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Electric Voltage Response of Multiferroic Material Based on $BaTiO_3$-$BiFeO_3$ System in Single Phase

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Abstract

This research tries to synthesize ceramic as multiferroic material based on $BaTiO_3$-$BiFeO_3$ system, which $BaTiO_3$, an electric material is integrated into $BiFeO_3$ as multiferroic material in single phase. It is hoped that the integration of $BiFeO_3$ with electrical material, $BaTiO_3$ will provide magnetic field and electrical voltage response higher than those of $BiFeO_3$ itself. This research used sol-gel synthesis method using compound of a purity of 99.99% such as $Bi_5O(OH)_9.(NO_3)_4$, Fe $(NO_3)_3.9H_2O$, HNO_3, H_2O, Ba $(NO_3)_2$, TiO_2 and citric acid $C_6H_8O_7$ as fuel. It used weight ratio of $BaTiO_3$: $BiFeO_3$ = 1: 1.The calcination process was done at 350^oC for 4 hours and sintering process at 700,750 and 800^oC for 2, 4 and 6 hours respectively. To characterize ceramics, it was used X-Ray Diffraction (XRD) test using XRD Phillips PW 1835 type, 20^o-100^o diffraction angle and CuK_α, to confirm single-phase formation. Test of magnetic field effect on electric voltage response used function generator that will produce magnetic field. From result of XRD test, it is known that there is single phase which is dominat phase, $BaBiFe_2O_5$ more than 80% for all process conditions. The highest of electrical voltage response is given by ceramic sintered at 750^oC for 6 hours. This condition also produces ceramic with the largest percentage of dominant phase of 99.62%.

Keywords: *Magnetic Field, Electric Voltage Response, Sol-Gel, Multiferroic.*

1. Introduction

The multiferroic material is a class of materials that exhibits two or more ferrous phases and combines several ferroic properties, namely ferroelectric, ferromagnetic, ferroelasticity, and ferodicity. Electromagnetism and magnetism have been combined in a common discipline since the nineteenth century that led to Maxwell's equations. Currently, several studies are focused on materials that combine electrical and ferromagnetic properties [1,2]. The material is composed of ferroelectric-magnetic material is called multiferroic term. This magnetic property is generated from interactions between magnetic dipoles derived from the skin of electron-filled orbitals, while the electrical properties occur due to the local electric dipole [3]. A ceramic system that combines electrical materials ($BaTiO_3$) into multiferroic materials $BiFeO_3$ is widely developed for the enhancement of multiferroic properties of materials. The combination of magnetic, polar and piezo-elastic properties makes multiferroic materials very attractive for fundamental research but also technological applications because it could improve quality of multiferroic material. The present challenges are the discovery and manufacturing of multiferroic materials and structures that show large magneto-electric coupling at room temperature, and the development of accurate experimental characterization techniques [4]. The high room-temperature ME coupling in single phase of $BaTiO_3$-$BiFeO_3$ ceramics, provides a possibility of developing electrically or magnetically tunable thin-film devices [5.6.7.8]. It also increase magnetoelectric couping especially for ultimate memory devices application. In multiferroic magnetoelectric (ME) materials, coupling occurs between the magnetic and electric subsystems. This enables the control of dielectric polarization P by a magnetic field H and the manipulation of magnetization M by an electric field E [9.10].

The aim of this research is to know the effects of sinter temperatures and times of sol-gel process on the effect and response of magnetic and electric field. Process variables used are sinter temperature of 700,750 and 800^oC and sinter time of 2, 4 and 6 hours respectively. The characterization of the ceramic powder is X-Ray Diffraction (XRD) test to confirm the formation of a single phase and test of magnetic field effect on electric voltage response using function generator producing magnetic field. The basic compounds used are of pro-analysis. $Bi_5O(OH)_9.(NO_3)_4$, $Fe(NO_3)_3.9H_2O$, HNO_3, H_2O, $Ba(NO_3)_2$, TiO_2 and citric acid $C_6H_8O_7$ as fuel. The synthesis used weight ratio of $BaTiO_3$: $BiFeO_3$ = 1: 1.

2. Materials and Method

The method (sol-gel) used is same as with previous research [11,12] shown in Figure 1.

