

# Preparation of barium ferrite $BaFe_{12}O_{19}$ and the study of the effect of fast neutrons on its magnetic and dielectrical properties.

Dr. Jassim Mohammed Yaseen  
University of Mosul / College of Basic Education

Received: 7/3/2011 ; Accepted: 2/6/2011

## Abstract:

Hard hexagonal barium ferrite  $BaFe_{12}O_{19}$  was prepared by solid state reaction method using a precursor ( $BaO- 6 Fe_2O_3$ ) mixture at calcinations temperature 1100 C for 2 hr. The XRD patterns of the calcined samples show the formation of  $BaFe_{12}O_{19}$  at this temperature .In this work, some of the samples were irradiated by fast neutron ( $^{241}Am-Be$ ) in average energy 5 MeV with flux ( $1.5 \times 10^6 n/cm^2.s$ ). The fast neutron irradiation did not affect the magnetic properties of prepared samples obviously, but it affected the electrical resistivity in direct relation in which the increasing of irradiation dosages lead to increasing of electrical resistivity obviously .

## تحضير الباريوم فرايت $BaFe_{12}O_{19}$ ودراسة تأثير النيوترونات السريعة على خواصه المغناطيسية والكهربائية

م.د. جاسم محمد ياسين  
كلية التربية الاساسية / جامعة الموصل

### ملخص البحث:

تم تحضير مادة الباريوم فرايت  $BaFe_{12}O_{19}$  بطريقة التفاعل الصلب عن طريق خلط المركبين  $BaO$  و  $Fe_2O_3$  بالنسبة المولية ( $BaO- 6 Fe_2O_3$ ). بعد اجراء عمليات الخلط الرطب والتجفيف تم حرق الخليط بدرجة حرارة C 1100 ولمدة ساعتين . باستخدام تقنية الحيود للاشعة السينية تم الحصول على نموذج الحيود السيني لطور الباريوم فرايت  $BaFe_{12}O_{19}$  المحضر وفق الظروف اعلاه. في هذا العمل تم تشعيع بعض النماذج بالنيوترونات السريعة ( $^{241}Am-Be$ ) وبمعدل طاقي قدره 5 MeV وبفيض نيوتروني قدره ( $1.5 \times 10^6 n/cm^2.s$ ) . نتائج التشعيع أظهرت أن التشعيع النيوتروني وفق الظروف اعلاه لم يؤثر على الخواص المغناطيسية للباريوم فرايت بشكل واضح ، في حين أثرت بشكل كبير على المقاومة الكهربائية للمادة ، حيث أن المقاومة الكهربائية تزداد بزيادة الجرعة الإشعاعية .

## Introduction

Barium Ferrites are well known hard magnetic materials , which are based on iron oxide .They are also called as ferrite magnets and could not be easily replaced by any other magnets . Hexagonal barium ferrite having the chemical formula of  $BaFe_{12}O_{19}$  are widely used in magnetic recording media , microwave devices and electromagnetic shielding fields .Barium ferrite possesses relatively high curie temperature , coercive force and magnetic anisotropy field ,as well as its excellent

chemical stability and corrosion resistivity .Ferrite magnets are still widely used although they have less magnetic strength than rare earth magnets . Comparing ferrite magnets and rare earth magnets could be concluded by determination of the ratio of remanence ( $B_r$ ) which is about 1:3,the ratio of coercive force ( $H_C$ ) which also 1:3 [1] .Nikkhah et al prepared barium ferrite and studied the effect of neutron and  $He^3$  Irradiation on the magnetic properties of perm alloy thin film[2 ].Pullar et al, prepared barium ferrite by sol-gel method and studied the characterization of barium ferrite fibres [3 ]. Lisfi and Lodder studied the effect of ZnO on micro structural and magnetic properties of barium ferrite thin films ,it was found that a ZnO promotes the perpendicular orientation of the c-axis to the film [ 4 ]. Much another papers studied the magnetic, structural properties of barium ferrite such as Ping et al [5 ] . Srivastava et al [6 ] .Waldemar, et al [7 ] .Cao and et al [8].Kohn and Eckart [9].The reaction between the different radiations and the crystals lead to the production of many types of defects, the neutrons radiation is the most significance between them because it is neutral particles ,therefore it can penetrate in the materials in more effectiveness without a lack in its energy as a result of coulomb reaction with electrons [10].If a perfect crystal placed in front of neutron radiation source ,crystal defect will appear and the crystal became imperfect, in which this defects to be left over until after the irradiation process( this is called radiation damage. During this process , many physical properties are being modified, this is called radiation effect [11].

