The Effect Of Temperature On The Dielectric Strength Of BaTiO3 Ceramic

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Abstract:

In this work , barium titanate (BaTiO3) ceramic was prepared using two systems (BaO- TiO2) , (Ba acetate-TiO2) by solid state reaction method . X-ray diffraction patterns showed that the (BaO- TiO2) prepared BaTiO3 ceramic was a good growth when it calcimine at 1200 C for 2 hr . But (Ba acetate –TiO2) prepared BaTiO3 was a bad growth at 1200 C ,hence it requires calcimine temperature above 1200 C Using optical microscopy, the particle size and shape for each powder has been noted .

The results of dielectric strength measurements showed that the dielectric strength strongly depend on the temperature , in which the dielectric strength decrease as temperature increase with more significant above 120 C .

تأثير درجة الحرارة على متانة العزل لمادة الباريوم تيتانيت $BaTiO_3$

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ملخص البحث :

في هذا العمل تم تحضير مادة الباريوم تيتانيت BaTiO3 باستخدام النظامين (BaO-TiO2) و (Ba acetate-TiO2) وباستخدام طريقة الحالة الصلبة. فحوصات حيود الاشعة السينية XRD اظهرت ان مادة BaTiO3 المحضرة باستخدام النظام (BaO-TiO2) لها درجة نمو جيدة عند حرقها بدرجة حرارة 1200 C لمدة ساعتين بينما لم يكتمل نمو مادة BaTiO3 المحضرة باستخدام النظام(Ba acetate-TiO2) . عند حرقها بدرجة حرارة 1200 C .

نتائج قياسات متانة العزل اظهرت ان متانة العزل تعتمد بشكل كبير على درجة الحرارة ، حيث ان متانة العزل تنخفض بزيادة درجة الحرارة ويزداد معدل الانخفاض في درجات الحرارة فوق 120 C .

Introduction:

Barium Titanate BaTiO3 was discovered independently from US or the U.S.S.R at the end of world war п [1].

It is one of the most ferroelectrics. Ferroelectricity is the spontaneous polarization in the absence of an electric field [2].

BaTiO3 – based ceramics show high dielectric constants and therefore these materials are suited for and widely used to capacitors applications [3]. In addition to that, polycrystalline BaTiO3 displays positive temperature coefficient PTCR , making it a useful material for thermistors and self regulating electric heating systems [4] .

The dielectric properties of BaTiO3 ceramic has a strongly temperature dependence and a pronounced maximum at the Curie point (120).

When very high electric fields are applied across dielectric materials, large numbers of electrons may suddenly be excited to energies within the conduction band . As a results, the current through the dielectric by the motion of these electrons increases dramatically ; sometimes localized burning produces irreversible degradation and perhaps even failure of the material .This phenomenon is known as dielectric breakdown (strength) [5] .

There are many of the research study examined the dielectric properties of barium titanate ,such as Blanchart and Baumard [6] they have found that the electrical resistivity of $BaTiO_3$ strongly depend on the impurities . ; Murakami and Miyashita [7] they have showed that the electrical conductivity of $BaTiO_3$ increase as a maximum value as the Gadolinium Oxide Gd_2O_3 ratio increase to 0.2 wt%, then the electrical conductivity decrease as Gd_2O_3 ratio increase. ; Klaus [8] has prepared barium titanate using solid state reaction method with dielectric strength 1.5-10 Kv/cm. ; Mukhachev and Mukhacheva [9] they have showed that a sharp decrease in the dielectric strength with increase in temperature .

In order to improve the specification of the barium titanate and the development of the practical applications must be to study the effect of temperature on the dielectric properties of this material .Therefore, the objective of this study was to examine the effect of temperature on the dielectric strength property of this material through it work in the vicinity of relatively high temperature .

Experimental

In this work, two systems were used (BaO-TiO2) [1:1]as a (batch 1) and (Ba acetate-TiO2) as a (batch 2) for the preparation a high purity barium titanate with good growth .Then selection the best in a achieving the goal of this work between them .

Raw materials:

Compound	Company	Purity (%)	Impurity (wt %)
BaO	Fluka	97	Cl(0.02),Cu(0.04),Fe(0.02) ,Zn(0.005)
Ba-acetate	BDH	99	Fe(0.01), Cl(0.04)
TiO2	BDH	95	Fe(0.01),Mn (0.04), Cu (0.05)

Samples preparation:

After the raw material mixing process with ethanol for 12 hr by using electrical ball-mixer ,two batches were calcined using solid state reaction method at 1200 C for 2 hr .Then ,the calcined powder were grinded for 9 hr by using ball-milled for 6 hr , then pressed into pellets of 9 mm diameter and 3-4.5 mm thickness, and then sintered at 1200 C for 2 hr.