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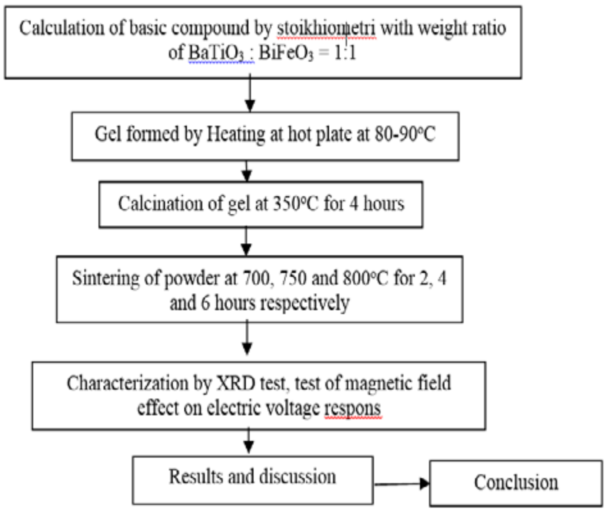

Fig.1. Flowchart of Multiferroic Ceramic Based on $BaTiO_3$-$BiFeO_3$ System Synthesized by Sol-Gel Method

Figure 1 shows that to produce single phase multiferroic ceramic based on $BaTiO_3$-$BiFeO_3$ system used calcination at 350°C for 4 hours and sintering at 700,750 and 800°C for 2, 4 and 6 hours respectively. It uses proxy of 99.99% such as $Bi_5O(OH)_9$. $(NO_3)_4$, $Fe(NO_3)_3.9H_2O$, HNO_3, H_2O, Ba $(NO_3)_2$, TiO_2 and citric acid $C_6H_8O_7$ as fuel. To confirm the single phase, it was used XRD test and to know the effect of external magnetic field on the response of electric voltage, it was used function generator to produce pro analysis magnetic field by giving effect to magnetoelectric material as the emergence of electric potential difference.

3. Results and Discussions

3.1 Results of X-Ray Diffraction Test

The results show that the method produce powder with XRD pattern is almost same for all condition as shown in Figure 2.

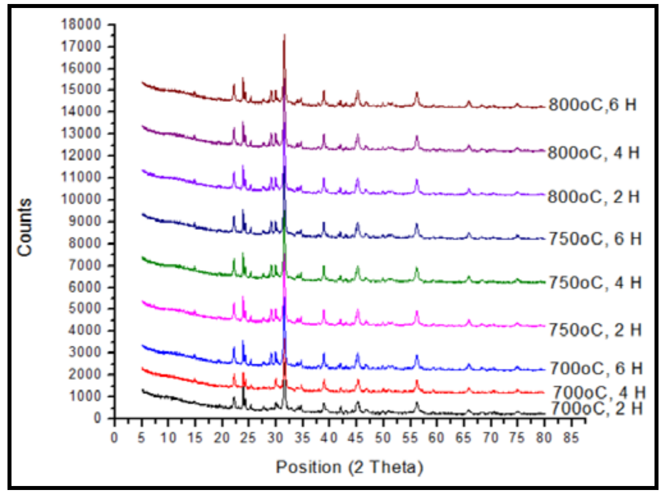

Fig.2. X-Ray Diffraction Pattern of Powder at Differences of Sintering Temperatures and Times

Figure 2 shows that ceramic at sintering temperature of 700°C and sintering time 2 and 4 hours have different pattern comparing with other condition especially at 25-30 degree position (2 Theta). Generally it is formed single phase as dominant phase, $BaBiFe_2O_5$ in difference percentage shown in Table 1.

Table 1: Percentage of Dominant Phase for All Variables.

Number	Sinter Treatment	$BaBiFe_2O_5$ (%)
1	700°C, 2 hours	82.71
2	700°C, 4 hours	83.05
3	700°C, 6 hours	92.74
4	750°C, 2 hours	95.98
5	750°C, 4 hours	96.21
6	750°C, 6 hours	99.62
7	800°C, 2 hours	97.17
8	800°C, 4 hours	95.08
9	800°C, 6 hours	93.55

Table 1 shows that sintering conditions at 700°C for 2 and 4 hours are insufficient conditions to produce a single phase, the percentages less than 85%. There are no conditions to produce single phase 100% and the highest percentage 99.62% belongs to ceramic at sintering temperature of 750°C and sintering time of 6 hours. There is increasing single phase percentage with increasing sintering temperatures and times but at sintering temperature of 800°C, the condition changed, the percentage decreases with increasing sintering times. It is caused by another oxide phase formed at higher sintering temperature.

3.2 Results of Electric Voltage Response Test

The results of electric voltage response at ceramic if ceramic is subjected to an external magnetic field shown in Figure 3, 4 and 5.

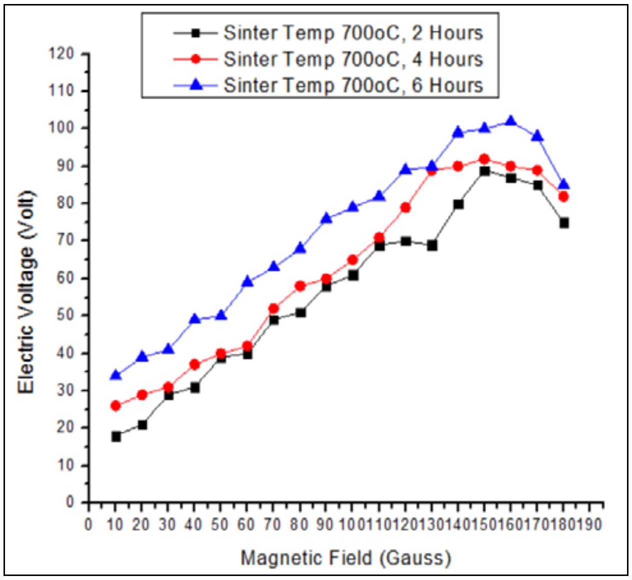

Fig. 3. Effects of Magnetic Fields on Electric Voltage Response of Ceramics at Sintering Temperature of 700^{o}C and Sintering Times of 2, 4 and 6 Hours

