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RESEARCH ARTICLE

THE FREQUENCY STUDY OF THE DIELECTRIC PROPERTIES OF BT

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ABSTRACT

This work is interested in the frequency study of the dielectric properties of BT ceramics. In this regard, we used two methods for measuring capacitance. In the first method the frequency was varied in the interval 100Hz – 1000 kHz and the measuring temperature was varied with a rise rate of 1°C/min, whereas in the second method the measurement temperature was first fixed and after its stabilization the capacitance measurement was started in a frequency range which varies between 1 kHz and 2 MHz by a step of 1 kHz. In_particular, the results found show, that the values of the dielectric constant are higher and the transition temperature Tc lowered by 12 °C in the second method.

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INTRODUCTION

The micro technology has experienced a significant growth since the fifties. Hence, manufacturing techniques have evolved and have contributed to a reduction in production cost, and nowadays many applications incorporate small devices. Indeed, the actuators and sensors are a class of these devices, which utilize piezoelectric materials as active elements in medical imaging (scan) and velocimetry (piezoelectric motors, sonar sensor, electromechanical filters, low-power ultrasonic transducers injection mechanisms, sonar and ultrasonic cleaning tanks) (Nagata *et al*., 2013, Jaffe., 1971, Saito., 2004, Peng.,). Energy harvesting is the process of extracting, converting and storing energy from the environment that can also be described as a response of smart materials when they are subjected to an external stimulus such as pressure, vibrations, motion and temperature (Eerenstein *et al*., 2006; Nagarajan *et al*., 2003; Angus *et al*., 2005; Xiaobing *et al*., 2004). Consequently, $BaTiO_3$ material is a particularly interesting compound for this type of application. On the other hand the potential of BaTiO3 is linked particularly to the existence of dielectric and piezoelectric properties (Rawat *et al*., 2013, Wei-Gang *et al*., 2012, Kyung *et al*., 2013). The study of these properties is necessary before any development. The ultimate goal o f this work is to study the effect of heat treatment time on the dielectric properties of barium titanate; these properties compare two methods of dielectric measurement.

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Procedure

The different steps of preparation of barium titanate were presented in another work (Elbasset *et al*., 2015). Raw powder, after grinding, was calcined in air at temperature 1000°C, in a programmable oven. These compositions were then pressed into pellets of 12 mm diameter and a thickness of 1 mm under a uniaxially pressure equal to 10 tons/cm^2. The pelletized samples were finally sintered at 1100°C for 8 h and 4h in a programmable furnace. Silver paste was added to both faces of the disks the disks, which were then fired at 60 °C as electrode.

RESULTS AND DISCUSSION

In this work we used two methods to measure the capacity of our pellets. In the first method (a) the frequency values were set in a frequency range from 100Hz to 1000 kHz and the measuring temperature was varied with a rise rate of 1 ° C / min. Whereas in the second method (b) the measuring temperature was set by programming the furnace and after its stabilization the capacitance measurement was started in a frequency range which varies between 1 kHz and 2 MHz by a step of 1 kHz. The results obtained by means of these methods of the dielectric constant of BT plotted as a function of the temperature at different frequencies are illustrated by the curves of Fig. 1.

Table 1. The values of ε'_{max} and Tc measured by two methods (a) and (b)

	Frequency (*kHz*)						Temperature at Tc
	1000	500	100	10	1	0 ,5	
$\varepsilon'_{max\ de}$ BT (a)	2970	1964	1790	1818	1852	1870	147°C
$\varepsilon'_{max\ de}$ BT (b)	3982	3197	2796	2810	2870	2912	135°C