XRD test :

XRD test was achieved in The Baghdad University by using Philips PW1316/90 single-pen recorder/ CuKα target .

Microstructure test :

In order to determine the characterize of the internal structure of the prepared $BaTiO_3$, microstructure test was achieved in The Ministry Of Science And Technology using optical microscope type Nikon,ME 600 with digital camera DXM 1200 F.

Dielectric strength test :

Based on the analysis of XRD patterns and microstructure, samples of $BaTiO_3$ (batch 1) were selected for the examination of dielectric strength. Dielectric strength test was achieved in The University of Technology using a glass basin filled with oil (dielectric strength 33 Kv/cm) contact with D.C power supply (RSG system) ,Fig.1.

That the calculation of the value of the dielectric strength is by dividing the reading system ,which represents the value of the electric field (which collapses the sample) on the thickness of the sample . Therefore a unit of measurement is Kv/cm .

I have been using a oven to heating the samples with different temperatures before being placed between the poles of the RSG system to measure the dielectric strength change with temperature change.

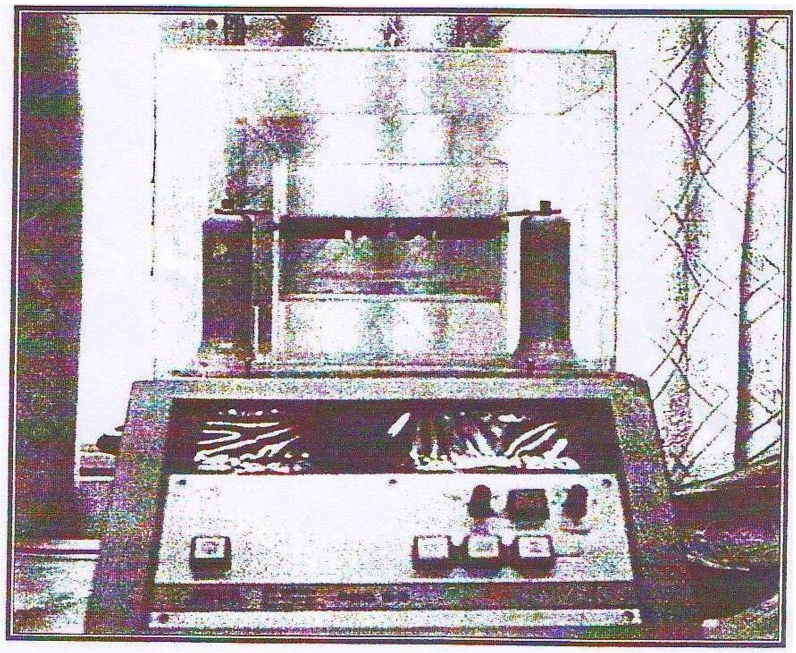

Fig.1 : The system RSG used to measure the dielectric strength in this work

Result and Discussion

Fig (2) show the XRD pattern of the calcinted powder of a $BaTiO_3$ (batch1).

This figure showing the four distinctive peaks of tetragonal $BaTiO_3$ phase . Seen from this figure that these peaks have grown well with the greatest crystallinity peak (110) [d-spacing 2.82 A at position 2θ=31.8] in which is the major peak of tetragonal $BaTiO_3$ phase in addition to the other peaks are (100) [d =3.99 A , 2θ =22.3] , (111) [d = 2.36 A , 2θ=39] , (002) [d= 2.01 A, 2θ=45.3], (200) [d=1.99 A, 2θ=45.5] . The small peaks marked numbers 1,2 and 3 belong to un reacted TiO_2 material . As well as ,absence of the un reacted BaO material .Finally ,conclude that the prepared $BaTiO_3$ (batch 1) is characterized by good growth with absence of unwanted phases and impurities .

