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# Dielectric and Ferroelectric Properties of Ho<sub>2</sub>O<sub>3</sub> Doped Barium Strontium Titanate Ceramics

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**Abstract:** The crystalline structure, surface morphology, dielectric and ferroelectric properties of 0~10wt% Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics prepared by conventional solid state method were studied using X-ray diffractometer, scanning electron microscopy, LCR measuring system and ferroelectric property test systems aiming for ceramic capacitor applications. It is found that proper amount of Ho<sub>2</sub>O<sub>3</sub> can refine grains of the system. With the increase of Ho<sub>2</sub>O<sub>3</sub> doping content, the average grain size of (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics decreases. When Ho<sub>2</sub>O<sub>3</sub>>8 wt%, (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> based ceramic samples are multi-phase compounds with typical perovskite structure accompanied by the appearance of cylindrical grains. The Ho<sup>3+</sup> ions substitute the host A sites and B sites of (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> perovskite lattice, resulting in the lattice distortion of the system and the change of the relative dielectric constant and dielectric loss at room temperature. With the increase of Ho<sub>2</sub>O<sub>3</sub> doping content, the relative dielectric constant at room temperature of the system increases first and then decreases. The maximum of relative dielectric constant at room temperature can be found in the 1 wt% Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics. When Ho<sub>2</sub>O<sub>3</sub>>1 wt%, the maximum of relative dielectric constant  $\epsilon_{rmax}$  decreases and the temperature corresponding to the maximum of relative dielectric constant  $T_m$  shifts toward lower temperature with the increase of Ho<sub>2</sub>O<sub>3</sub> doping content. The (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics with high Ho<sub>2</sub>O<sub>3</sub> content show relaxor-like behavior which is characterized by the typical diffuse phase transition and frequency dispersion of dielectric constant. However, the (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics with low Ho<sub>2</sub>O<sub>3</sub> content do not exhibit permittivity frequency dispersion. According to the *P-E* hysteresis loops of Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics, the ferroelectricity was increased and then decreased with the increase of Ho<sub>2</sub>O<sub>3</sub> doping content. With the increase of Ho<sub>2</sub>O<sub>3</sub> doping content, the *P-E* relationships turn out to be straight lines, implying the paraelectric phase for (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics with high Ho<sub>2</sub>O<sub>3</sub> content.

**Keywords:** Barium Strontium Titanate, Perovskite, Relaxor Characteristic, Ferroelectric Properties

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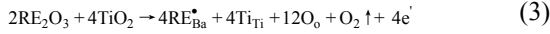
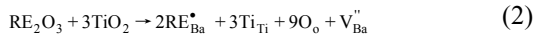
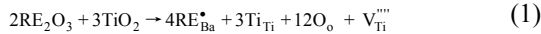
## 1. Introduction

Barium strontium titanate ((Ba<sub>1-x</sub>Sr<sub>x</sub>) TiO<sub>3</sub>, BST), as an infinite solid solution of BaTiO<sub>3</sub> and SrTiO<sub>3</sub>, maintains perovskite structure (ABO<sub>3</sub>) similar to BaTiO<sub>3</sub>, and has outstanding properties such as high dielectric constant, low dielectric loss and excellent ferroelectric properties [1-2]. In addition, its Curie temperature can be adjusted over a wide range of temperature by changing Ba/Sr ratio, making the BST systems become one of the basic ceramic materials for ceramic capacitors [3].

