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SATURATION MAGNETIZATION, THERMAL CONDUCTIVITY, DIELECTRIC CONSTANT, AND RESISTIVITY FOR Li-Zr FERRITES

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ABSTRACT

Li -Zr_x $Fe_{2-x}O_4$ ferrite was prepared by the general ceramic method. The study of the effect of γ - irradiation damage on Zr doped Li ferrites, specially on the dielectric constant, the thermal conductivity, the resistivity and the saturation magnetization was carried out. The behavior of these physical parameters before and after irradiation was correlated with creation of ferrous ions, due to the interaction of γ radiation with ferric ions at B-sites leading to higher conductivity and dielectric polarization. The decrease of thermal conductivity with Zr additions was due to creation of lattice vacancies which were centers for phonons scattering.

INTRODUCTION

The polycrystalline ferrites have very good dielectric properties depending on several factors including the method of preparation, sintering temperature and the sintering atmosphere. In the process of preparation of ferrites in the polycrystalline form, ferrite powder is sintered under slightly reducing conditions. As a consequence, the divalent iron produced in the bulk of the material forms high conductivity grains separated by low conductivity layers, so that the ferrites behave as homogeneous dielectric materials. In order to explain the mechanism of electrical conductivity and the dielectric behavior of the ferrites, the cation distribution was studied by investigating the saturation magnetization (1). Also, in recent years a number of investigators have attempted to determine the thermal conductivity of the ceramics for diagnostic purpose (2). Since the thermal conductivity is a structure sensitive property, the values obtained from measurements on polycrystalline aggregates are not generally applicable unless the effect of microstrcture on these values are known. Up to our knowledge no attempts were made to study the effect of γ irradiation on the physical parameters of Li Zr ferrite. The aim of the present work is to study the effect of γ - irradiation on the thermal conductivity, the saturation magnetization, the dielectric constant, and the resistivity of the samples ($Li\text{-}Zr_x Fe_{2-x} O_4$).

EXPERIMENTAL

Samples in the system $Li\text{-}Zr_x Fe_{2-x} O_4$ (x = 0,0.2, 0.4, 0.6 0.8, 1.0 were prepared using usual ceramic technique. The starting materials were highly pure ferric oxide, lithium carbonate and zirconate oxide. They were mixed and then ground to very fine powder in an agate mortar of carborrundum. The samples in the form of discs were sintered at 1200°C for 8 hours and slowly cooled to room temperature. The samples were polished to produce uniform surfaces and contact on the sample surfaces were made with silver paste for the electrical and thermal measurements.

The saturation magnetization was measured by winding 20 turns from copper wire around the circumference of the samples disc, the inductance of the ferrite coil was measured using R L C bridge. The following relations were used for estimating the magnetic permeability which leads to estimate the magnetization

$$\mu = (L. 1) / n^2 A$$

$$\mu = 1 + 4 \pi x$$

$$M = x . H$$

$$H = (4 \pi I n) / (10 1)$$

where μ is the magnetic permeability, L is the self inductance, n is the number of turns, A is the cross setion area of the sample, 1 is the thickness of the sample, M is the magnetization of the sample, x is the magnetic susceptibility, H is the magnetic field intensity , I is the current in ampere.

Thermal measurements

The apparatus used for thermal measurements is shown in fig. (1).

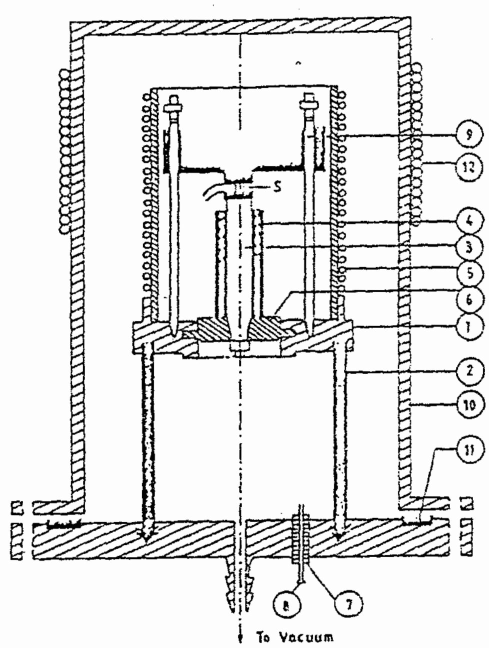

Fig. 1. Cross-section of the apparatus used for the thermal measurements.

