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Effect of sintering temperature on structural and electrical switching properties of cadmium ferrite

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ABSTRACT

Cadmium ferrite was prepared by standard ceramic method and characterized by XRD, IR and SEM techniques. The X-ray analysis confirms the formation of single phase cubic spinel structure. The lattice constant decreases slightly and porosity increases with increase in sintering temperature. The crystallite size of the samples lies in the range of 22.83 to 24.44 nm. The IR study shows two absorption bands around 400 cm^{-1} and 600 cm^{-1} corresponding to octahedral and tetrahedral sites respectively. The grain size increases and switching field decreases with increases in sintering temperature. Copyright © 2013 VBRI press.

Keywords: Cadmium ferrite; grain size; structural; electrical switching.

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Introduction

The structural, electrical, magnetic and electrical switching properties of cadmium ferrite have been already studied **[1-3]**. Its applications in the field of magneto-optical and gas sensors are reported **[4, 5]**. Cadmium ferrite has a normal spinel structure **[6]**. The solid–solid reaction between CdO and Fe_2O_3 takes place at a temperature about 600^0C gives $CdFe_2O_4$ of moderate degree of crystallinity **[7]**. Nayak *et al.* **[8]** reported increment in particle size with increase in temperature. The sintering temperature effect is studied by Islam *et al.* **[9]** of Ni-Zn ferrite and showed that the sintering temperature is mainly affects the permeability, density, grain size and Curie temperature. At the higher sintering temperature, density gets decreased due to increase in intra-granular porosity resulting from the discontinuous in the grain growth. Electrical switching phenomenon was first reported by Yamashiro *et al.* **[10]** in $CuFe_2O_4$ and simultaneously studied by Vaingaonkar *et al.* **[11]** in polycrystalline for bulk $CuFe_2O_4$. Further switching phenomenon in ferrites were reported by Histake *et al.* **[12]**, Sagare *et al.* **[3]** by Li-Cd ferrites, Miller *et al.* **[13]** by Ni ferrite and Babbitt *et al.* **[14]** by Lithium ferrites and showed that grain size depends on switching property. Mg-Mn ferrites core are studied by Tancrell *et al.* **[15]**. $Cd_xCo_{1-x}Fe_{2-y}Cr_yO_4$ system is studied by Vasambekar *et al.* **[16]**. The CCNR type of high field instability in Ti^{+4} substituted Mn-Zn ferrites are reported by Saija *et al.* **[17]** and they showed that switching field increases with increase in Ti^{4+}content. Electrical switching properties of Cr^{3+} and Al^{3+} substituted $NiFe_2O_4$ were reported by Patange *et al.* **[18, 19]**. The current-voltage (I-V) characteristics of single SnO_2 nanowire measured at different temperatures **[20]**. The ferrite switching materials are mostly used in different applications such as computer cable, microelectronics and data storage etc **[14-19]**. Kiri *et al.* reviewed the solid state thermochromic materials are studied and show that the intelligent thermochromic glass require switching temperatures between 18-25°C **[21]**.

In the present communication we report the effect of sintering temperature on structural and electrical switching properties of cadmium ferrite.

Experimental

Ferrite sample preparation

The $CdFe_2O_4$ was prepared by standard ceramic method. The AR grade cadmium oxide 99.5% (Hi Media) and ferrous oxide 98% (Thomas baker) were weighed as per stoichiometric proportion. They were mixed in agate mortar with acetone and milled in ½ hrs. The mixture was then put into temperature controlled Muffle furnace for 6 hours at 600^0C for pre-sintering. After furnace cooling the powder was again milled in agate mortar of ½ hrs with acetone base. The powders were put into furnace and sintered at three different temperatures 900^0C, 1000^0C and 1100^0C for 10 hours and after furnace cooled. The powder was again milled with acetone base. Using 5% poly vinyl alcohol the powder was pressed under hydraulic press with the pressure is 6 ton/cm^2 for 5 minutes to form 10mm diameter pellet. Finally the pellets were sintered for 6 hours at different sintering temperatures. The cooling and heating rate of the furnace is at 80°C per hour. The physical density of the sample was investigated by the Archimedes principle.