As an important component of electronic products, ceramic

capacitors require superior and more stable performance in smaller sizes. In order to meet the needs in different applications, people add metal oxides or their derivatives to BST systems to improve their comprehensive properties. The rare earth metal oxides play important roles in the property modification for dielectric materials, which has aroused great interest of many researchers [4-9]. D. C. Sinclair et al. studied the rare earth metal ions RE<sup>3+</sup> doped barium titanate ceramics, and proposed that when the RE<sup>3+</sup> ions enter the A site of the perovskite lattice, charge imbalance is created which must be compensated by either cation vacancies on the A or B site (ionic compensation), or by electrons (electronic

compensation) [10-11]. Three point defect reactions can be identified:



When the  $\text{RE}^{3+}$  ions enter the B site of the perovskite lattice, charge imbalance is created which must be compensated by the oxygen vacancies [10]. The point defect reaction can be seen as follows:



In general, the large size  $\text{RE}^{3+}$  ions tend to occupy the A site; The small size  $\text{RE}^{3+}$  ions tend to occupy the B site; The middle size  $\text{RE}^{3+}$  ions have the amphoteric behavior occupying both A and B site [12]. Y. Li et al. studied on the dielectric properties of  $\text{Sm}_2\text{O}_3$  doped  $\text{Ba}_{0.68}\text{Sr}_{0.32}\text{TiO}_3$  ceramics, and proposed that the substitution preference of  $\text{Sm}^{3+}$  in the lattice also depends on  $\text{Sm}_2\text{O}_3$  doping content [13]. C. Zhao et al. prepared  $\text{Y}_2\text{O}_3$  and  $\text{Dy}_2\text{O}_3$  doped  $\text{Ba}_{0.7}\text{Sr}_{0.3}\text{TiO}_3$  ceramics with comprehensive properties ( $\epsilon_r=3.66 \times 10^3$ ,  $\tan\delta=9.3 \times 10^{-3}$ ,  $\Delta\epsilon_r/\epsilon_r=14.1\%$ ) [14]. In addition, some researchers studied the effect of grain size on dielectric and ferroelectric properties of  $\text{Ba}_{0.80}\text{Sr}_{0.20}\text{TiO}_3$  ceramics [15-16].

In our present work, 0~10 wt%  $\text{Ho}_2\text{O}_3$  doped ( $\text{Ba}_{0.75}\text{Sr}_{0.25}$ )  $\text{TiO}_3$  ceramics were prepared by solid state reaction method. The effects of  $\text{Ho}_2\text{O}_3$  doping content on crystalline structure, surface morphology, dielectric and ferroelectric properties of the system were investigated. The substitution characteristics of  $\text{Ho}^{3+}$  ions in ( $\text{Ba}_{0.75}\text{Sr}_{0.25}$ )  $\text{TiO}_3$  perovskite lattice will be determined and the interrelationship between the macroscopic dielectric constant, dielectric loss, temperature-dependent properties and microscopic defect behavior will also be established.

## 2. Experimental

### 2.1. Sample Preparation

In this paper, high purity  $\text{BaCO}_3$  (>99.0%),  $\text{SrCO}_3$  (>99.0%) and  $\text{TiO}_2$  (>98.0%) powders used as starting raw materials were proportionally weighed according to the formula ( $\text{Ba}_{0.75}\text{Sr}_{0.25}$ )  $\text{TiO}_3$  and ball-milled for 24 h. After drying, the obtained powders were calcined at  $1080^\circ\text{C}$  for 2 h to form main crystalline phase. The calcined powders were mixed with 0.2 wt%  $\text{MgO}$  ( $\geq 98.5\%$ ), 0.2 wt%  $\text{ZnO}$  ( $\geq 99.0\%$ ) and 0~10 wt%  $\text{Ho}_2\text{O}_3$  (>99.0%), reground for 24 h, dried and added with 5 wt% polyvinyl alcohol (PVA) as a binder for granulation. The mixtures were sieved through 40-mesh screen and then pressed into pellets 10mm in diameter and 2~3 mm in thickness. Sintering was conducted in air at  $1400^\circ\text{C}$  for 2 h, and the sintering regime was illustrated on Figure 1. For dielectric properties measurement, both the flat

surfaces of the sintered samples were coated with BQ-5311 silver paste after ultrasonic bath cleaning and then fired at  $800^\circ\text{C}$  for 10 min.