It consists of holder (1) held on three iron rods (2). The sample holder consists of stinless steel bar (3) fixed in the central axis of a tubular stinless steel furnace (4) and (5). The two heaters and the stinless steel bar are fixed to the holder base. The central steel bar copper leads thermocouple wires and heater connections are insulated from the holder base plate by a ceramic disc (6). The conecting wires and thermocouples pass through ceramic tubes and leads pass throug out side the teflon tubes (7) in the apparatus base plate by means of copper leads (8). The sample S is tightly pressed between two copper electrodes by means of the pressure of the load (9) screwed the rods. The base plate is surrounded by a metal jacket (10). which rests on annular vacuum rubber ring (11). The cooling copper coil (12) is sealed on the surrounding of the metal jacket. For measurement stability, the system is provided with a connection to the vacuum system = 10^3 mm Hg to avoid heat loss by convection. The temperature of the hot surface of the sample was at 50°C. The dielectric constant of the samples were measured using capacitance bridge (RLC bridge type B 151). For measurement of d.c.bias voltage was provided by a power supply and the current was recorded by an electronic ammeter. The voltage across the sample was monitored by a digital voltmeter in order to determine the resistivity of the sample. All measurements were carried out at 37°C (room temp.) The samples were irradiated using Co^{60} cell at dose rate 25 rad/sec. The various samples were exposed to absorb dose of γ 10^6 rad in air at room temperature at "Arab institute of Radiation and isotopes "Doki, cairo, Egypt.

RESULT AND DISCUSSION

Saturation magnetization

Fig. (2) represents the dependence of the saturation magnetization of the Li Zr Fe O_4 on Zr contents. It is clear that $4 \pi M_s$ for our sample at x = O is 0.40 while that reported for unsubistituted lithium ferrite is 0.37 (3).

The saturation magnetization value decreases with increasing Zr content, as expected because nonmagnetic Zr^{4+} ions ocupying the octahedral sites replacing Fe^{+3} ions. decreases the saturation magnetization. Our explanation is similar to previous work on Li ferrite by another techniques (4, 5).

Saturation Magnetization

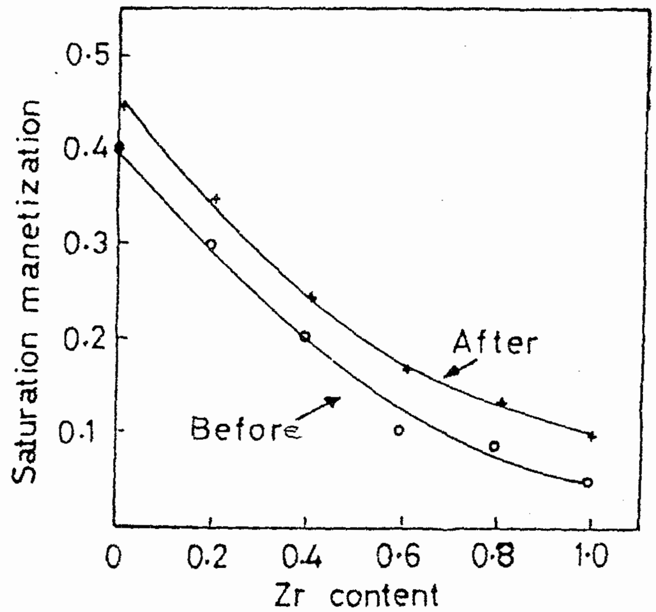

Fig. 2. Satuation magnetization vs Zirconium content.

