 daripada kelompok-2 dan -5.25 dB pada 9.90 GHz untuk sampel x = 0.0 daripada kelompok-3. Sampel BFO tulen berketebalan 3 mm yang telah disinter pada 600 °C telah menunjukkan *RL* terendah sebanyak -19 dB pada 8 GHz di mana ianya lebih tinggi dibandingkan dengan sampel BFO tulen yang diukur pada ketebalan 1 mm. RL_{min} tersebut mencerminkan sifat-sifat penyerapan mikrogelombang terhadap sampel-sampel yang disediakan. Lantaran itu, keputusan mencadangkan bahawa sifat-sifat penyerapan mikrogelombang untuk kesemua sampel boleh dimanipulasi dengan mengubah jumlah penggantian yttrium ke dalam sebatian BFO dan ketebalan sampel-sampel tersebut. Juga, keputusan mencadangkan bahawa sampel x = 0.2 sebagai aplikasi feromagnet berkeupayaan yang memiliki nilai M_s yang tinggi membuatkan ianya sesuai untuk pemprosesan pantas dan peranti ingatan capaian-rawak magnetoelektrik (MERAM) storan data yang lebih tinggi.

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This thesis was 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 were as follows:

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Date: 9 March 2022

Declaration by graduate student

I hereby confirm that:

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LIST OF ABBREVIATIONS

ABO_3	Perovskite structures
BFO or $BiFeO_3$	Bismuth ferrites
EM	Electromagnetic
TGA	Thermogravimetric analysis
XRD	X-ray diffraction
FESEM	Field emission scanning electron microscope
EDX	Energy-dispersive X-ray spectroscopy
VSM	Vibrating-sample magnetometer
MNA	Microwave network analyzer
Fe_3O_4	Iron (II,III) Oxide or Ferrosoferric Oxide or Magnetite
Fe^{2+}	Iron(II) ions or ferrous ion
Fe^{3+}	Iron(III) ions or ferric ion
$BaTiO_3$	Barium titanate
$KNbO_3$	Potassium niobate
K_2SeO_4	Potassium selenate
Cs_2CdI_4	Cesium tetraiodocadamate
$BaNiF_4$	Barium tetrafluoronickelate
TM	Transverse magnet
TE	Transverse electric
MUT	Material under test
FEM	Finite element method
NRW	Nicholson-Ross-Weir

FDTD	Finite difference time domain
MoM	Method of moment
MATLAB	Matrix laboratory
DSC	Differential scanning calorimetry
DTA	Differential thermal analysis

LIST OF SYMBOLS

T_C	Curie temperature
T_N	Néel temperature
ω	Angular frequency of a wave (rad/s)
σ	Conductivity (S/m)
χ	Magnetic susceptibility
f	Frequency (Hz)
E	Electric field intensity (V/m)
D	Electric flux density (C/m^2)
J	Electric current density (A/m^2)
H	Magnetic field intensity (A/m)
B	Magnetic flux density (T)
ρ	Electric charge density (C/m^3)
Z_o	Impedance of free space (377 Ω)
γ	Complex propagation constant (1/m)
α	Attenuation constant (1/m)
β	Phase constant (rad/m)
μ_o	Permeability of free space, $\mu_o = 1.257 \times 10^{-6}$ H/m
ε_o	Permittivity of free space, $\varepsilon_o = 8.854 \times 10^{-12}$ F/m
ε_r^*	Complex relative permittivity
μ_r^*	Complex relative permeability
tan δ	Loss tangent
M_s	Saturation magnetization (emu/g)

M_r	Remnant magnetization (emu/g)
H_c	Coercivity or coercive force or coercive field (Oe)
S-parameters	Scattering-parameters (e.g. S_{11}, S_{21}, S_{12}, S_{22})
RL_{min}	Minimum reflection loss (dB)