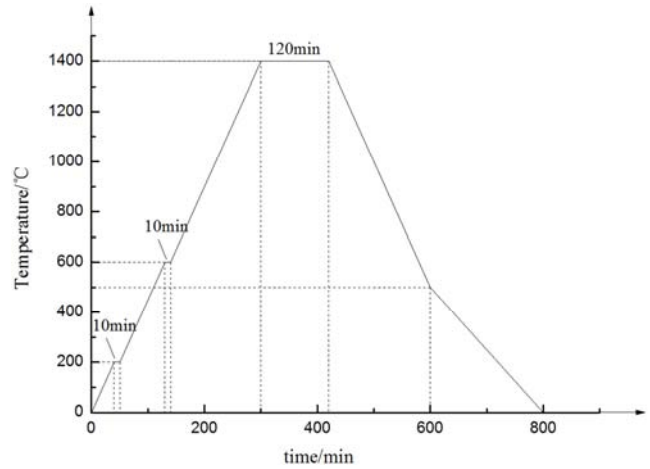


Figure 1. Sintering regime for the samples.

### 2.2. Equipment and Characterization

The crystal structures of the samples were confirmed by X-ray diffraction analysis (XRD, Rigaku D/max 2500v/pc) with  $\text{Cu K}\alpha$  radiation; The phase and plane index ( $hkl$ ) were obtained by search/match using Jade 6.0. The surface morphologies of the gold-sprayed ceramic samples were observed using the SEM (JSM-6480 ESEM). The capacitance quantity ( $C$ ) and dissipation factor ( $D$ ) were measured with TZDM-200-300B testing system. The relative dielectric constant ( $\epsilon_r$ ) and dielectric loss ( $\tan\delta$ ) were calculated by the following Equations:

$$\epsilon_r = \frac{14.4Ch}{\Phi^2} \quad (5)$$

$$\tan\delta = D \quad (6)$$

where  $C$  is the capacitance quantity (pF);  $h$  is the thickness (cm);  $\Phi$  is the diameter of the electrode (cm);  $D$  is the dissipation factor. The temperature dependence of dielectric parameters was measured at 1~100 kHz from  $-150$  to  $150^\circ\text{C}$ . The P-E hysteresis loops of  $\text{Ho}_2\text{O}_3$  doped ( $\text{Ba}_{0.75}\text{Sr}_{0.25}$ )  $\text{TiO}_3$  ceramics at room temperature was obtained using the ferroelectric property test system.

## 3. Results and Discussion

### 3.1. XRD Analysis

The XRD patterns of  $\text{Ho}_2\text{O}_3$  doped ( $\text{Ba}_{0.75}\text{Sr}_{0.25}$ )  $\text{TiO}_3$  ceramics are shown in Figure 2. It appears that all samples are single phase solid solutions with typical perovskite structure. No obvious secondary phase is found even for the 10 wt%  $\text{Ho}_2\text{O}_3$  doped ( $\text{Ba}_{0.75}\text{Sr}_{0.25}$ )  $\text{TiO}_3$  ceramics based on the XRD patterns.

