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Effect of pressure on the resistivity of spinel ferrite

M.A. Ahmed[a,*], S.F. Mansour[b], S.I. El-Dek[a]

[a]Materials Science Laboratory (1), Physics Department, Faculty of Science, Cairo University, Giza, Egypt
[b]Physics Department, Faculty of Science, Zagazig University, Zagazig, Egypt

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Abstract

The far-infrared spectra of six mixed ferrites ($Cd_xCo_{1-x+t}Ti_tFe_{2-2t}O_4$; $x = 0.2$, $0.00 \leqslant t \leqslant 0.25$) in the range 200–1000 cm^{-1} are reported. Two strong high-frequency bands v_1 and v_2 are observed. The first one v_1 is assigned to the tetrahedral and the second v_2 is assigned to the octahedral site. A small kink v_3 around near v_2 is observed and its intensity increases with divalent octahedral metal ion concentration. Seebeck coefficient measurements showed that the substitution of tetravalent ion Ti^{4+} does not change the polarity of the Seebeck coefficient from p- to n-type. The activation energy and the carrier mobility μ were also calculated. The effect of mechanical pressure on the dc resistivity was investigated.

Keywords: CoCd ferrite; FTIR; Dc resistivity; Pressure effect

1. Introduction

Ferrites play a useful role in many magnetic applications because their electrical conductivity is relatively low in comparison with that of magnetic materials. Their physical properties are strongly dependent on cation distribution among the tetrahedral (A) and octahedral (B) sites in the crystals. The dielectric properties of $Co_{1-x}Cd_xFe_2O_4$ ($0 \leqslant x \leqslant 1$) ferrites were studied by Hemeda and Barakat [1]. The electrical conductivity of ferrites with composition Fe_3O_4, $CdFeO_4$, and $Co_xZn_{1-x}Fe_2O_4$ ($0 \leqslant x \leqslant 1$) was studied by Mousa et al. [2] in N_2 atmosphere as a function of temperature. Fe_3O_4, $ZnFe_2O_4$, and $CdFe_2O_4$ showed n-type conduction, whereas $CoFe_2O_4$ showed p-type conduction [2].

Inverse spinel cobalt ferrite ($CoFe_2O_4$), exhibiting ferrimagnetism below 793 K [3], has been paid a great deal of attention for its applications such as high-density magnetic and magneto-optic recording media. The octahedral $Co^{2+}(d^7)$ ions in $CoFe_2O_4$ are in the high-spin state and the tetrahedral and the octahedral $Fe^{3+}(d^5)$ ions are in the high-spin state with the spin directions antiparallel to each other. Co-ferrite is especially interesting because of its cubic magnetocrystalline anisotropy [4], high coercivity [5], moderate saturation magnetization, high chemical stability, wear resistance, and electrical insulation [6].

The goal of our study is to prepare and investigate the structural characterizations and the temperature dependence of the dc electrical conductivity and the effect of Ti addition on the mobility of Co–Cd ferrite. Also, one aimed to probe the sensing properties of the prepared samples by applying external mechanical pressure to open a new era in the applications of substituted Co-ferrite.

2. Experimental techniques

Samples of the formula $Cd_xCo_{1-x+t}Ti_tFe_{2-2t}O_4$; $x = 0.2$, $0.00 \leqslant t \leqslant 0.25$ were prepared by the conventional solid-state reaction from analar grade form oxides (BHD). Stoichiometric amounts were good mixed and grinded using agate mortar for 3 h, transferred to agate ball mill for another 3 h. The samples were pressed into pellets form using uniaxial press of pressure 5×10^8 N/m^2. Presintering was carried out in air at 850 °C for 6 h with a heating rate of 2 °C/min and then cooled to room temperature with the same rate as that of heating, regrinded again, sieved and pressed into disks of diameter 1 cm and thickness

*Corresponding author. Tel.: +20 25676742.
E-mail address: moala47@hotmail.com (M.A. Ahmed).

