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Preparation the Barium Titanate ($Batio_3$) Material and study the effect of Fast Neutrons, Gamma–Ray on Its Dielectric Properties and Microstructure

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ABSTRACT

In this paper, $BaTiO_3$ was prepared by solid state reaction method using (BaO- TiO_2) compounds as a starting material, where their mixture calcined at 1300 ^{0}C for 9 hr. The dielectrical properties and microstructure of $BaTiO_3$ were investigated before and after the irradiation with (3. 1 x 10^{10} n cm^{-2}) fast neutrons (14 MeV) and (1.51 x 10^8 Rad) gamma-ray. The fast neutrons and gamma –ray led to decrease the dielectric constant from 3541.42 to 3265. 52 , 1979.13 at Curie temperature (120 ^{0}C) respectively ,it also led to decrease in the dielectric loss factor in different rates, while leading to an increase in electrical resistivity, All of this may be due to the great change caused by irradiation in the microstructure (grain size, shape and porosity) of the $BaTiO_3$ material.

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INTRODUCTION

Barium titanate ($BaTiO_3$) is classified as a ferroelectric material, which are spontaneous polarizing dielectric materials , BaTiO3 is one of the compounds of the perovskites with general formula ABO_3 which represent one of the secondary groups that belonging to the ferroelectric materials , where(A) represents a binary or monovalent metal and (B) represents a quadrilateral or pentavalent metal [1,2,3].

$BaTiO_3$ undergoes a transition from a ferroelectric tetragonal phase to a paraelectric cubic phase at Curie temperature (120 C^0) [4]. Dielectric materials are used in many electrical systems where they are almost used in all fields whether in microelectronics or in fields of high pressure especially $BaTiO_3$ material because it has a high dielectric constant therefore its widely used in manufacture of capacitors . Due to the importance of this material with respect to high dielectric properties , it has been dealt with in many researches since the beginning of twentieth century and so far. Some of these researches have been examined the effect of adding some compounds as impurities on the dielectrical properties of $BaTiO_3$ material [5,6].Xia et al , was prepared $BaTiO_3$ by hydrothermal method [7] ,also Khort and Podbolotov were prepared $BaTiO_3$ nanopowders by the solution combustion method [8]. Other researchers have studied the effect of fast neutrons , gamma- rays on the dielectric, crystalline structure properties of BaTiO3 material [9,10,11,12]. In this work, the aim is to determine whether the neutrons and gamma-rays have been a negative or positive effect on the dielectrical properties of BaTiO3 material, especially that this material may be used as piezoelectric sensor in nuclear reactor environment.

EXPERIMENTAL WORK

1- Samples preparation:

In this work, BaO (purity 95 %), TiO_2 (purity 98 %) compounds that prepared by (BDH chemicals Ltd, England) were used to prepare $BaTiO_3$ material depending on the phase diagram of the BaO –TiO_2 system [13]. According to this system, BaO, TiO_2 compounds were mixed in molar ratio [1:1] in a gate mortar for 12 hr , then the resulting mixture was divided into four groups and each group was calcined at different temperatures (1100 – 1400 C^0) and different soaking time (3 – 9) hr to determine the best conditions for preparation of $BaTiO_3$ material . As a result of the initial experiments above , it was found by examining the prepared samples using XRD technique that the best calcining temperature is 1300 C^0 for 9 hr. The calcined mixture was ground and adding drops of poly vinyl – alcohol as binder to increasing the efficiency of the pressing process and to obtain samples of good shape and cohesive . Afterwards, the pellets were heated to 500 C^0 for 1 hr to burn and expel the binder (poly vinyl- alcohol) [14] . Then the heat temperature was raised to 1300 C^0 for 9 hr for sintering process .

2-Irradiation processes:

Some of the $BaTiO_3$ pellets were irradiated with 14 MeV monoenergetic fast neutrons with integrated flux (3.1 x 10^{10} n cm^{-2}) using neutron generator . Other $BaTiO_3$ pellets were exposed to gamma – ray using Co^{60} (1.332MeV , 1.173 MeV) [15] with integrated dosage (1.51 x 10^8 Rad).

3-Microstructure:

For microstructure test , both surfaces of each pellets were coated with a gold layer of 500 A^0 thickness using (JEOL – JFC- 1100 ion sputter). Then , the microstructure test was performed using SEM type (JEOL JSM- 6400 scanning microscope) .