Characterization techniques

The X-ray diffraction patterns were recorded at step size of 0.02 in angular range 10^0–100^0 (2θ) at 40 kV and 25 mA with Cr-Kα radiation (λ = 2.29165 A°) using Philips PW-3710 X-ray powder diffractometer. FT-IR spectrum was recorded in the range of 350–800cm^{-1} using Perkin-Elmer spectrum one spectrophotometer (USA) using KBr pellet technique. SEM was carried to analyze microstructure of fractured surfaces of the pellets on JEO JSM 6360 SEM (Japan) at 10000 magnifications.

Electrical switching

Electrical switching was recorded at room temperature using Aplab high voltage dc power supply and Meca 81K multimeter. The electrical switching of sample was recorded with the help of silver foil connecting wires of conducting cell.

Results and discussion

The X-ray diffraction patterns of cadmium ferrite sintered at three different temperatures (900^0C, 1000^0C and 1100^0C) under investigation are presented in **Fig. 1**. The XRD confirms the formation of single phase cubic spinel structure in all the samples. The presence of (220), (311), (422), (333) and (440) planes were observed. The X-diffraction patterns agree with JCPDS card number-02-0975. Lattice constant of sintered cadmium ferrites under investigation was calculated using the Bragg's equation **[22]**,

$$a = d_{hkl}\sqrt{h^2+k^2+l^2} \qquad (1)$$

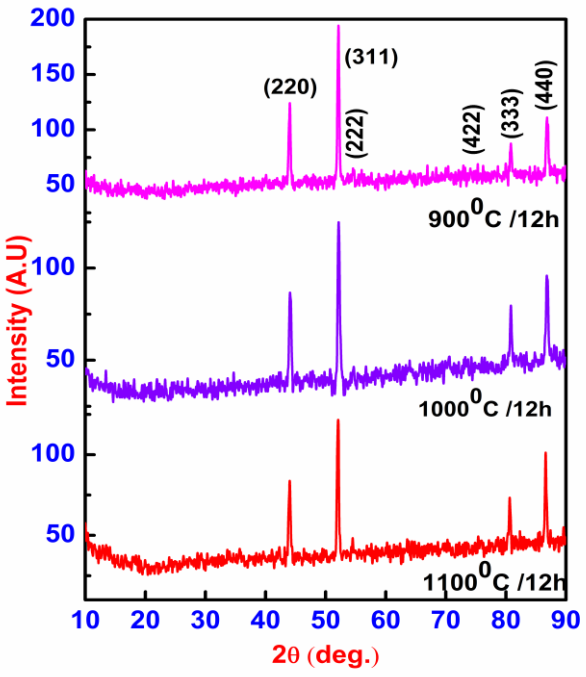

Fig. 1. XRD of Cd ferrite sintered at (900^0C, 1000^0C and 1100^0C).

Table 1. Structural parameters and electrical switching field for Cd ferrite sintered at 900^{0}C, 1000^{0}C, 1100^{0}C.

Sintering temperature (^{0}C)	Lattice constant (A^0)	Crystallite size (nm)	Grain size (μm)	X-ray density (g/cm^3)	Physical density (g/cm^3)	Porosity (%)	Electrical field (V/cm)	Absorption band. (cm^{-1}) υ_1	υ_2
900^{0}C	8.705	38.6	1.10	5.828	5.326	09.42	4600	575	435
1000^{0}C	8.700	36.2	1.26	5.835	5.269	10.70	4200	578	438
1100^{0}C	8.687	42.3	1.32	5.837	5.254	11.09	3200	576	436

where, d_{hkl} is the interplanner distance and (h, k, l) are the Miller indices of planes. The calculated lattice constants are presented in **Fig. 2**. From this figure, the lattice constant decreases slightly with increase in sintering temperature. Mostafa *et al.* **[7]** reported similar results for cadmium ferrite. The average crystallite size of the samples was calculated from the most intense (311) peak of XRD by using Debye Scherer equation **[23]**.