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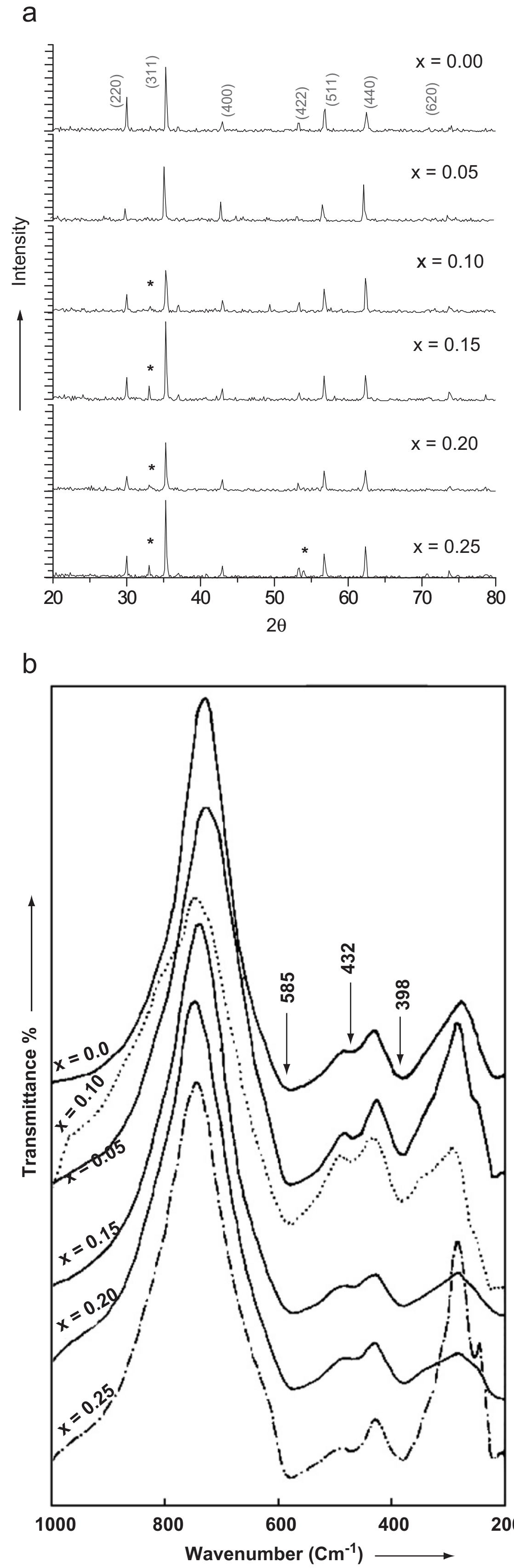

Fig. 1. IR absorption spectra of ($Cd_xCo_{1-x+t}Ti_tFe_{2-2t}O_4$; $x = 0.2$, $0.00 \leqslant t \leqslant 0.25$) in the range 200–1000 cm^{-1}. (*$CoTiO_3$).

of $\cong 1.5$ mm and fired finally at 1150 °C for another 10 h in air with a heating rate of 2 °C/min.

The IR spectra were recorded at room temperature in the range 200–1000 cm^{-1} using Perkin-Elmer infrared spectrometer model 1430.

For the electrical properties measurements, the two surfaces of each pellet were good polished, coated with silver paste and then checked for good conduction. Dc resistivity was measured using two probe technique with the potential drop method. Seebeck coefficient voltage measurements were carried out using the differential method where a constant temperature difference of 10 K was maintained across the two surfaces of the samples and the resulting emf was recorded using a microvoltmeter taking into consideration its sign. The effect of mechanical pressure on the dc resistivity was carried out using a homemade apparatus where the pressure was calculated from $P = mg/A$, where A is the cross-sectional area and m is the load.

Table 1
IR transmission bands of $Cd_xCo_{1-x+t}Ti_tFe_{2-2t}O_4$; $x = 0.20$, $0.00 \leqslant t \leqslant 0.25$

x	v_1 (cm^{-1})	I_1	v_2 (cm^{-1})	I_2	v_3 (cm^{-1})	I_3	θ_D (K)
0.00	585	55.8	398	18.6	432	2.9	706.7
0.05	589	53.0	389	23.5	433	3.9	703.0
0.10	589	50.0	391	19.6	432	3.9	704.6
0.15	582	49.0	389	10.8	432	3.4	698.0
0.20	585	50.0	392	11.7	430	4.0	702.4

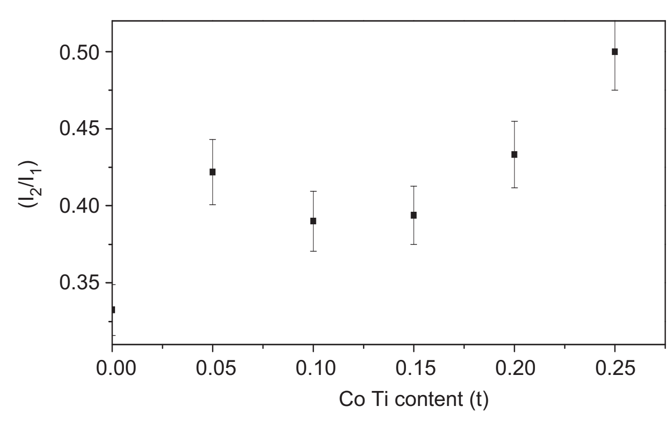

Fig. 2. Dependence of (I_A/I_B) on CoTi content (t).

Table 2
Values of the activation energies for $Cd_xCo_{1-x+t}Ti_tFe_{2-2t}O_4$; $x = 0.20$, $0.00 \leqslant t \leqslant 0.25$

t	E_I (eV)	E_{II} (eV)
0.0	0.22	0.22
0.05	0.14	0.13
0.10	0.33	0.27
0.15	0.20	0.44
0.25	0.20	0.75