Investigation Physical and Electrical Properties of $Mn_{1-x}Mg_xFe_2O_4$ Ceramics

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ABSTRACT

This research investigates physical and electrical properties of $Mn_{1-x}Mg_xFe_2O_4$ ceramics were prepared by co–precipitation method. The ratio values of doping were varied with x = 0.3, 0.4 and 0.5. $Mn_{1-x}Mg_xFe_2O_4$ ceramics were calcined at 1100 °C and sintered at 1200 °C, 1300°C and 1400 °C respectively. The effects of Mg content and sintered temperatures on the phase formation by XRD, morphology by SEM and electrical properties were investigated.

The study found at ratio of x = 0.3 sintered at 1400 °C. The sample had maximumed of density at 3.58 g/cm^3. The XRD analysis of the as synthesized powders confirm the formation of the single phase $MnMgFe_2O_4$ cubic spinel structure. The microstructure exhibited a rectangular square grain in all samples. The average grain size of the ceramics increased from 7.7 μm to 13.7 μm. The dielectric constant and dielectric loss value increases when increases temperature.

Keywords: $MgMnFe_2O_4$;Ferrite ; Co–precipitation ; Dielectric constant ; Grain

Introduction

The dielectric material is a kind of half conductor, its property is to contain electric particle which is called capacitance. When we give the electric field to dielectric the polarization will happen. The dielectric material was first discovered in 1921. The barium titanate ($BaTiO_3$) is the material which is used to be an electric particle container because of its high with relative **[1]** besides this, there are many groups of dielectric material which is similar to barium titanate such as lead titanate, ($PbTi0_3$), lead zirconium titanate (PZT), lead tantanium zirconium titanate,(PLZT) and lead magnesium niobate (PMN) **[2]**. The dielectric material is adapted to use in the industrial and electronic widely. For example a diode transistor electric particle is made of dielectric material. This material usually composes of lead (Pb), it causes the evaporating (PbO) the oxide of burning lead while producing or destroying the material procedure which can be harmful to humans and environment widely. The researcher is interested in studying and developing the dielectric material with lead-free ceramics to replace the lead-based ceramics. The manganese magnesium ferrite ceramic ($Mn_{1-x}Mg_xFe_20_4$) that has a structure as spinal cubic ($A^{2+}B^{3+}O_4$) and can show the property of electricity at the high temperature. It is suitable for applying to use in electronic with high frequency as an electric particle and a resistor **[3, 4, 5]**.

So from the problems above, the researcher tries to synthesis the manganese magnesium ferrite ceramic ($Mn_{1-x}Mg_xFe_20_4$) in order to study and develop the leadless dielectric material to be used in the near future, according to study the effect of Mg content, sintered temperatures that effects the physical and electrical properties of ceramics.

Experimental procedure

$Mn_{1-x}Mg_xFe_2O_4$ (MMF) ceramics were prepared by co-precipitation method (x = 0.3, 0.4 and 0.5). Raw materials of $Mn(NO_3)_2$ (99.0%), $Mg(NO_3)_2$ (99.0%) and $Fe(NO_3)_3$ (98.0%) were mixed in their respective stoichiometry. The precipitation was carried out using drop wise of NaOH solution under constant stirring. The pH of the solution was constantly monitored as the NaOH solution was added. The precipitate was washed by double distilled water many times to remove NaOH (pH ≈ 7). The sample powders were dried and calcined at 1100 $^{\circ}$C for 2 h. Thereafter; calcined powders were remixed and pressed into 13.1 mm-diameter pellets and sintered 1200 $^{\circ}$C 1300 $^{\circ}$C and 1400 $^{\circ}$C for 4 h respectively. The phase formation of MMF powders and ceramics were analyzed and identified by X-ray diffraction (XRD, Philip PW 3040/60 X'Pert Pro). The microstructures of the specimens were observed by scanning electron microscopy (SEM, LEO1450VP). The densities of the sintered pellets were measured by the Archimedes method. Dielectric properties were measured by the precision impedance analyzer (Agilent 4263B) at 1 kHz.