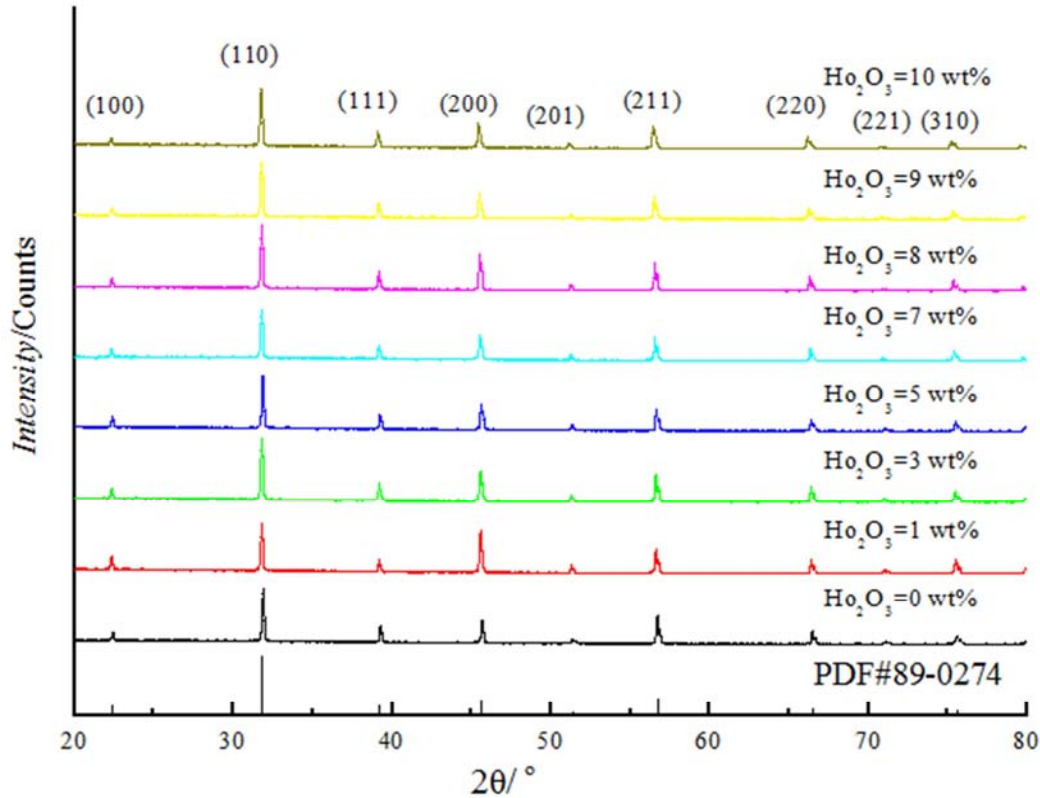


Figure 2. XRD patterns of Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics.

### 3.2. SEM Analysis

Figure 3 shows the SEM images of Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics. It appears that all samples exhibit dense microstructures and possess uniform grain size. With the increase of Ho<sub>2</sub>O<sub>3</sub> doping content, the average grain size of (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics decreases. The reason is

that Ho<sup>3+</sup> ions are easily segregated near the grain boundary, which hinders the further grain growth [17]. However, the cylindrical grains indicating the appearance of secondary phase (marked using red circles in Figure 3 (g) and (h)) which is not detected by XRD due to its small amount exist in the 9 and 10 wt% Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics.