CHAPTER 1

INTRODUCTION

1.1 Multiferroics

The term "multiferroic" was first introduced by Hans Schmid in 1994, which describes a class of materials that show simultaneous coexistence of at least two or more ferroic order properties (i.e. ferroelectricity, ferromagnetism, ferroelasticity, ferrotoroidic, ferrimagnetic) in the same material (Eerenstein et al., 2006; Pradhan et al., 2005) (Figure 1). The interaction or coupling between the magnetic and electrical order parameters in the multiferroic materials is called the magnetoelectric (ME) effect (Ding et al., 2011; Wang et al., 2006). On the other hand, the magnetoelectric effect describes the effect of the external magnetic field induces electric polarization or the external electric field induces magnetic moment on the physical properties of crystals (Siratori et al., 1992). From the applications aspect, the magnetoelectric coupling effect could permit data to be written electrically and read magnetically such as ferroelectric random access memory (FeRAM) and magnetic data storage (Mikolajczyk et al., 2008). Multiferroic materials also show great potential in spintronics devices, sensors and transducers. (Li et al., 2007b; Mukherjee et al., 2015; Mukherjee et al., 2012b). Some examples of a material exhibiting multiferroics behavior are $TbMnO_3$, $LuMnO_3$, $LuFe_2O_4$, "PZTFT", $BiFeO_3$ and $BiMnO_3$ (Cheong & Mostovoy, 2007; Evans et al., 2013; Rao et al., 2012). Among these materials, $BiFeO_3$ has attracted much attention because it has relatively high ferroelectric Curie temperature (T_C) and antiferromagnetic Nèel temperature (T_N) at room temperature as compared with other multiferroic materials (Majid et al., 2015).

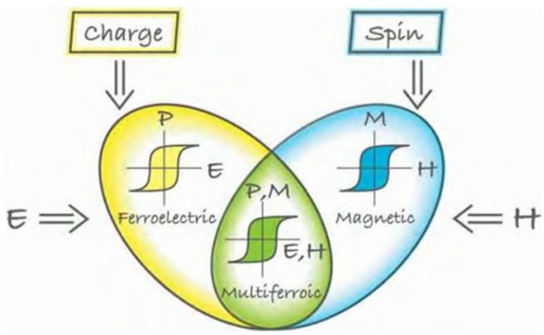

Figure 1: Schematic diagram of multiferroic materials (Areef Billah, 2016)

1.2 Bismuth Ferrite

Bismuth ferrite ($BiFeO_3$ or BFO) is one of the multiferroic family, that possess the existence of antiferromagnetic and ferroelectric ordering simultaneously at room temperature (Ruette et al., 2004; Vijayanand et al., 2009). BFO has captured great attention due to its distinctive ability to maintain both electric and magnetic dipole moments at room temperature (Mikolajczyk et al., 2008). BFO has a rhombohedral distorted perovskite structure with space group R3c (Luo et al., 2014). BFO also has an antiferromagnetic Nèel temperature, T_N ~ 370 °C, and ferroelectric Curie temperature, T_C ~ 830 °C (Miao et al., 2008; Mukherjee et al., 2012b).

1.3 Microwave Absorption as Part of Microwave Studies in BFO

The study of the microwave absorption properties in BFO has captured great attention nowadays due to its applications and benefits. Microwave absorption is dominated by the complex relative permittivity and permeability of a material. The development of smartphone technologies, wireless, or defense for anti-radar coatings (Ramezanzaeh et al., 2017; Rusly et al., 2018; Sharbati and Amiri, 2017) produces radiations and electromagnetic interference (EMI) (Mousavinia et al., 2014; Sharbati and Amiri, 2017). These activities can cause serious problems to human health and disturb the operation of machines (Singh et al., 2018). Thus, it is important to produce a material which can absorb the microwaves energy to protect the humans from electromagnetic hazards known as microwave absorber material (MAM).

Good performance of MAMs can be achieved by controlling several parameters such as the chosen element and amount of doping, thickness of the absorber material, synthesis process, and temperature. Several studies have been reported that BFO can be used as good MAMs (Sun et al., 2020; Mohd Idris et al., 2016). Recently, BFO composites have been expected to exhibit high-efficiency MAMs because of its good magnetic and electric properties. BFO has a special feature combining the G-type antiferromagnetic spin ordering with the T_N ~ 370 °C and ferroelectric properties with the T_C ~ 830 °C simultaneously at room temperature. Furthermore, it exhibits featured frequency response in the microwave fields due to the crystal structure distortion, defects and its magnetoelectric (ME) coupling.