4- Dielectric properties measurements:

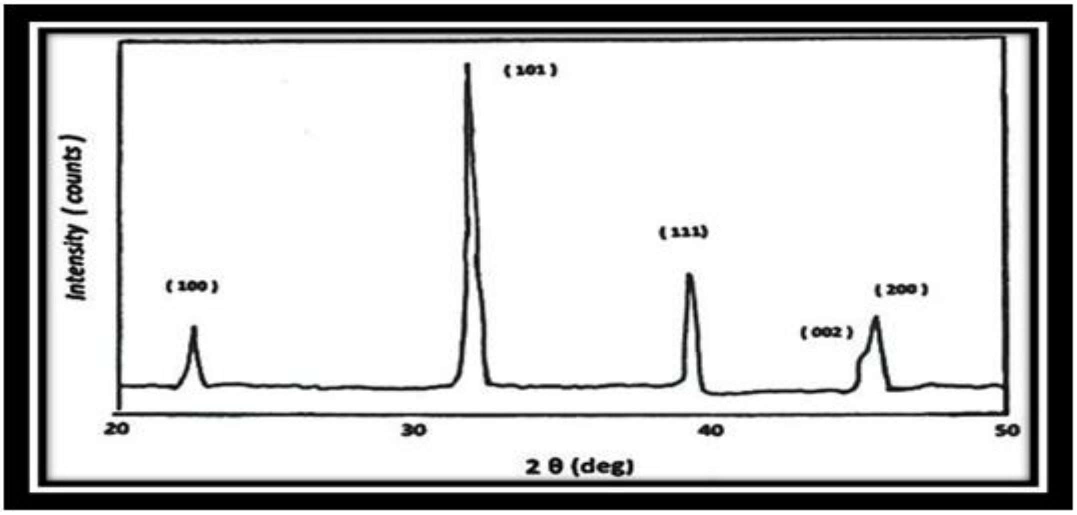
The dielectric properties of $BaTiO_3$ pellets were investigated using (RCL –meter) after two surfaces was coated with a thin aluminum layer and connect them with two wires using silver paste to connect them with electrodes of the device.

RESULTS AND DISCUSSION

Fig. (1) shows the XRD pattern of $BaTiO_3$ phase that prepared at 1300 C^0 for 9 hr . In this pattern ,we can see the formation of $BaTiO_3$ in good growth of main peaks ($2\theta = 20^0 – 45^0$) with a tetragonal structure at room temperature Fig.(2) shows the microstructure of BaTiO3 material which was prepared at 1300 C^0 for 9 hr , this figure shows that there is a relatively large variation in the particle size of this material ranging from (0.5 – 15.3 µm) and the average particle size is estimated to 4.6 µm . Fig. (3) shows the microstructure of fast neutrons (14 MeV) irradiated $BaTiO_3$ material . this figure shows that the proportion of large grains has decreased significantly due to the damage caused in there grains as result of bombing with fast neutrons in addition to appearance of needle shape structure resulting in increased the vacancies and lower grain size from (4.6 -3.8 µm) .

Fig. (4) shows the microstructure of gamma-ray irradiated $BaTiO_3$ material. In this figure, we can observe very clearly a needle structures as well as the deformation of the grains which appears more detailed in figure (5) which may play a significant role in changing of dielectric properties as will be seen later. Fig. 6,7,8 shows the dielectrical properties of irradiated and unirradiated $BaTiO_3$ material as a function of temperature . Fig (6) shows that the irradiation with fast neutrons and gamma led to a decrease in the dielectric constant($\acute{\varepsilon}$) from 3541.42 to 3265.52, 1979.13 at Curie temperature respectively ,also we can see that in temperatures up to 60 C^0 the dielectric constant of all increases with increasing temperature to reach maximum value at Curie temperature , but in range less than 60 C^0 , we can observe that the dielectric constant of unirradiated BaTiO3 material decreases from room temperature to reach minimum value at 60 C^0 while the dielectric constant of irradiated BaTiO3 is fairly stable in this region.

Fig (7) shows that the dielectric loss factor($\ddot{\varepsilon}$) increases with increasing of temperature, and to explain that behavior, may be due to increased alternating electrical conductivity due to decrease in the viscosity which leads to a drop in energy spent in the material due to friction caused by the rotation of the dipoles , also we can see that the irradiation of BaTiO3 material with fast neutrons and gamma-ray led to decrease in the loss factor with different rates . Fig (8) shows that the electrical resistivity decreases sharply with increasing temperature , also, the irradiation with fast neutron and gamma –ray led to a significant increasing in the electrical resistivity , this behavior may be interpreted on the basis that the irradiation may be lead to the formation of superficial and deep crystalline defects which act as carrier capture centers and then increasing the electrical resistivity.



Fig(1): XRD pattern of $BaTiO_3$ material prepared at 1300^0C for 9 hr.