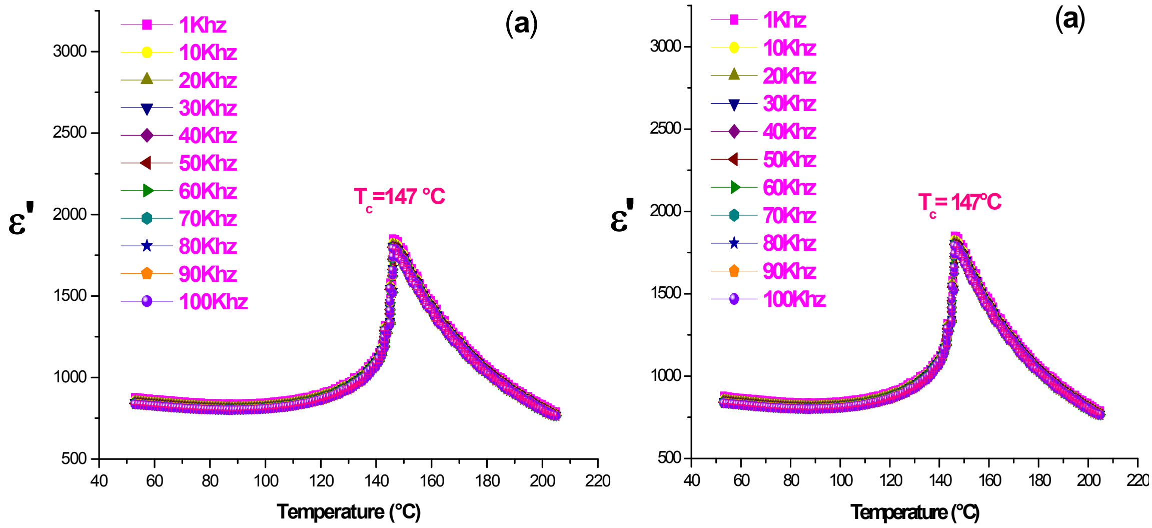

Figure 1. Evolution of the dielectric constant measured by two methods (a) and (b)

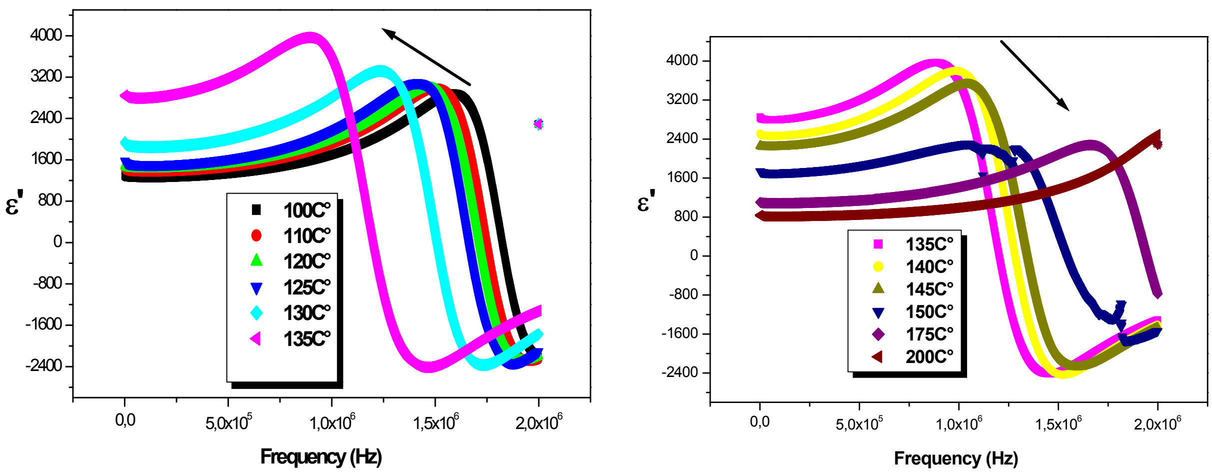

Figure 2. Evolution of the BT dielectric constant, at different temperatures, as a function of frequency