1.4 Problem Statement

Various synthesis method was introduced to synthesize the BFO compound such as the conventional solid-state reaction method, rapid liquid phase sintering method, mechanochemical method, microwave sintering method, and several chemical routes such as wet chemical method, sol-gel method, hydrothermal method, modified Pechini method, auto-combustion method, ferrioxalate precursor method and microwave-assisted method. However, the conventional solid-state reaction method uses high reaction temperatures and produces coarser powder with micro-sized particles (Nalwa & Garg, 2008). In the solid-state reaction (Achenbach et al., 1967; Kumar et al., 2000) and sol-gel method (Kim et al., 2005), the synthesized BFO powders were leached with nitric acid to eliminate the impurity phases. Most of the chemical routes were chosen to fabricate the BFO nanoparticles. Most of the techniques involve the use of low reaction temperature and produces nano-sized particles. However, they require several parameters such as temperature, pressure, time, solvent, chelating agent and polymerizing agent. Other techniques like the microwave sintering method (Cai et al., 2013) and mechanochemical method (Egorysheva et al., 2013) are laborious and time-consuming. In this study, the thermal treatment method is applied to decrease the sintering temperature of BFO as well as to provide the nano-scale particles of BFO. Moreover, the thermal treatment method provides many advantages such as easy to handle, high flexibility, reproducibility with constant quality, environmentally friendly and capable to amend the chemical structure into desirable properties by controlling its particles sizes as well as the movement of the metallic ions and oxygen atoms during the heating process (Goodarz Naseri et al., 2011b). Synthesis and characterization of $BiFe_{1-x}Y_xO_3$ samples using modified thermal treatment method has been rarely done. Although the mentioned methods enhanced the ferroelectric properties of the BFO system, the magnetic properties remain inferior. Bulk BFO usually has a weak magnetic behavior or low magnetization value (Das et al., 2012; Najm et al., 2016; Suharno et al., 2014; Yan et al., 2013; Yang et al., 2010b) due to residual magnetic moments from canted spin structures (Pradhan et al., 2005) that hinders or limits its practical applications. BFO has a spiral spin structure with an incommensurate spiral period of ~62 nm, which prevents the net magnetization and the observation of the linear magnetoelectric effect (Mao et al., 2012). To overcome these problems, researchers have attempted to dope with alkaline earth metal, lanthanide, or rare-earth metal element like Ba, La, Sm, Gd and Y (Nalwa et al., 2008; Singh et al., 2014; Uniyal & Yadav, 2008; Yang et al., 2010a; Yuan et al., 2007) on A-site of BFO, or doping with Cr and Ti (Kumar & Yadav, 2011; Kumar & Yadav, 2007) on B-site of BFO, or co-doping with Gd and Co (Song et al., 2014b), Ba and Gd (Das et al., 2012), Y and Mn (Mukherjee et al., 2014a) and Eu and Mn (Zhu et al., 2017) on A- and B-sites of BFO. Previous works have shown that doping/substitution at Fe-sites could enhance the magnetization of BFO systems (Kumar & Yadav, 2011; Kumar & Yadav, 2007; Najm et al., 2016). The modified thermal treatment method corresponds to a modification technique that has been done to this method such as the use of nitric acid to dissolve the bismuth nitrate salt during the mixing process (Mustapa Zahari et al., 2017). Y^{3+} is a nonmagnetic ion and it was expected to give a possible contribution to the enhancement magnetic properties of BFO due to change in Fe-O-Fe bond angles (Najm et al., 2016). Furthermore, no literature has been found reporting on the microwave properties of $BiFe_{1-x}Y_xO_3$ ceramics at the X-band frequency range and the characteristics of Y-substitution using a modified thermal treatment method are not yet known. Recently, attempts have been made focusing on the absorption properties of BFO at 2-18 GHz in the form of composite (e.g. paraffin composite, epoxy resin composite, wax composite) (Luo et al., 2014; Rusly et al., 2020). However, less info has been reported on the absorption properties of BFO ceramics at room temperature and at 8-12 GHz. In this work, we have reported the structural, magnetic, and microwave properties of $BiFe_{1-x}Y_xO_3$ ceramics at room temperature prepared via a modified thermal treatment method.