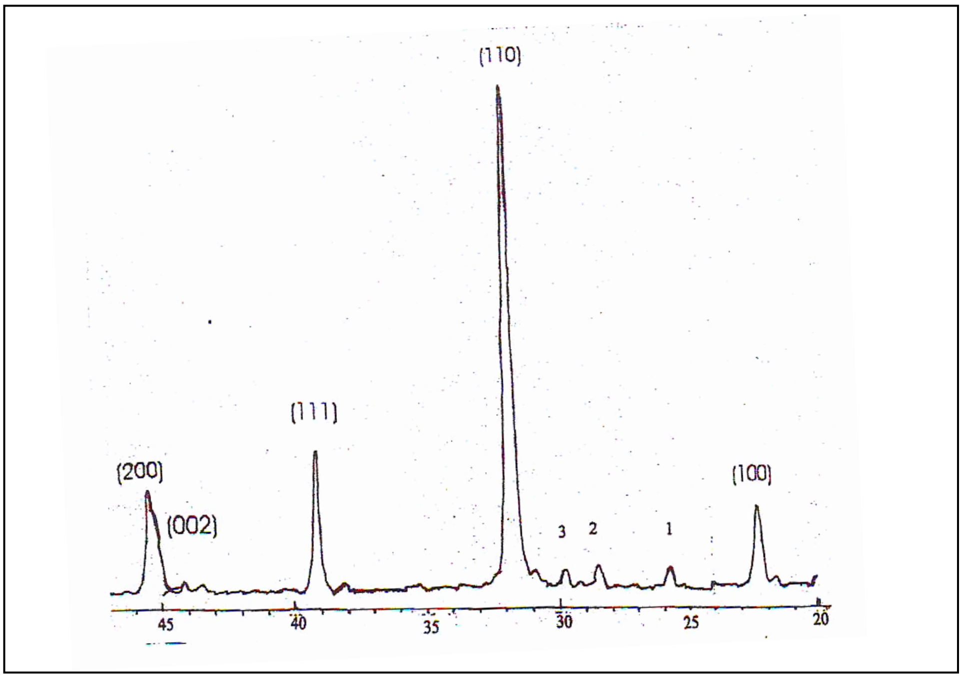

Fig.2: XRD pattern of (BaO-TiO2) powder calcined at 1200 C for 2 hr.

Fig (3) showing the XRD pattern of calcinated powder of BaTiO3 (batch2). This figure shows the non-completion of the process of the growth and crystallization of BaTiO3 and that it become clear if we compare between this figure and figure (1) . Where we find that the greatest crystalline at (2 θ=31.7 A) smaller than these in figure (1) by about (48%) . In addition to that , the other distinctive peaks at positions (d= 3.99 , 2θ=22.3) , (d= 2.36 , 2θ=39.2) are bad crystallinity (un complete reaction)with exactly absence of fourth and fifth peaks which are (d= 2.01 A ,2θ=45. 3) (d=1.99 A , 2θ=45.5).As well as ,we note that this pattern was shifted toward (-2θ) by (2θ=0.1) .

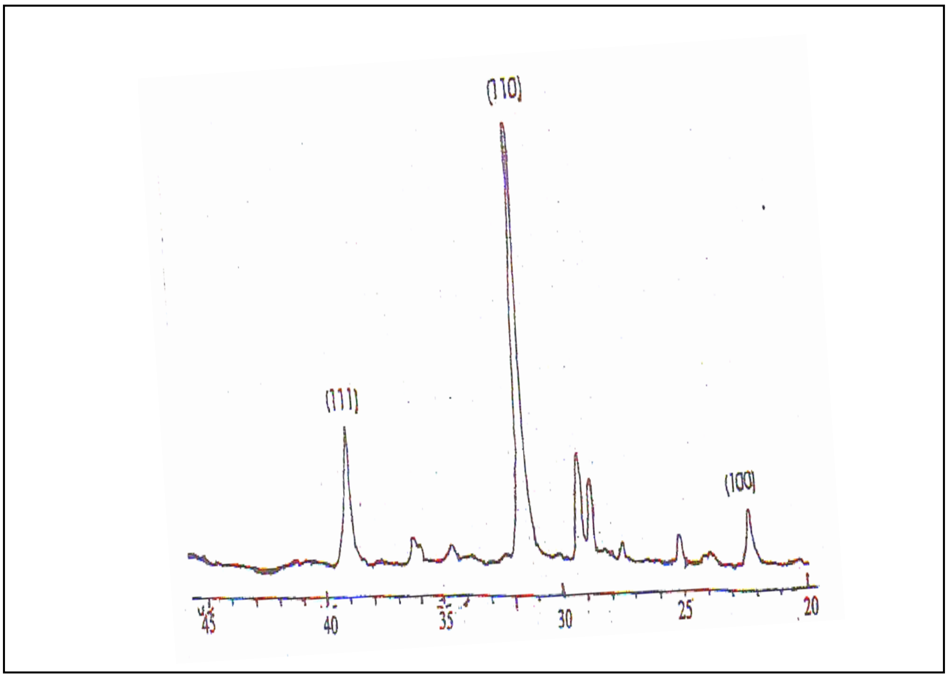

Fig.3: showing the XRD pattern of calcinated powder of $BaTiO_3$ (batch 2)

From the above ,we can deduce that the batch (1) produce a $BaTiO_3$ with growing well when they are calcinated at 1200 C ,which is a temperature as possible in this work. While the batch (2) requires a calcinations temperature more than 1200 C to complete the growth process of $BaTiO_3$ phase .Therefore, the batch (1) was used in the preparation of the samples for examining the effect of temperature on the dielectric strength.