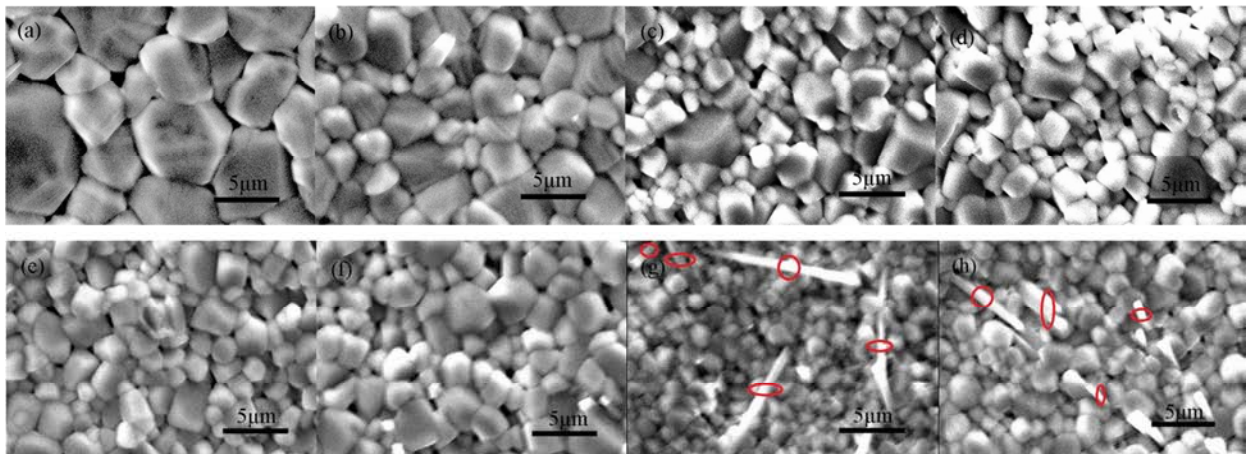


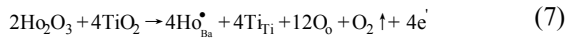
Figure 3. SEM images of Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics: (a) Ho<sub>2</sub>O<sub>3</sub>=0 wt%; (b) Ho<sub>2</sub>O<sub>3</sub>=1 wt%; (c) Ho<sub>2</sub>O<sub>3</sub>=3 wt%; (d) Ho<sub>2</sub>O<sub>3</sub>=5 wt%; (e) Ho<sub>2</sub>O<sub>3</sub>=7 wt%; (f) Ho<sub>2</sub>O<sub>3</sub>=8 wt%; (g) Ho<sub>2</sub>O<sub>3</sub>=9 wt%; (h) Ho<sub>2</sub>O<sub>3</sub>=10 wt%.

### 3.3. Dielectric Properties at Room Temperature

In the ABO<sub>3</sub> type perovskite structure, the coordination numbers of A and B site are 12 and 6, respectively. The radius of Ho<sup>3+</sup> ion (1.23 Å, in 12 coordination) is smaller than that of

Ba<sup>2+</sup> ion (1.61 Å, in 12 coordination) and Sr<sup>2+</sup> ion (1.44 Å, in 12 coordination); The radius of Ho<sup>3+</sup> ion (0.90 Å, in 6 coordination) is bigger than that of Ti<sup>4+</sup> ion (0.61 Å, in 6 coordination) [18]. Therefore, Ho<sup>3+</sup> ion can substitute the A or B site of (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> perovskite lattice. When Ho<sup>3+</sup> ion

substitutes the A site, the point defect reaction is as follows:



When  $\text{Ho}^{3+}$  ion begins to substitute the B site, the point defect reaction can be expressed as follows:

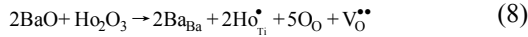


Figure 4 shows the relative dielectric constant and dielectric loss of  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics at room temperature with variation of  $\text{Ho}_2\text{O}_3$  content. It is obvious that all ceramics

possess high relative dielectric constant ( $\epsilon_r \geq 1.69 \times 10^3$ ) and low dielectric loss ( $\tan\delta \leq 6.4 \times 10^{-3}$ ) at room temperature. With the increase of  $\text{Ho}_2\text{O}_3$  doping content, the relative dielectric constant of the system increases first and then decreases. The maximum of relative dielectric constant at room temperature can be found in the 1 wt%  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics. The dielectric loss of the system increases first, then decreases, and finally increases with the increase of  $\text{Ho}_2\text{O}_3$  doping content.