1.5 Research Objectives

1. To synthesize $BiFe_{1-x}Y_xO_3$ samples with x = 0.0, 0.1, 0.2, 0.3, 0.4, and 0.5 using a modified thermal treatment method.
2. To study the effects of yttrium substitution at the Fe-site of BFO system on the structural and magnetic properties using the XRD, FESEM in conjunction with EDX, and VSM.
3. To study the effects of yttrium substitution on the microwave properties using a closed waveguide technique at the frequency range of 8-12 GHz. Microwaves characterization technique gives information on the reflection, transmission and absorption properties of the samples.
4. To study the effects of different sintering temperatures in $BiFe_{1-x}Y_xO_3$ (x = 0.0, 0.1, 0.2, 0.3, 0.4, and 0.5) samples on its structural, magnetic, and microwave properties using the XRD, FESEM, VSM and MNA analysis

1.6 Limitations

Lack of calcined powder to exhibit good magnetic properties in all samples requires the powder to be sintered at 50 °C higher than the calcination temperature in each batch of the samples. Calcination and sintering temperatures above 700 °C led to the melting of pellets. For electromagnetic studies, there are some limitations in the research work such as the frequency range is limited to the waveguide sensor which operates at only 8-12 GHz following the recommended frequency for rectangular waveguide (TE_{10}, WR90) (Rulf & Robertshaw, 1987), and also the thickness of the measured samples was thin, which was 1 mm.

1.7 Chapter Organization

The whole thesis contains six chapters. The first chapter describes a general introduction of the multiferroics compound and bismuth ferrites as one of the group members in the multiferroic family. The problem statements and research objectives are also stated in this chapter. The second chapter is the literature review section. This chapter reviews the bismuth ferrites as multiferroic material and their electrical and magnetic properties as well as methods to synthesize the bismuth ferrites. This chapter also summarizes the doping or substitution elements at the A-sites, B-sites, and co-doping at A- and B-sites of the bismuth ferrites system. The structural, morphological and magnetic analysis related to bismuth ferrites is reviewed. The previous works related to microwave measurement techniques, their limitations, and several research works related to microwave absorption studies of bismuth ferrites are also reviewed. The third chapter discusses the theory of magnetism which relevant to bismuth ferrites as a magnetic material. The earlier chapter describes the origin of magnetism and the classification of magnetic materials. This chapter also discusses the magnetic hysteresis loop, polarization in dielectrics, mechanism of dielectric polarization, ferroelectric behavior, and mechanism of multiferroic. The wave equation, the calculation of the reflection and transmission coefficient of a three-layered media, the Nicholson-Ross-Weir method to determine the complex permittivity and permeability from S_{11} and S_{21}, the half-wavelength effect due to sample thickness effect, and finally the reflection coefficient equation determined by microwave absorption measurement are described in brief at the end of this chapter. The fourth chapter discusses the experimental procedure such as the materials and methods to synthesize the $BiFe_{1-x}Y_xO_3$ samples. The characterization of $BiFe_{1-x}Y_xO_3$ samples using TGA, XRD, FESEM, EDX, VSM and MNA as well as its basic principle is discussed in brief in this chapter. The fifth chapter discusses the formation of BFO nanoparticles using a modified thermal treatment method. The thermal, structural, magnetic, and electromagnetic analysis of $BiFe_{1-x}Y_xO_3$ samples using TGA, XRD, FESEM, EDX, VSM, and MNA are discussed in this chapter. The last chapter of the thesis or the sixth chapter summarizes the conclusions and suggestions or recommendations in future work. This chapter also lists the references and appendices of the research work.

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