Results and discussion

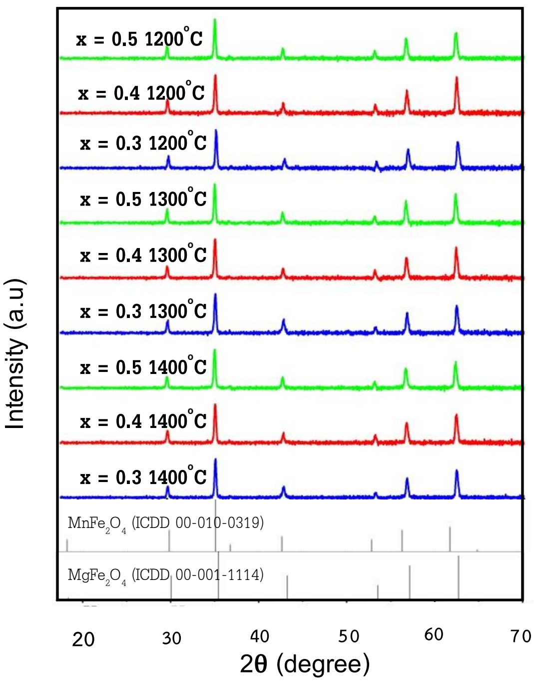

Fig 1. X-ray diffraction patterns of the $Mn_{1-X}Mg_xFe_2O_4$ (x = 0.3, 0.4 and 0.5) sintered at 1200 $^{\circ}$C 1300 $^{\circ}$C and 1400 $^{\circ}$C for 4 h.

Fig 1. Show XRD patterns of the $Mn_{1-X}Mg_xFe_2O_4$ six characteristic peaks at 30.27° 35.53° 43.16° 53.29° 56.97° and 62.50° corresponding to the crystal planes of a pure $MnFe_2O_4$ (ICDD 00-010-0319) and $MgFe_2O_4$ (ICDD 00-001-1114) with a cubic spinal structure and no characteristic peak of impurities are detected in the XRD pattern. **Fig 2.** Shows SEM micrographs of the MMF ceramics (x = 0.3, 0.4 and 0.5) sintered at 1200 $^{\circ}$C 1300 $^{\circ}$C and 1400 $^{\circ}$C for 4 h. The microstructure of MMF ceramics had exhibited a rectangular square grain in all samples and some pore exist in grain boundary. The average grain size increased from 7.7 μm to 13.7 μm and the density of the ceramics increased with decreasing Mg content. It is shown that clear grain boundary and uniformly distributed grain size could enhance the density of the MMF ceramics and may be advantageous to the electrical properties **[6].**

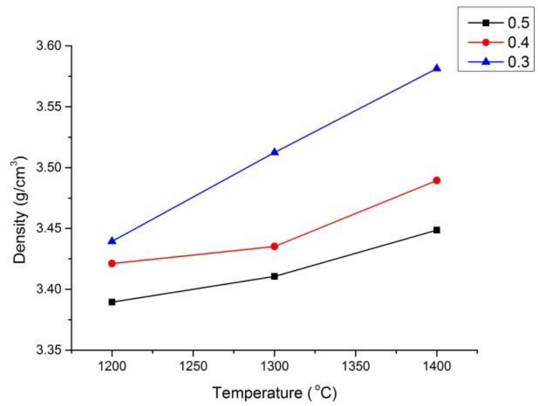

Fig 3. Density of the $Mn_{1-X}Mg_xFe_2O_4$ (x = 0.3, 0.4 and 0.5) sintered at 1200 $^{\circ}$C 1300 $^{\circ}$C and 1400 $^{\circ}$C for 4 h.

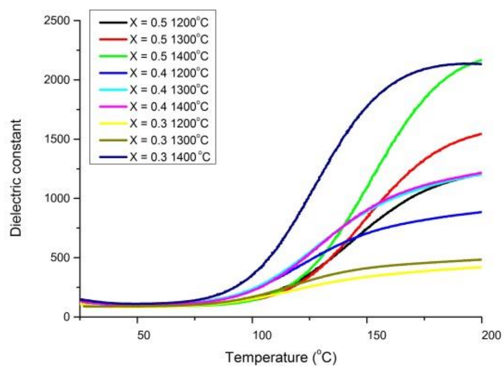

Fig 4. Temperature dependence of dielectric constant of the $Mn_{1-X}Mg_xFe_2O_4$ (x = 0.3, 0.4 and 0.5) sintered at 1200 $^{\circ}$C 1300 $^{\circ}$C and 1400 $^{\circ}$C for 4 h measured at 1 kHz.