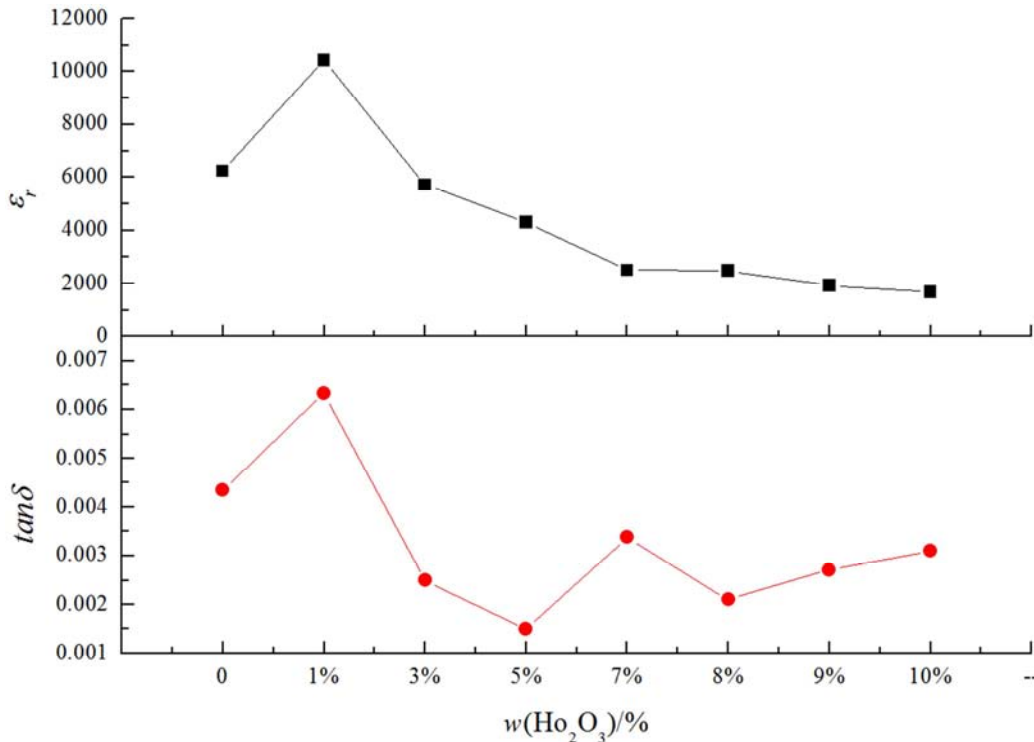


Figure 4.  $\epsilon_r$  and  $\tan\delta$  of  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics at room temperature.

When  $\text{Ho}_2\text{O}_3 \leq 1$  wt%,  $\text{Ho}^{3+}$  ions tend to substitute the A site ions of the perovskite lattice. The difference of the ionic radius causes the shrinkage deformation of the perovskite unit cells and the increase of the internal stress which result in the increase of relative dielectric constant [19]. When  $\text{Ho}_2\text{O}_3 = 1 \sim 8$  wt%,  $\text{Ho}^{3+}$  ions gradually enter the B site. The bigger  $\text{Ho}^{3+}$  ions in the B site restrict the activity of B site ions and thus weaken the spontaneous polarization, which causes the relative dielectric constant decrease significantly with the increase of  $\text{Ho}_2\text{O}_3$  doping content. When  $\text{Ho}_2\text{O}_3 > 8$  wt%, non-ferroelectric secondary phase induced by the excessive  $\text{Ho}_2\text{O}_3$  addition dilutes the ferroelectric phase, which makes the relative dielectric constant further decrease with the increase of  $\text{Ho}_2\text{O}_3$  doping content [20].

As for the dielectric loss, When  $\text{Ho}^{3+}$  ions enter the A site of the perovskite lattice, the electrons as shown in Equation (7) are trapped by  $\text{Ti}^{4+}$  to form  $\text{Ti}^{3+}$ , leading to the increase of the dielectric loss gradually [21]. When  $\text{Ho}_2\text{O}_3 = 1 \sim 5$  wt%, the weakened spontaneous polarization results in the decrease of