$$D = \frac{0.94\,\lambda}{\beta\cos\theta} \qquad (2)$$

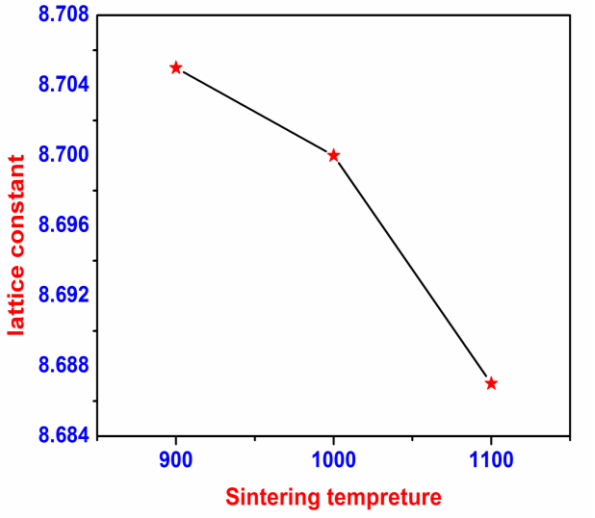

Fig. 2. Variation of lattice constant with sintering temperature.

Where λ is the wave length of X-rays, β is the full width half maximum (FWHM) and θ is the Bragg's angle. The average crystallite size lies in the range 36.2 to 42.3 nm and is presented in **Table 1**. These results are in good agreement with results reported by Nayak *et al.* **[8]**. The variation of X-ray density and physical density of all samples at different sintering conditions are presented in the **Table 1**. The X-ray density values are slightly larger than the physical density this is because of mass to volume ratio. **Table 1** shows that porosity increases with the increase in sintering temperature. The porosity is of two type, one is intragranular porosity and another is intergranular porosity; the intragranular porosity get increases with increase in higher sintering temperature due to discontinuous grain growth **[9]**.

The IR spectra shows two major absorption bands near 400 cm^{-1}and 600 cm^{-1} corresponding to octahedral and tetrahedral sites respectively. The IR spectra for all samples under investigation are presented in **Fig 3**. In bulk Cd ferrite similar results are reported by Desai *et al* **[2]**. The values of absorption bands (υ_1 and υ_2) corresponding to tetrahedral and octahedral sites are presented in **Table 1**.

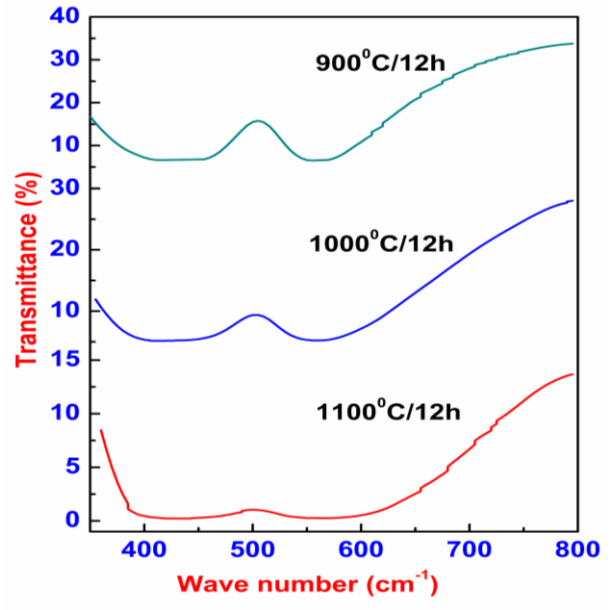

Fig. 3. IR of Cd ferrite sintering at 900^{0}C, 1000^{0}C and1100^{0}C.