This paper report the results of magnetic properties of  $BaFe_{12}O_{19}$  powder synthesized from BaO and  $Fe_2O_3$  and the effect of neutron radiation on the magnetic, dielectrical properties of  $BaFe_{12}O_{19}$  .

## Experimental Section

### 1- Sample Preparation

Powders of BaO (BDH company with purity 98 % ) and  $Fe_2O_3$  ( BDH Company with purity 97 % ) in the molar ratio (BaO- 6  $Fe_2O_3$  ) depending on the phase diagram of  $Fe_2O_3$ -BaO system [1] Then ,the mixture ground in agate mortar for 90 min at room temperature before wet mixed for 48 hr. The prepared mixture was dried at 60 C for 3 hr ,followed by precalcination at 500 C for 1 hr and calcinations at 1100 C for 2 hr. After that, the powder of  $BaFe_{12}O_{19}$  was ground to get a powder in good homogenizing, small grain size. Then the powder was pressed to samples in 2 cm diameter and 0.5 cm thickness ( with addition vinyl- alcohol as a binding material) using electric press. The disks were sintered at 1250 C for 3 hr.

### 2- Irradiation of samples

Some of  $BaFe_{12}O_{19}$  disks irradiated by fast neutrons in different doses and energy range ( 2-10 MeV) [13]. using the ( Am –  $Be^{241}$  ) as a neutron source in neutron yield (  $10^7$  n/s ) with flux (  $1.5 \times 10$  n/cm.s ) and different integrated flux as shown in table (1).

### 3- Characterization

Powder x-ray diffraction (XRD) was recorded on an XRD Philips PW1316/90 single open recorder/  $CuK_\alpha$  target.

Magnetic properties were obtained on the Magnet-Physik device (Russian origin) connected with computer to drawing the hysteresis loop at room temperature.

The electrical resistance of samples was obtained by using Ohm-meter at room temperature. The electrical resistivity (  $\rho$ )was calculated by using the equation :