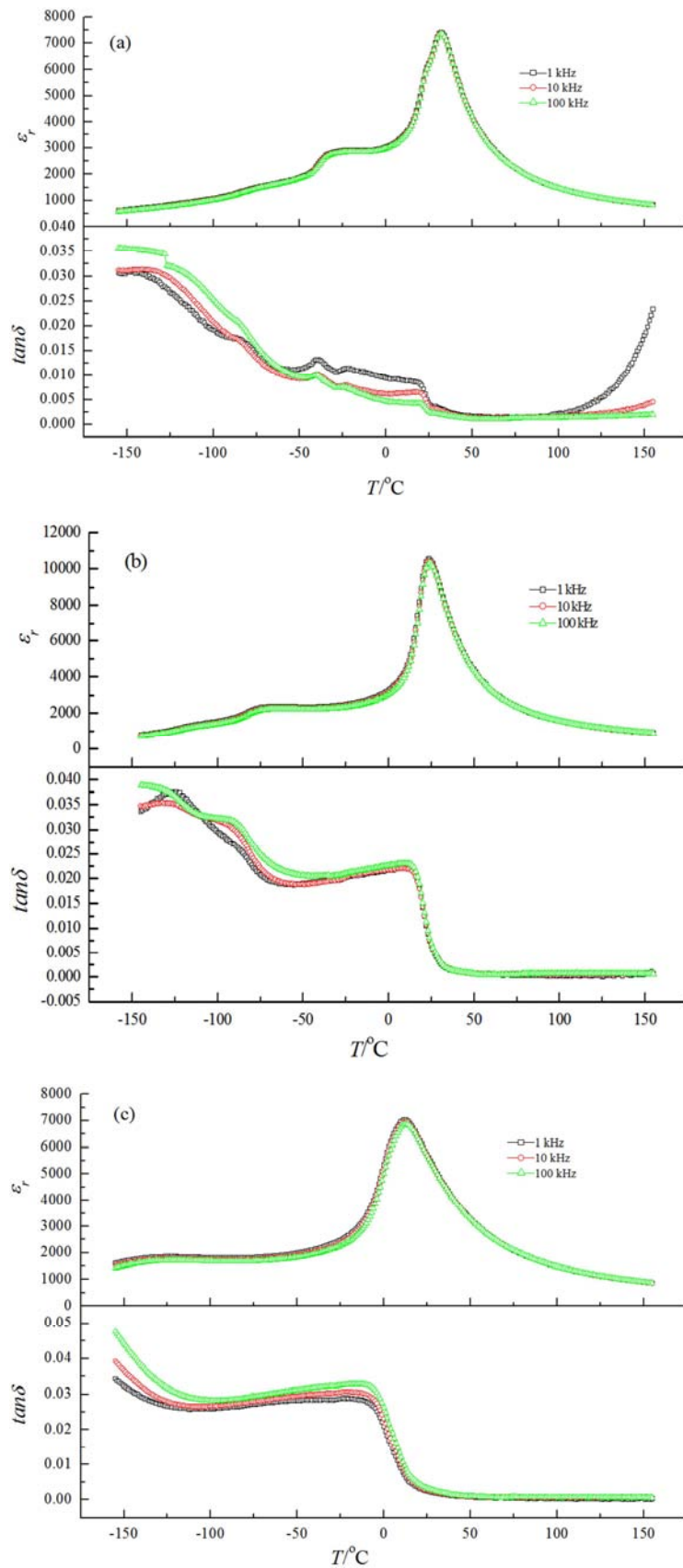
the dielectric loss significantly with the increase of  $\text{Ho}_2\text{O}_3$  doping content. On the other hand, the oxygen vacancies as shown in Equation (8) have pinning effect on the ferroelectric domains, which also causes the decrease of dielectric loss [22-24].