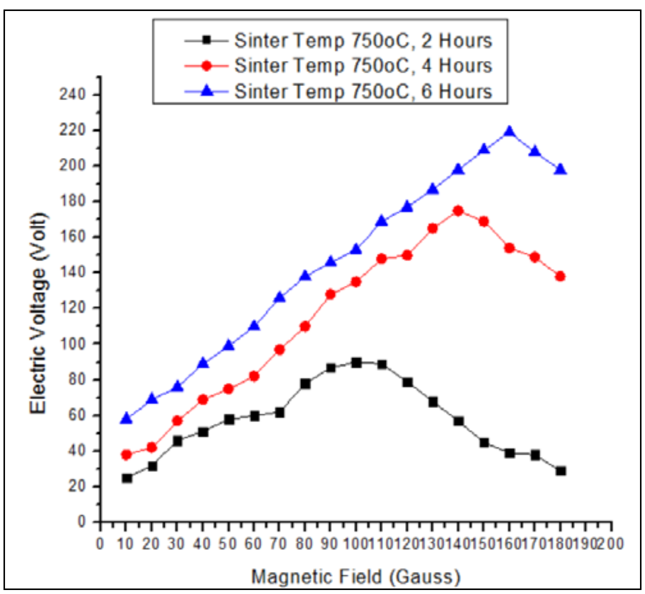

Fig. 4. Effects of Magnetic Fields on Electric Voltage Response of Ceramics at Sintering Temperature of 750^{o}C and Sintering Times of 2, 4 and 6 Hours

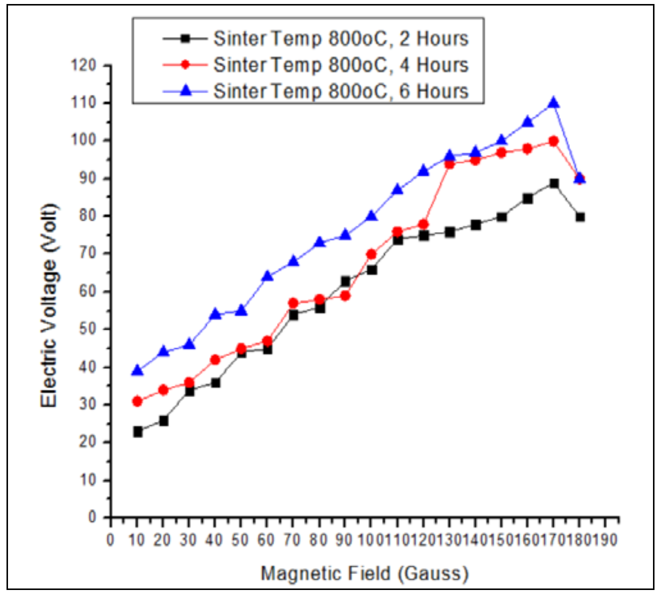

Fig.5. Effects of Magnetic Fields on Electric Voltage Response of Ceramics at Sintering Temperature of 800^{o}C and Sintering Times of 2, 4 and 6 Hours

Figures 3, 4 and 5 show that all ceramic samples have electric voltage response if the ceramics are given an external magnetic field. Increasing sintering times could increase electric voltage and the highest value of electric voltage belongs to sintering time of 6 hours for all sintering temperatures. Ceramics with sintering temperature of 750^{o}C has the highest response. The response decrease with increasing of sintering temperatures. It has relation between single phase formed and the response. The response decrease with decreasing of single phase percentage. The magnetoelectric coupling has strong effects on ceramics with higher of single phase percentage.

4. Conclusions

In this research, it has been produced multiferroic ceramics based on $BaTiO_3$-$BiFeO_3$ system due to be an electric voltage response if the material is given an external magnetic field. The system also produces single phase (dominant phase), $BaBiFe_2O_5$ more than 80% percentage. The response of electric voltage increase with increasing of sinter temperatures of 700-750^{o}C and then decrease at sinter temperatures of 800^{o}C. At each sinter temperatures, the response increase with increasing of sinter times. The highest respons belongs to ceramic with sinter temperatures of 750^{o}C and sinter time of 6 hours. There is a relation between percentage of single phase and value of electric voltage response. The response increase with increasing of percentage of single phase.

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