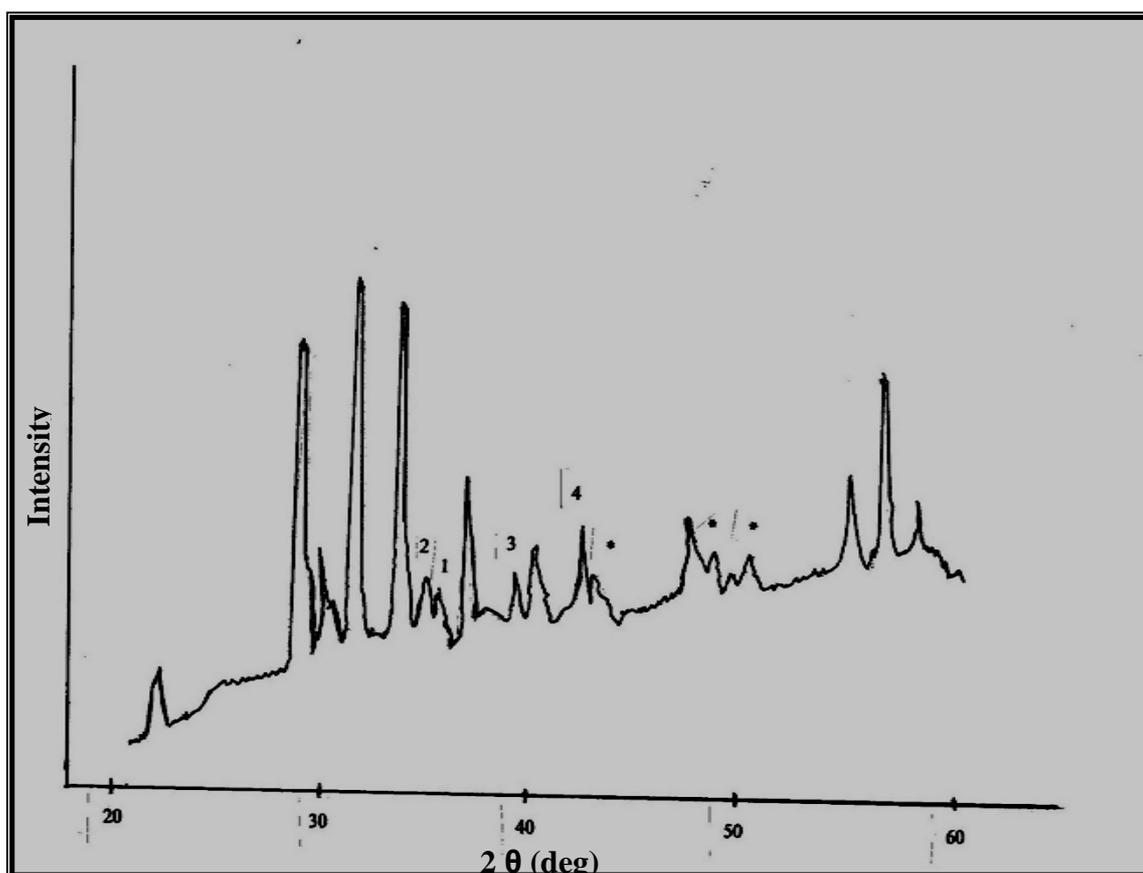
$$(\rho = R A /d )$$

Were, A: surface area of sample in  $cm^2$  , d : thickness in cm.

## Result and discussion

In this work, I chose the solid state reaction method because it produces adequate amounts of the required material in relatively short time, as well as it needs oxides as raw materials which are available in contrast to other methods that needs to solutions, acetate compounds which are not available within the country .

Figure( 1) shows the x-ray diffraction pattern of synthesized barium ferrite powder .this pattern exhibit typical peaks that can be indexed to the standard pattern of BaFe<sub>12</sub>O<sub>19</sub> crystals [13]. Also there are shifts in typical intensity peaks by ( -1.2 theta) when it is compared with standard card of BaFe<sub>12</sub>O<sub>19</sub> phase , this is because the effect of thermal vibration of the atoms on a powder pattern in which lead to decreasing the intensity of diffraction lines,  $2\theta$  [14].The peaks marked in 1 ,2 represent Fe<sub>2</sub>O<sub>3</sub> compound and peaks 3,4 represent BaO compound ,while peaks marked by (\*) represent the impurities in raw materials



**Fig.1: The XRD pattern of BaFe<sub>12</sub>O<sub>19</sub> phase prepared at 1100 C for 2 hr.**

Figures (2-6) and table 1 shows the results of magnetic factors which it coercive force and remanence magnetic flux for neutron irradiated ,un irradiated samples in different dosages at room temperature. These figures and table (1) shows that there is a small change in magnetic parameters especially sample number (4), but this change is lower than the background level that exists in the calibration process of the testing device. Therefore , I conclude that the neutron radiation in used dosages in this work does not affect seriously on the magnetic parameters , and these results coinciding to the results of Gordon [15].

**Table (1)**  
**Values Of the magnetic factors and rate of the used irradiation dosages.**

Sample No.	Dosage n/cm.s	H <sub>C</sub> (KOe)	B <sub>r</sub> (KG)	BH <sub>max</sub> MGoe
1	0	2.48	1.71	0.55
2	3×10 <sup>10</sup>	2.51	1.64	0.51
3	6.4×10 <sup>10</sup>	2.61	1.64	0.53
4	1.3×10 <sup>11</sup>	2.49	1.61	0.50
5	3.6×10 <sup>11</sup>	2.63	1.66	0.53

Table (2) shows the results of electrical resistivity of irradiated, un irradiated samples. It is obvious that there is strong correlation between the electrical resistivity and radiation, in which the electrical resistivity increased with increasing of radiation dosages. This behavior is because the increasing of radiation dosages gives rise to increasing the deformation in crystal lattice which leads to increasing the point defects which obstructs the motion of electrons in the crystal structure of samples which causes an increase in the electrical resistance [10]. Mousa et al, reported that the electrical resistivity of cobalt ferrite increasing with increasing of gamma radiation dosages [16].