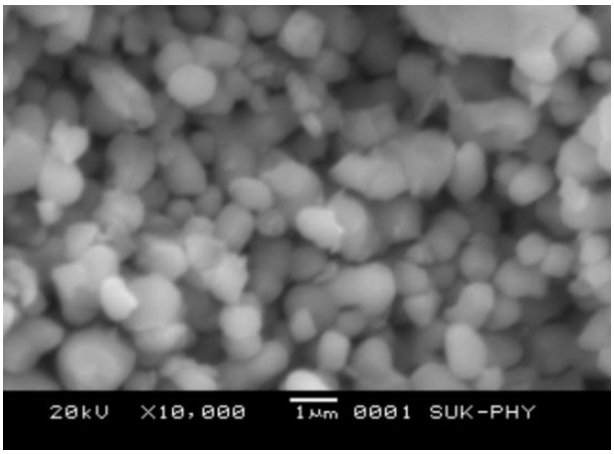

Fig. 4. Typical micrograph of Cd Fe_2O_4 sintered at 1000^{0}C.

The microphotographs of fractured surfaces of pellets under investigation are presented in **Fig. 4**. The grain size was calculated by linear intercept method **[24]**.

$$G_a = \frac{1.5L}{MN} \quad (3)$$

The morphology of particle structure is almost spherical and regular in shape and is uniformly dispersed. The grain size of the samples increases with increase in sintering temperature. It is due to the increase in density with increasing sintering temperature **[9]**.

The plot of current against dc electric field for samples under investigation is presented in **Fig. 5**. From this figure it can be noticed that the CCNR type electrical switching is observed in the samples under investigation. The curves shows that, it linearly increases up to 5 mA then current increases quickly and switch the sample with increases in current and decreases in voltage. The current passed through the instability conduction region and entered into an extremely high conductivity region i.e. the conductivity is switched between two conductivity regions via an instability region **[9, 15, 17]**. Switching field decreases with increase in sintering temperatures of all the samples are presented in **Table 1**. From table the switching field decreases with increase in sintering temperature, which is attributed to increase in grain size. The lattice constant decreases with decrease in switching field because the lattice dimension is dependence on switching field. The investigative /observed switching fields are very high as reported earlier **[11, 16]**.

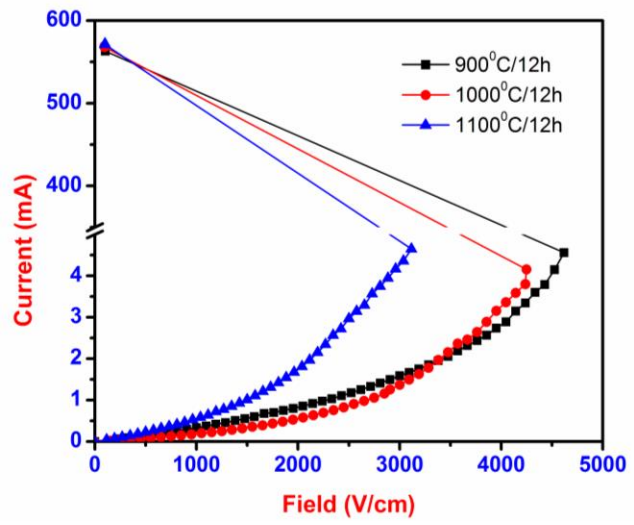

Fig. 5. Current Vs dc electrical field for Cd ferrite

The cadmium ferrites of different sintering temperatures are under investigation, when the cycle was repeated after two weeks. The result may be noted that there is no 'ageing effect' in this ferrite. The ferrite samples were subjected to a second cycle of switching, which was run immediately after the first cycle **[17]**. None of the models can satisfactorily explain the electrical switching in this system, the existence of SCL-current could be possible because of switching phenomenon **[17]**.

Conclusion

Ferrite samples under investigation show single phase cubic spinel structure. The Lattice constant is found to decrease slightly while porosity and grain size increase with increasing sintering temperature. The crystallite size of the samples lies in the range 22.83 to 24.44 nm. The absorption bands around 400cm^{-1} and 600cm^{-1} correspond to octahedral and tetrahedral sites. The CCNR type electrical switching is observed in the all samples under investigation. The electrical switching fields are decreases with increase in sintering temperature.

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