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Influence of Currents and Electric Fields in YNMO Ceramics

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Abstract. Development of ceramic materials is critical for new and improved electronic applications. Herein, the J-E response of Y_2NiMnO_6 (YNMO) ceramics composited by a solid state reaction method was investigated. Sintering temperature and time were found to have significant influence on the ceramics electrical properties. In particular, higher temperatures and longer sintering times resulted in more favourable dielectric properties of the YNMO ceramics. A current of 40 mA/cm^2 at 20,000 mV/cm was obtained by sintering at 1300 °C for 12 hours, whereas a current of 9 mA/cm^2 at 4000 mV/cm can be achieved by sintering at 1400 °C for 24 hours. These results will be useful for identifying applications for YNMO ceramics. The electrical properties of the YNMO ceramics can be tuned for different electronic components such as dry batteries and capacitors.

Introduction

Ceramic materials are used in wide variety of electronic components, including capacitors, batteries and transistors. Ceramics of Y_2NiMnO_6 (YNMO) are similar to synthetic double perovskites by crystal structure, and also with their associated magnetic and dielectric properties [1]. The dielectric behaviour and activation energy of YNMO ceramics are comparable to that of charge ordered La_2NiMnO_6 [2]. In particular, activation energy is close to the energy required to transfer an electron from Ni^{2+} to Mn^{4+}, which is sufficient to substitute the direction of the polar region, indicating a conformable dielectric characteristic in Y_2NiMnO_6, which should be ascribed to the charge ordering space [3].

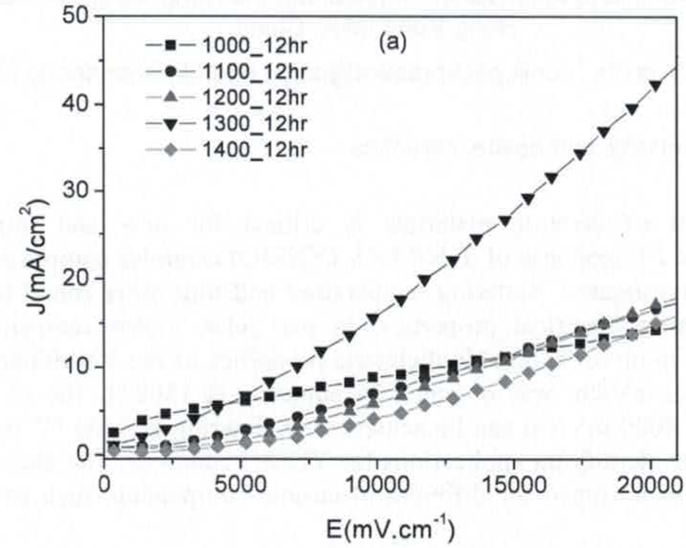
In this work, the Y_2NiMnO_6 ceramics are prepared by sintering at several temperatures and for different times [6-9] to investigate the J-E curves of the ceramics.

Experimental details

The bulk Y_2NiMnO_6 samples were synthesized using $Y(CH_3COO)_3.xH_2O$ (Yttrium(III) acetate hydrate, 99.9%), $Ni(CH_3COO)_2.4H_2O$ (Nickel (II)acetate tetrahydrate, 99.0%) and $Mn(CH_3COO)_2.4H_2O$ (Manganese (II)acetate tetrahydrate, 99.0%). The starting precursors were mixed in deionized (DI) water with the ratio of precursors to water of 1:7.5. The mixtures were stirred at room temperature for approximately 3 hours to yield a homogeneous solution. Firstly, the solution was heated in air from 100 °C to 800 °C over 11 hours and then held at 800 °C for 6 hours to obtain the powder for sintering. Secondly, the powder was heated further at a rate of 5 °C/min until reaching the final sintering temperature. Sintering was carried out from 1000 °C to 1400 °C for 6, 12, 18 and 24 hours. The final ceramics were made by compressing the sintered powder into a disk.

In order to measure the J-E response of the YNMO ceramics, two electrical contacts were prepared by silver painting on either side of the disk, and air dried overnight. The current response of the sample was measured using the Agilent 4294A Precision Impedance Analyzer.