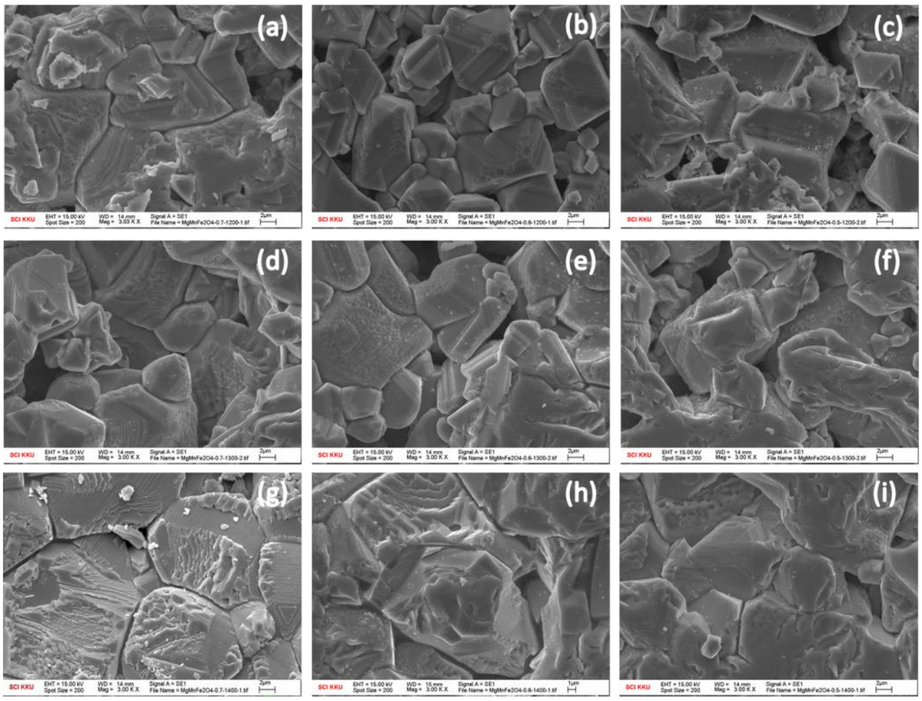

Fig 2. SEM micrographs of the $Mn_{1-x}Mg_xFe_2O_4$ ceramics **(a)** x = 0.3;1200 °C **(b)** x = 0.4;1200 °C **(c)** x = 0.5; 1200 °C **(d)** x = 0.3;1300 °C **(e)** x = 0.4;1300 °C **(f)** x = 0.5;1300 °C **(g)** x = 0.3;1400 °C **(h)** x = 0.4;1400 °C and **(i)** x = 0.5;1400 °C

Fig 3. Shows density of the MMF ceramics (x = 0.3, 0.4 and 0.5) sintered at 1200 °C 1300 °C and 1400 °C for 4 h. The density increased with increasing sintering temperatures and increased with decreasing Mg content, and reached a maximum value of 3.58 g/cm^3 with x = 0.3 sintered at 1400 °C. Because the sintered temperature causes the microstructure is homogeneous and no pore exists in the grain boundary this is consistent with **Fig 2.**

Temperature dependence of dielectric constant for the MMF ceramics is show in **Fig 4.** The dielectric constant value increased with increasing temperature for all compositions and reached a maximum value with x = 0.3 sintered at 1400 °C. It found that the dielectric constant, this is consistent with the density values.

Conclusion

$Mn_{1-x}Mg_xFe_2O_4$ (MMF) ceramics were prepared by co-precipitation method (x = 0.3, 0.4 and 0.5). XRD results revealed that all the samples are polycrystalline and cubic spinel structure. SEM result shows rectangular square grain in all samples. The dielectric constant value increases when increase temperature. For x = 0.3 sintered at 1400°C the results indicate a maximum in dielectric constant. Our work provides a new way for designing lead-free materials with dielectric materials.

Acknowledgements

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