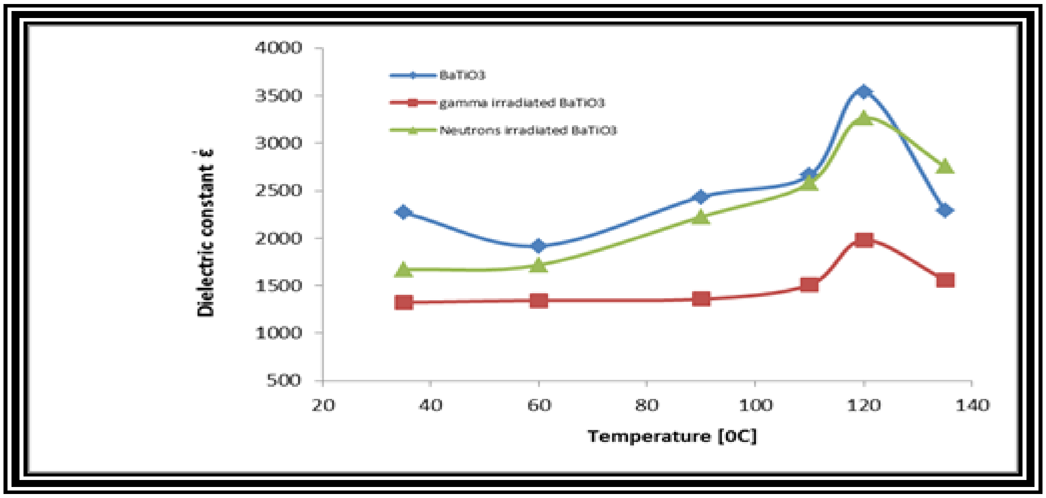


Fig (2): Variation of dielectric constant of irradiated, un irradiated $BaTiO_3$ material with temperature at 1 KHz frequency.

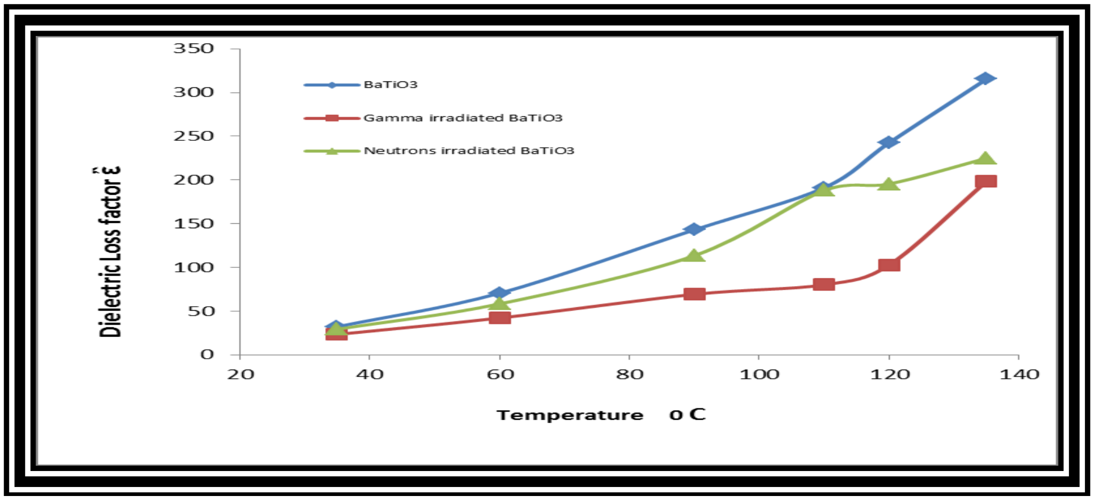


Fig (3): Variation of dielectric loss factor of irradiated, un irradiated $BaTiO_3$ material with temperature at 1 KHz frequency.

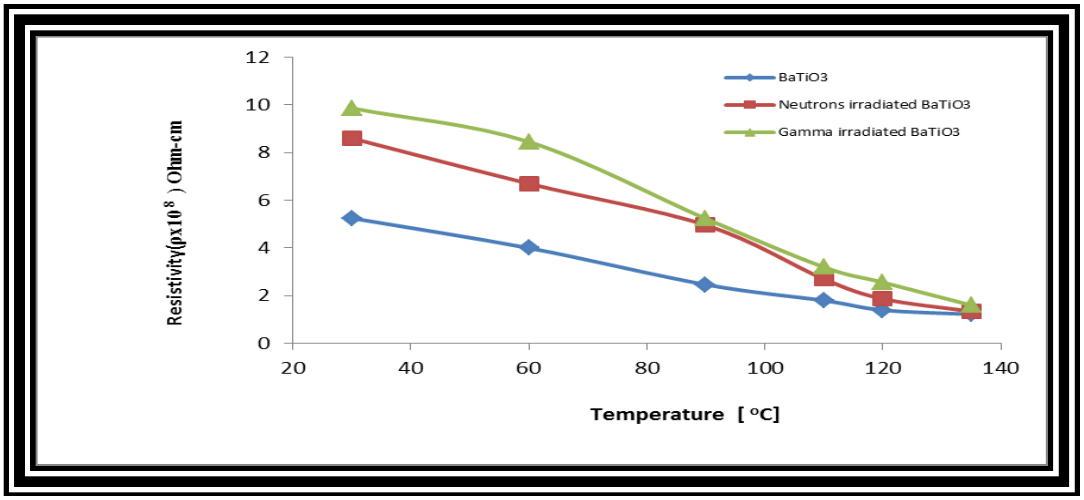


Fig (4): Variation the electrical resistivity of irradiated, un irradiated $BaTiO_3$ material with temperature.

CONCLUSION

The optimum calcining temperature for preparation of BaTiO3 (BaO-TiO2) is 1300 0C. Fast Neutrons and gamma rays have had a significant effect on the dielectrical properties of barium , in which the irradiation led to decrease in dielectric constant , dielectric loss factor of BaTiO3 while increasing the electrical resistivity. This shows that the neutrons and gamma rays have a similar effect in terms of the change that occurs in crystalline structure taking into account the proportion of that change and this is evident in the microstructure figures.

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