Fig(4) showing the microstructure of tetragonal $BaTiO_3$ phase (batch 1) . In this figure there is an appearance of $BaTiO_3$ ceramic material was formed with high crystalline in the presence of complete grains formed, complete grain boundaries formed. As well as, it illustrate that there are multiple forms of grains such as tetragonal grains, irregular polygons grains. Also, this figure shows that the grain size varies between (7- 60 um). We also note the presence of green areas in which represent the phases of the impurities in raw material.

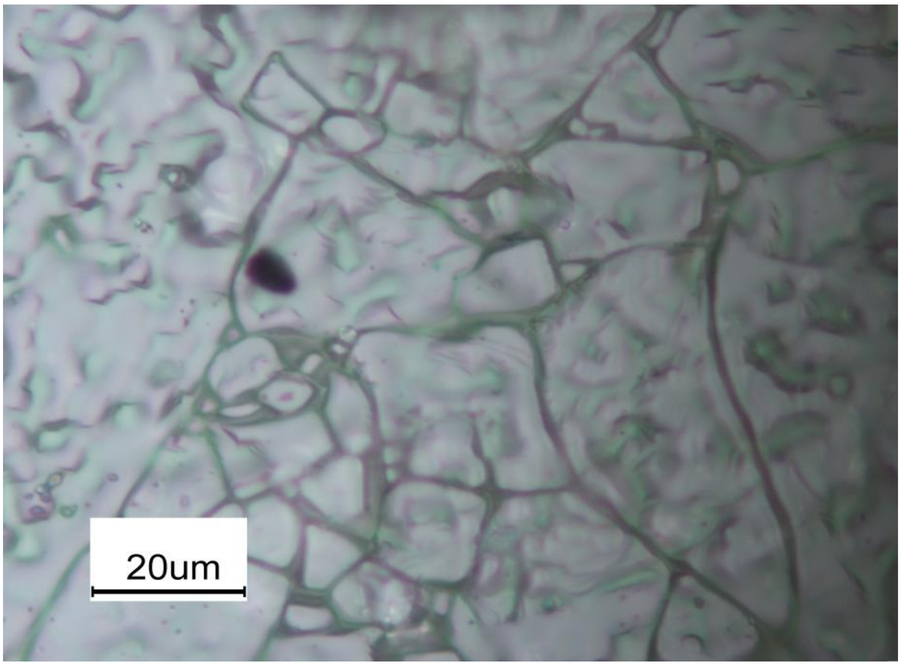

Fig.4: microstructure of BaTiO3 (batch 1), (x 1000)

Fig (5) showing the microstructure of incomplete BaTiO3 phase (batch 2). This figure shows the presence of multi- phases in the solid solution where the interaction is not complete .Also notes the growth of some grains which are very close to spherical shape.