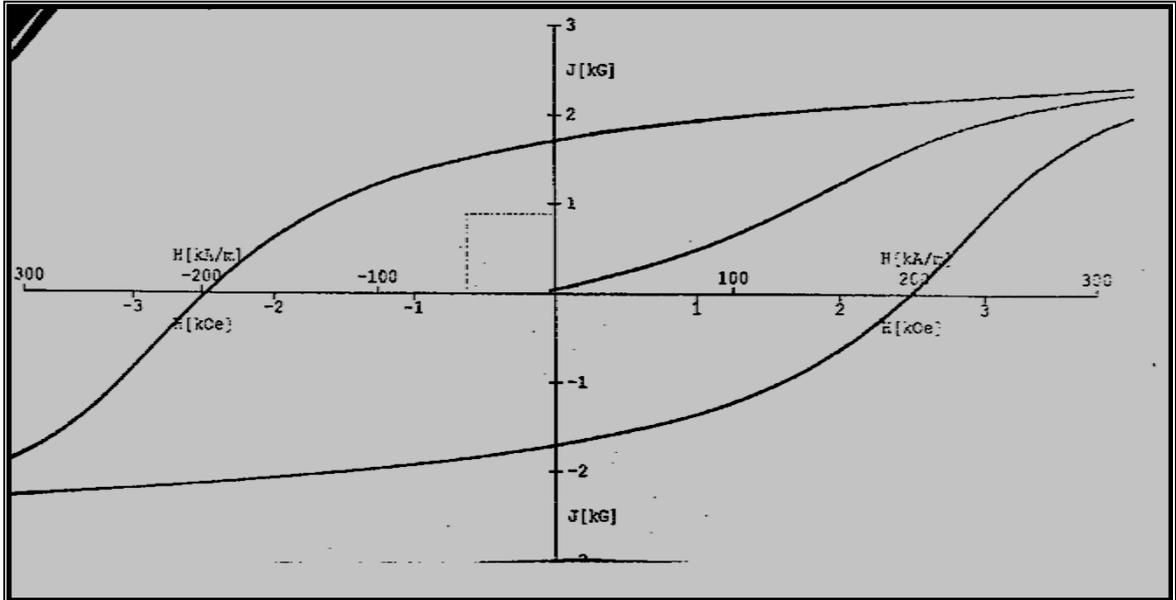
**Table(2)**  
**The effect of the irradiation dosages on the electrical resistivity of samples.**

Sample No	Integrated dosage (n/cm.s)×10 <sup>10</sup>	Electrical resistivity (Ohm.cm)×10 <sup>5</sup>
1	0	1.2
2	1.5	1.79
3	4.0	1.95
4	13.0	2.46
5	26.0	3.44