Composition dependence of the dielectric constant and resistivity

Fig (3,4) represents the dependence of dielectric constant and resistivity on Zr contents. It is clear that the dielectric constant decrease continuously with increasing Zr content, but the resistivity increases continuously with increasing Zr.

The replacement of Fe^{3+} with Zr^{4+} is ocupied by a decreases the iron concentration in the B-sites. when the concentration of magnetic ions such as Fe^{3+}, with higher spin magnetic moment decreased and the hopping between Fe^{2+} and Fe^{3+} decreased. The polarization of the hopping electrons in the direction of electric field is reduced leading to decease of dielectric constant. Our explanation is similar to previous work (8,9).

The increasing in the resistivity is due to the decrease in the number of

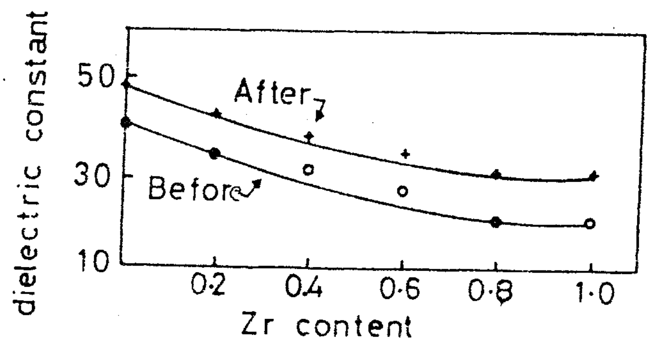

Fig. 3. Dielectric constant vs Zirconium content.

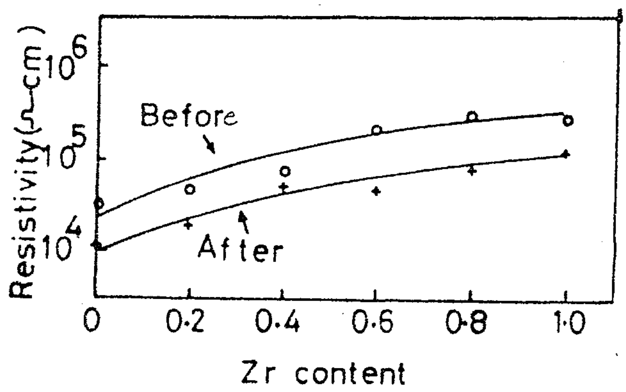

Fig. 4. Resistivity vs Zirconium content.

ferric ions on the octahedral sites. Thus the number of ferrous and ferric ions on the octahedral sites play a dominant role in the mechanism of conduction dielectric polarization and magnetization. This results is in agreement with the assumption made by Rabinkin the Novikova (7).

Effect of Zr addition on theraml conductivity of

($Li\ Z_x Fe_{2-x} O_4$)

The coefficient of thermal conductivity of the samples was determined using the formula

$$Q = I\,V / J = K\,A.\,(dT / dx)$$

Where Q is the quantity of heat transferred through the sample per unit time, and I, V, T and x are the current in amperes, the voltage across the internal heater in volts, the temperature and the sample thickness in cm respectively. The variation of thermal conductivity K with Zr addition x is shown in fig. (5), it is clear from fig. that K had decreased with increasing Zr content. This may be discussed as flowing: It is necessary to consider heat transport not only electrons, but also by lattice vibrations. Heat transport by phonon is the only significant mechanism of heat conduction, and the contribution of electrons to the thermal conductivity is reduced to size comparable with the contributions of phonons. The finite thermal conductivity of phonons arises because the waves are scattered by the crystal boundaries, defects and particularly other waves. The scattering of waves by other waves (phonon - phonon scattering) comes about because the lattice vibrations are not perfectly simple harmonic Fig 5. In our compositions the created vacancies increased the unharmonicity in the lattice vibrations leading to lattice scattering. The increase of lattice scattering decreased the thermal scattering.

It may be concluded that the increase of lattice scattering caused from liberation of lattice vacancies decreased the thermal conductivity.