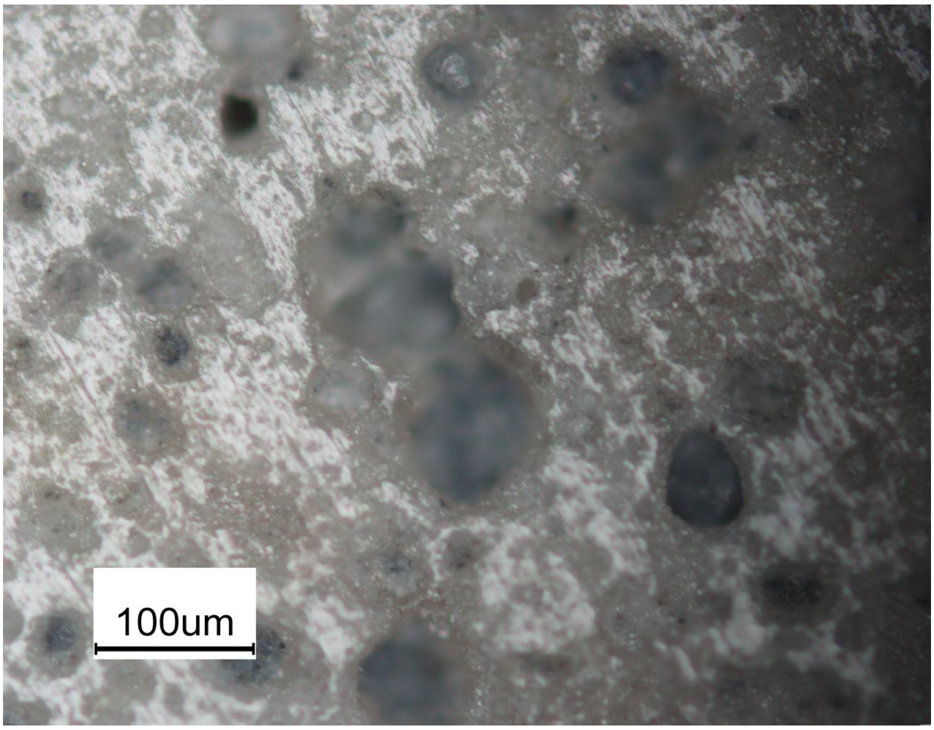

Fig.5: microstructure of BaTiO3 (batch 2), (x 1000).

The effect of temperature on the dielectric strength of the $BaTiO_3$ ceramic is shown in figure (6).

This figure shows that increasing the temperature in the range between (37- 100 C), lead to relatively slow decreasing in the dielectric strength **.**But in the temperature range (120- 200 C), strongly decreasing in the dielectric strength as temperature increasing. To illustrate this behavior ,may be the reason that the dielectric properties in generally significantly affected upon the arrival of the applied temperature to the curie temperature (120C) in which in this temperature a phase transition occurs from tetragonal to cubic phase which leads to the removal of grains, which in turn lead to changing the dielectric properties.

The forms of the dielectric collapse are either in the form of site fusion or the burning hole or window [10] . The collapse, which happened in our samples in this work was in the form of area burned in the middle of the hole .

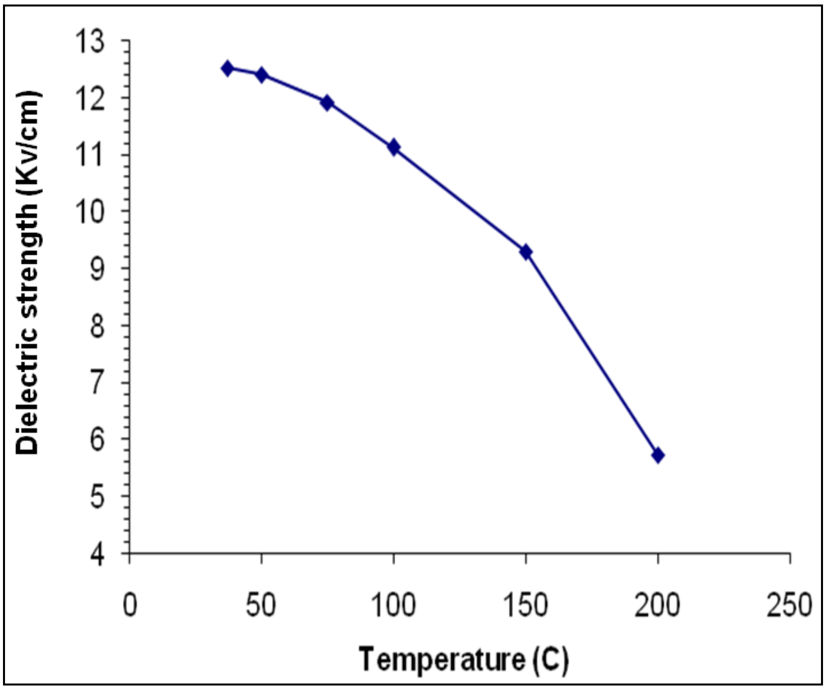

Fig.6: effect of temperature on dielectric strength of $BaTiO_3$ (batch 1) .

That the collapse means the emergence of electric charges moving within the dielectrics able to go through the material from one party to another and the source of these charges either from within the material as a result of liberation from the stability sites by the energy gained as a result of the electric field projection or be the result of movement of charges from the metal pole into the material and enable them to passing to another pole [3] .

Conclusion

The (BaO – TiO2) [1:1] system was a good in the producing of barium titanate ceramic at 1200 C for 2 hr, while The (Ba- acetate-TiO2) [1:1] system produces a weak growth barium titanate when it calcimine at 1200 C . Therefore, this system requires calcimine temperature above 1200 C (1350- 1400) .

The impurities in starting materials strongly have an effect on x-ray diffraction patterns.

The dielectric strength strongly depend on the temperature, in which it obviously decrease as the temperature increase ,especially above the curie temperature (120 C) .

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