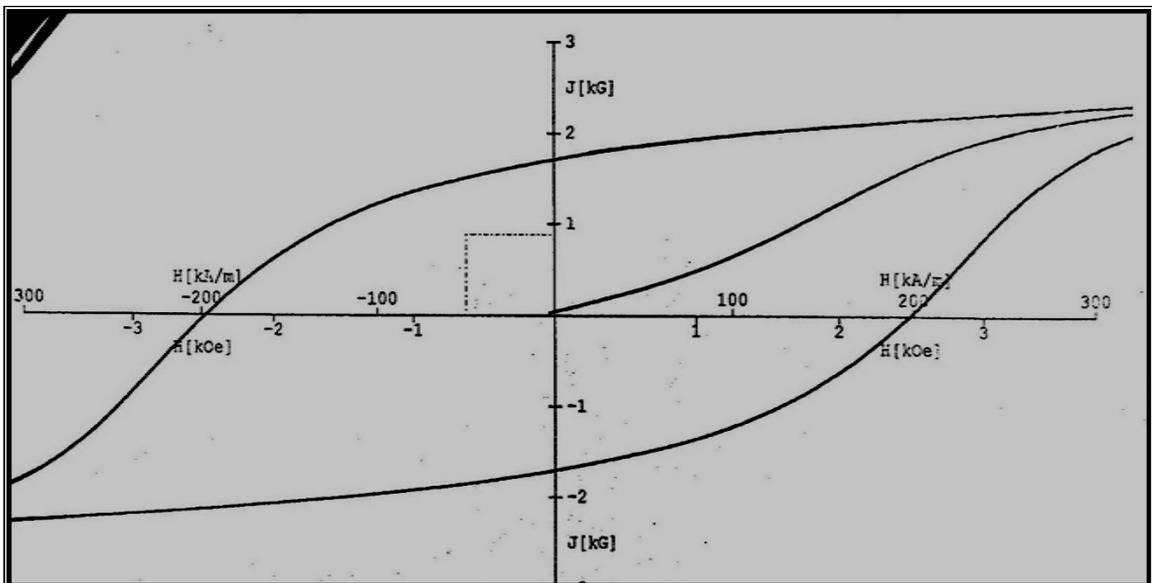
## Conclusion

Fine particles of barium ferrite BaFe<sub>12</sub>O<sub>19</sub> have been prepared at temperatures as low as 1100 C, by calcination of a precursor, BaO and Fe<sub>2</sub>O<sub>3</sub> mixture. The magnetic parameters such as coercive force (H<sub>C</sub>) and remanence magnetic flux (Br) not seriously affected by neutron radiation in dosages used in this work. The

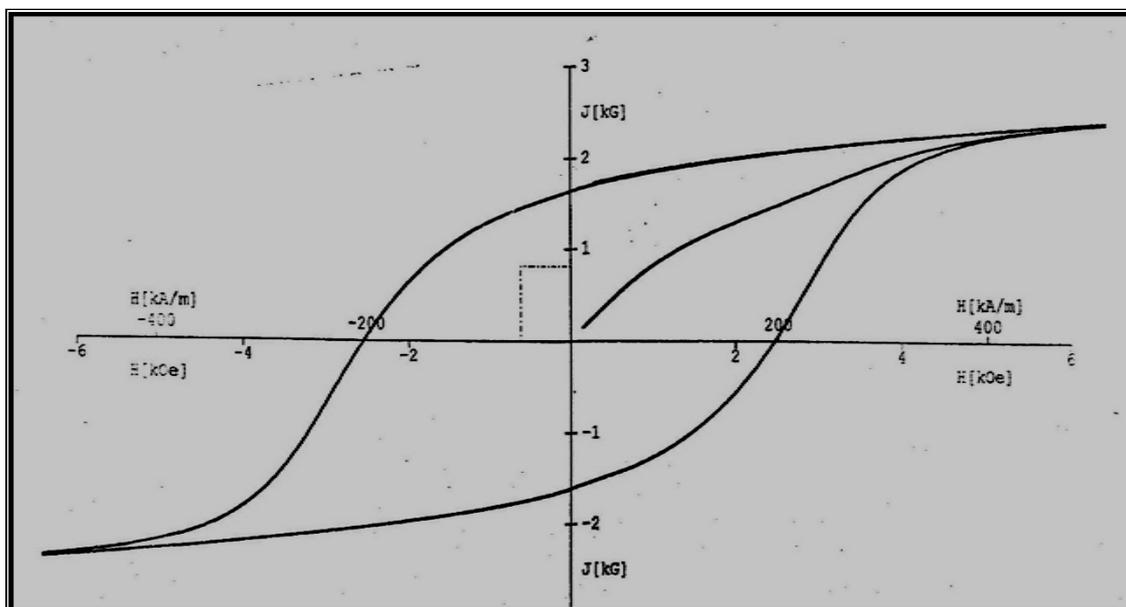
irradiation by fast neutron increasing the electrical resistivity obviously with different ratios depending on the dosages of radiation.