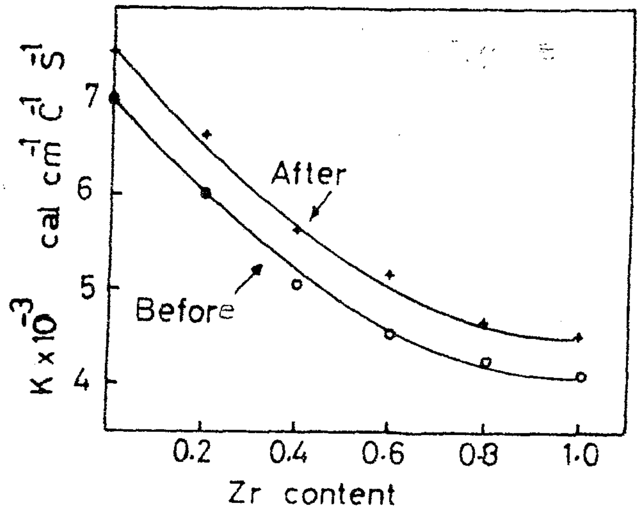

Fig. 5. Thermal conductivity vs Zirconium content, measured at temperature 50°C.

The effect of γ - irradiation

the decrease of the resistivity for all samples after irradiation may be discussed on the base that the effect of energetic γ - irradiation on Li Zr ferrite has significance in displacing atoms from their normal positions in the lattice, after some time many vacancies and interstitial atoms are created (11). Moreover, the interaction of γ rays with Fe^{3+} ions causes loss electrons from the outer shell and the number of Fe^{2+} ions increased These may facilitated the ionization, and thus leading to an increases in number of current carriers and hence a higher electrical conductivity. The increase of conductivity after irradiation damage of Li Zr ferrite is similar to previous work (12,13), on ZrO_2 and Ba ZrO_3 ceramic. The decreased in resistivity values leading to increase in the dielectric constant values because a more orientations of hopping electrons was achieved in the direction of electric field leading to higher polarization. This increase in polarization caused the dielectric constant and magnetization to increase.

CONCLUSION

The saturation magnetization of $LiZr_x Fe_{2-x} O_4$ decreases with increasing Zr additions. This decrease is attributed to substitutions of non magnetic Zr with magnetic sites of ferric ions.

The decrease of dielectric constant with Zr content is attributed to the fact that, the substitution of Zr^{4+} to Fe^{3+} decreased the hopping mechanism between Fe^{2+} and Fe^{3+} at B sites. and thus leading to less polarization.

The thermal conductivity decreases with increasing Zr content because doping causes lattice vacancies. These vacancies are centers of phonon scattering.

The increase of conductivity and dielectric constant after γ - irradiation damage is correlated with the creation of lattice vacancies leading to increase of electrical conductivity.

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دراسة التشبع المغناطيسي ، والتوصيل الحراري وثابت العزل والمقاومة الكهربية لفريتات الليثيوم والزركونيوم

د / محسن محمد مسعد
كلية التربية بكفر الشيخ

حضرت عينات من فريتات الليثيوم المطعمة بالزركونيوم بالطريقة السيراميكية المعتادة . وتم دراسة تأثير آشعة جاما علي فريتات الليثيوم المطعمة بالزركونيوم علي الخواص الفيزيائية لهذه المركبات ولا سيما ثابت العازل والتوصيل الحراري ، والمقاومة الكهربية والتشبع المغناطيسي .

ووجد أن تصرف هذه الخواص الفيزيائية قبل وبعد الاشعاع مرتبط بتولد أيونات الحديدوز وذلك لتفاعل آشعة جاما بأيونات الحديديك عند أماكن B (الترتيب السداسي الشكل) مسببا زيادة التوصيل الكهربي وزيادة الاستقطاب الذي يؤدي الي زيادة ثابت العزل للمركبات . ووجد أن النقص في التوصيل الحراري مع اضافات الزركونيوم يرجع الي خلق فراغات في الشبكية والتي تعتبر مراكز للتشتت الحراري (تشتت الفونونات) .