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

S.P. Dalawai¹*, A.B. Gadkari², T.J. Shinde³, P.N. Vasambekar¹

¹Department of Electronics, Shivaji University Kolhapur 416 004, India
²Department of Physics, GKG college, Kolhapur 416 012, India
³Department of Physics, Smt KRP Kanya Mahavidyalaya Islampur 416 409, India

*Corresponding author. Tel: (+91) 9890253825; E-mail: sanjeevdalawai@gmail.com

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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.

Sanjeev P. Dalawai is currently doing Ph.D in Department of Physics, Shivaji University Kolhapur. His fields of interest are structural, electrical, switching and ferrite gas sensing properties for gases like LPG, C₂H₅OH, and Cl₂.

Ashok Gadkari has obtained his M.Sc. and M.Phil. degree in 1983 and 1988 from SUK, Kolhapur. Presently he is Associate Prof. and head of department of physics. His field of research is synthesis of ferrite materials for structural, electric, magnetic, humidity and gas sensing properties at G K G college, Kolhapur. He has published 30 research paper in Journal.

T. J. Shinde has obtained his M.Sc. and M.Phil degree in 1990 and 2001 from SUK, Kolhapur. Presently he is Associate Professor and working on ferrites for electromagnetic wave and gas sensors in KRP kanya mahavidyalaya, Islampur. He has published 15 research articles in various scientific journals.

Pramod N. Vasambekar is Professor of electronics. He is working on soft ferrites, humidity and gas sensors, microwaves and communication electronics in Shivaji University Kolhapur. He has contributed 35 research papers in journals and 33 papers in the international and national conferences.
Introduction

The structural, electrical, magnetic and electrical switching properties of cadmium ferrite have already been 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 Fe₂O₃ takes place at a temperature about 600°C gives CdFe₂O₄ 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 CuFe₂O₄ and simultaneously studied by Vaingaonkar et al. [11] in polycrystalline for bulk CuFe₂O₄. 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]. Cd₃Co₁₋ₓFe₂ₓO₄ system is studied by Vasambekar et al. [16]. The CCNR type of high field instability in Ti⁺⁺ substituted Mn-Zn ferrites are reported by Saija et al. [17] and they showed that switching field increases with increase in Ti⁺⁺content. Electrical switching properties of Cr³⁺ and Al³⁺ substituted NiFe₂O₄ were reported by Patange et al. [18, 19]. The current-voltage (I-V) characteristics of single SnO₂ 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 CdFe₂O₄ 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°C 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°C, 1000°C and 1100°C for 10 hours at 1000°C for 6 hours. The furnace is at 80ºC 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 10⁰–100⁰ (2θ) at 40 kV and 25 mA with Cr-Kα radiation (λ = 2.29165 Å) using Philips PW-3710 X-ray powder diffractometer. FT-IR spectrum was recorded in the range of 350–800 cm⁻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°C, 1000°C and 1100°C) 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-ray 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].

\[ a = \frac{\sqrt{h^2 + k^2 + 1^2}}{d_{hkl}} \]

![Fig. 1. XRD of Cd ferrite sintered at (900°C, 1000°C and 1100°C).](image-url)
where, \( d_{hkl} \) is the interplanar 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].

\[
D = \frac{0.94 \lambda}{\beta \cos \theta} \tag{2}
\]

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

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 \((\nu_1 \text{ and } \nu_2)\) corresponding to tetrahedral and octahedral sites are presented in Table 1.

![IR spectra of Cd ferrite](image)

Table 1. Structural parameters and electrical switching field for Cd ferrite sintered at 900°C, 1000°C, 1100°C.

| Sintering temperature (°C) | Lattice constant (Å) | 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\(^{-1}\)) | \(\nu_1\) | \(\nu_2\) |
|---------------------------|----------------------|-----------------------|-----------------|-----------------------------|-----------------------------|--------------|------------------------|-------------------------------|----------|----------|
| 900°C                     | 8.705                | 38.6                  | 1.10            | 5.828                       | 5.326                       | 09.42        | 4600                   | 575                           | 435      |
| 1000°C                    | 8.700                | 36.2                  | 1.26            | 5.835                       | 5.269                       | 10.70        | 4200                   | 578                           | 438      |
| 1100°C                    | 8.687                | 42.3                  | 1.32            | 5.837                       | 5.254                       | 11.09        | 3200                   | 576                           | 436      |

Fig. 3. IR of Cd ferrite sintering at 900°C, 1000°C and 1100°C.

![Typical micrograph of Cd ferrite](image)

Fig. 4. Typical micrograph of Cd ferrite sintered at 1000°C.

![Typical micrograph of Cd ferrite](image)

Fig. 4. Typical micrograph of Cd ferrite sintered at 1000°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].

\[ G_a = \frac{1.5L}{MN} \]  

(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 voltage. The current could be possible because of increase in grain size. The lattice constant decreases with decrease in switching field because 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 all samples under investigation. The electrical switching fields are decreases with increase in sintering temperature.

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