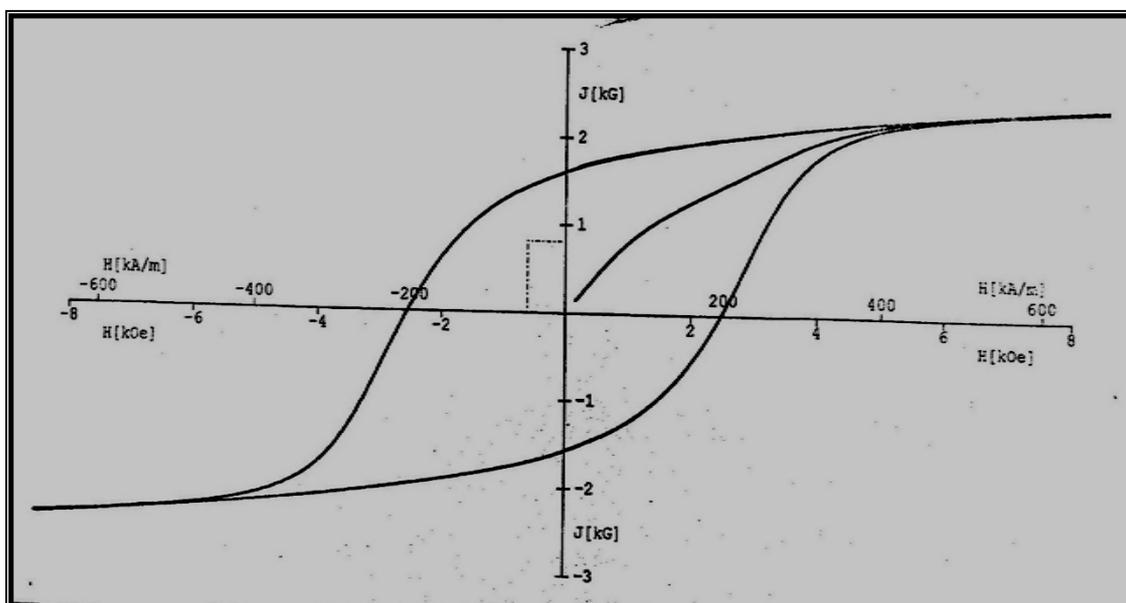
**Fig.2**  
The hysteresis loop of BaFe<sub>12</sub>O<sub>19</sub> sample ( No.1)



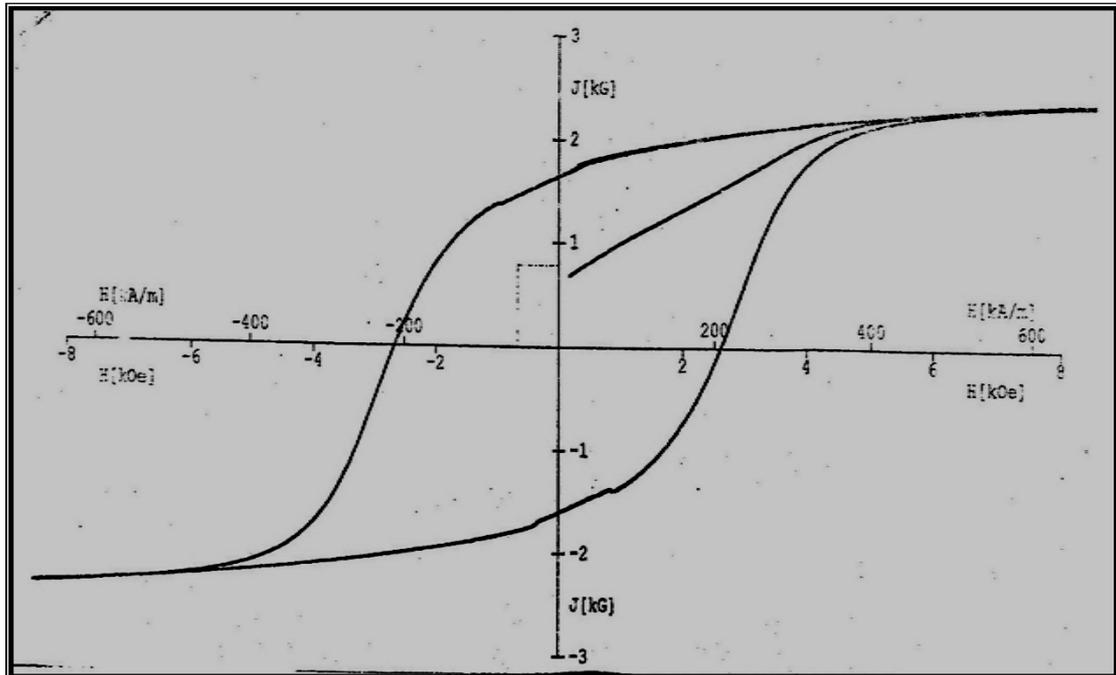
**Fig.3**  
The hysteresis loop of BaFe<sub>12</sub>O<sub>19</sub> sample ( No.2)