Results and Discussion



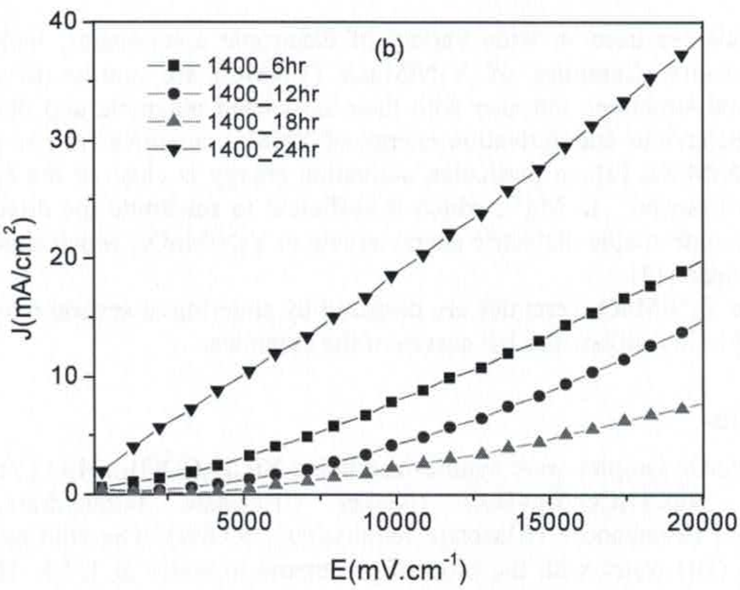


Figure 1. Current density-electric field (J-E) curves of Y_2NiMnO_6 ceramics sintered for 12 hours at 1000 °C to 1400 °C (a) and at 1400 °C for 6 to 24 hours (b).

Figure 1(a) shows the J-E curves of Y_2NiMnO_6 ceramics sintered from 1000 °C to 1400 °C over 12 hours. Generally, as the applied voltage increased the current increased. The values of current density increased most rapidly at high electrical fields for YNMO sintered at 1300 °C, achieving a value of 40 mA/cm^2 at 20,000 mV/cm. At all other sintering temperatures, the ceramic had lower current density. The current density was 8.88 mA/cm^2 at 1000 mV/cm for samples sintered at 1000 °C for 12 hours. However, at 5000 mV/cm the values of J are 6.18 mA/cm^2, 2.90 mA/cm^2, 1.77 mA/cm^2, 6.80 mA/cm^{2}and 1.31 mA/cm^2 for sintering temperatures of 1000 °C, 1100 °C, 1200 °C, 1300 °C and 1400 °C respectively. Therefore, with the exception of samples sintered at 1300 °C, it can be observed that increasing sintering temperature decreases current densities due to the conductivity of YNMO appearing at low temperatures. Figure 1 (b) demonstrates the J-E curves of YNMO ceramics sintered at 1400 °C for 6 hours, 12 hours, 18 hours and 24 hours, respectively. The values of current density increased dramatically with sintering time and with dc bias, similarly with fig. 1a. Increasing the dc bias heats the sample which will increase current flow. According to fig. 1a, it can be found that the high sintering temperature at 1400 °C had the lowest current density. The values of J decreased significantly with increasing sintering time and temperature due to high thermals, however, YNMO sintered at 1400 °C for 24 hours had a higher current density probably due to broken grain structure. The current densities are 20.16 mA/cm^2, 15.05 mA/cm^2, 7.91 mA/cm^2 and 40.00 mA/cm^2 of 6, 12, 18 hours and 24 hours at electrical field 20000 mV/cm, respectively.

Summary

Y_2NiMnO_6 ceramics were sintered over a temperature range from 1000 °C to 1400 °C for up to 24 hours to investigate the current density and electrical fields curves associated with sintering temperature and time. We found that the current density J increased dramatically with increasing electrical field, while J decreased significantly with increasing sintering temperature and time. However, at too high temperature ceramic broke down leading to high conductivity. The sintering conditions will influence different grain structures and conductivity within the ceramic, these can be tuned per application.

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