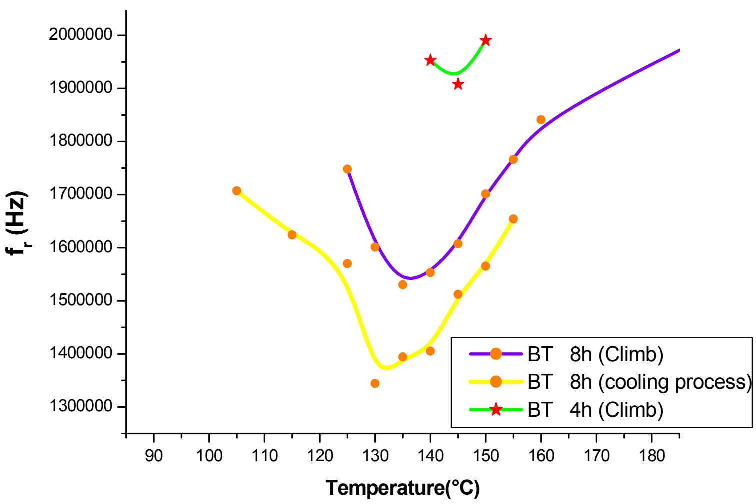

Figure 3. Thermal variation of f_r of BT as a function of temperature

In this figure, it is noted that the shape of these curves is independent of the measurement method. On the other hand, table 1 makes it possible to compare the values of the dielectric constant and Tc of BT found by the two methods, from which it is clear that the values of the dielectric constant for different measurement frequencies are higher in the second method, In addition one notices a lowering of the transition temperature, Tc, by about 12 ° C by method (b). These results show that the stabilization of the temperature (method (b)) gives the time required to have the complete contribution of all the elements of the pellet, and so improves the dielectric constant values contrary to those recorded from the first measurement method which does not reflect the true values of ε'; the difference observed becomes important with the increase in the rate of rise in temperature. It can be concluded from this study that the stabilization of the measurement temperature (method of measurement (b)) causes the dielectric constant ε' to increase for different frequencies and it moves the curie temperature Tc towards the low temperatures.

Figure 2 Shows the variation of the real part of the dielectric permittivity, ε' as a function of the frequency, at different measurement temperatures obtained for the ceramic BT; the shape of ε' exhibits a particular frequency evolution. Indeed, when the frequency increases, ε' passes through a maximum, then decreases and passes through a minimum and then increases; this phenomenon of resonance is accompanied with relaxation. We have plotted on the curves of figure 3 the variation of the relaxation frequency fr as a function of temperature for the studied samples during the two processes of heating and cooling. The results obtained show that the relaxation frequency of $BaTiO_3$ decreases with temperature until reaching its minimum value in the vicinity of Tc and then increases. The proposed relaxation mechanism is based on the fact that the Ti^{4+} ion is moved out of the center of the oxygen octahedron and can occupy different potential wells (dual well model). The relaxation process is then associated with cooperative jumps of Ti^{4+} ions between these different wells. This motion would be coherent over a length Ic corresponding to that of a correlation chain (Lambert *et al*., 1968, Maglion *et al*., 1989). The observed minimum can be explained by the increasing number of Ti^{4+} ions which contribute to the cooperative movement along the correlation chains when the temperature decreases towards Tc. Thus, the inertia of the chain increases (Ic increases) and the relaxation frequency decreases to a minimum value in the vicinity of the transition temperature. Figure 3 also shows the effect of sintering time on the relaxation frequency (fr) of BT. It shows that the value of the relaxation frequency at Tc decreases when the sintering time increases from 4 h to 8 h and also decreases in the cooling process. This is explained by the effect of temperature on the deformation of the octahedra BO_6, which probably implies correlation chains becomes shorter which leads to a decrease in the relaxation frequency, which may be related to the polarizability of the atoms.

Conclusion

Results from this study have shown that the stabilization of the measurement temperature causes the dielectric constant ε ' to increase for different frequencies, and moves the Curie temperature, Tc, towards lower temperatures. Then, in order to have high values of the dielectric constant and to lower transition temperature, the stabilization process may be adopted (method (b) in this study). It was also shown from the present study that the relaxation frequency of $BaTiO_3$ decreases with temperature until reaching its minimum value in the vicinity of Tc and then increases with temperature. Moreover, this relaxation frequency fr, at Tc, decreases, when the sintering time increases from 4 h to 8 h and also decreases in the cooling process.

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