**Fig.4**  
The hysteresis loop of BaFe<sub>12</sub>O<sub>19</sub> sample ( No.3)



**Fig.5**  
The hysteresis loop of BaFe<sub>12</sub>O<sub>19</sub> sample ( No.4)



**Fig.6**  
The hysteresis loop of BaFe<sub>12</sub>O<sub>19</sub> sample ( No.5)

## References

- 1- Nowosielski.N, Babilas.R, Dercs.G, Pajak.L, Wrona.J, Structure and properties of barium ferrite powder by milling and annealing , J.Mater. sci and eng., V28, No 12, PP 735, 2007.
- 2- Schindler.A, Williams.C., Investigations of the neutron and He<sup>3</sup> Irradiation on the magnetic properties of permalloy thin films, J. Appl. Phys , V35, No 3, PP877, 1964.
- 3- Pullar.R, Taylor.A, Shattacharya.A., Novel aqueous sol-gel preparation and characterization of barium ferrite BaFe<sub>12</sub>O<sub>19</sub> fibres, J. Mater Sci, V32, PP 349, 1997.
- 4- Lisifi.A ,Lodder.J., The effect of ZnO underlayer on microstructural And magnetic properties of BaFe<sub>12</sub>O<sub>19</sub> thin films, J. phys:condensed matt , V 13, No 26, PP 5917, 2001 BaFe<sub>12</sub>O<sub>19</sub>
- 5- WWW.E:/ ferrite /Synthesis and Magnetic Properties of Hexaferrite.
- 6- Srivastava.A, Singh.P, Gupta.P., Barium ferrite preparation by liquid mix technique and its characterization, J. Mater Sci V22, PP 1489, 1987 .
- 7- Waldemer .K, Witkowski, Leonowicz.M, Paszula.J., Effect of milling medium on the structure and magnetic properties of mechanically alloyed barium ferrite , Rev Adv Mater Sci, V 18, PP 497 , 2008.
- 8- Cao.X, Tan.Y, Meng.H., Synthesis process of Ba-Ferrites from  $\alpha$ - FeOOH and investigation of magnetic properties , J.Mater Sci, V 55 ,No 18 ,PP 1952, 2010.
- 9- Kohn.J, Eckart.D., New hexagonal ferrite establishing a second structural series , J. Appl Phys , V 35 ,No 3, PP 968, 1964.
- 10- Lewis.T., Radiation damage in crystals, Spottiswoode Ballantage Ltd , 1965.
- 11- Encyclopedic dictionary of physics, V 3, pergamon press, 1969. , Am-F , <sup>242</sup> Cm-Be isotrop
- 12- Lorch.E., Neutron spectra of <sup>241</sup>Am-Be- Sources , Int J. Radiation and isotopes, V24 , PP585, 1973.
- 13- JCPDS-international center for diffraction data, CD software , V 1.3 code no. 43-0002, 1997.
- 14- Cullity.B ., Elements of diffraction, 2<sup>nd</sup> edition , Adeson-Wesley publishing Co, Ink, 1978.
- 15- Gordon.D, Serry.R., Irradiation of iron and 5-79 Mo permalloy with 2- MeV electrons , J. Appl. Phys V 35 ,No 3, PP 879, 1964.
- 16- Mousa.M.A, Summan.A.M, Ahmed.M.A., Electrical conduction in  $\gamma$ -irradiated and unirradiated Fe<sub>3</sub>O<sub>4</sub>, Cd Fe<sub>2</sub>O<sub>4</sub> and Co<sub>x</sub>Zn<sub>1-x</sub>Fe<sub>2</sub>O<sub>4</sub> (0  $\leq$  x  $\leq$  1) ferrites., J.Mater.Sci, V 24, PP 2478, 1989.