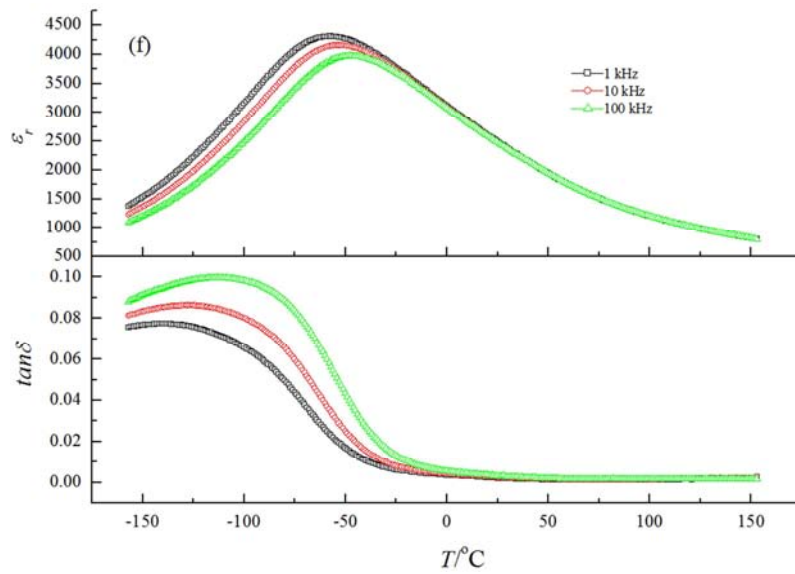
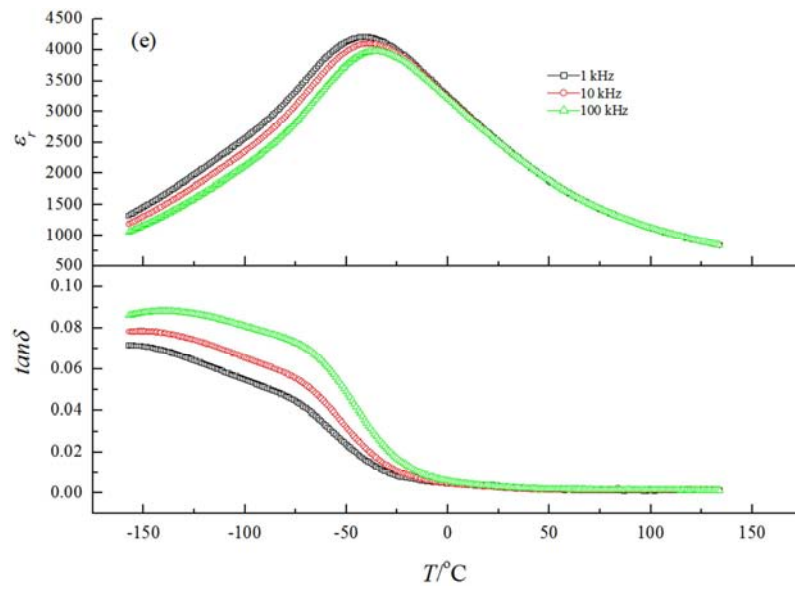
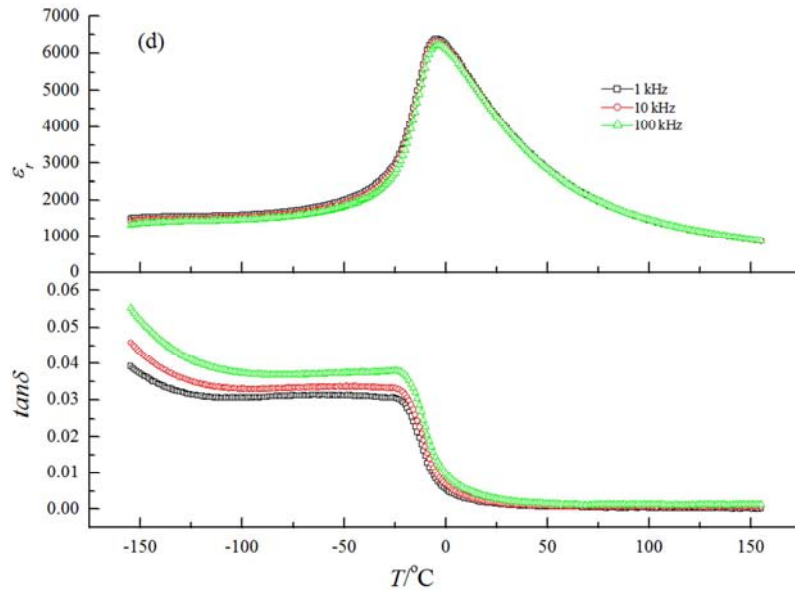
### 3.4. Temperature Dependence of the Relative Dielectric Constant and Dielectric Loss at Various Frequencies

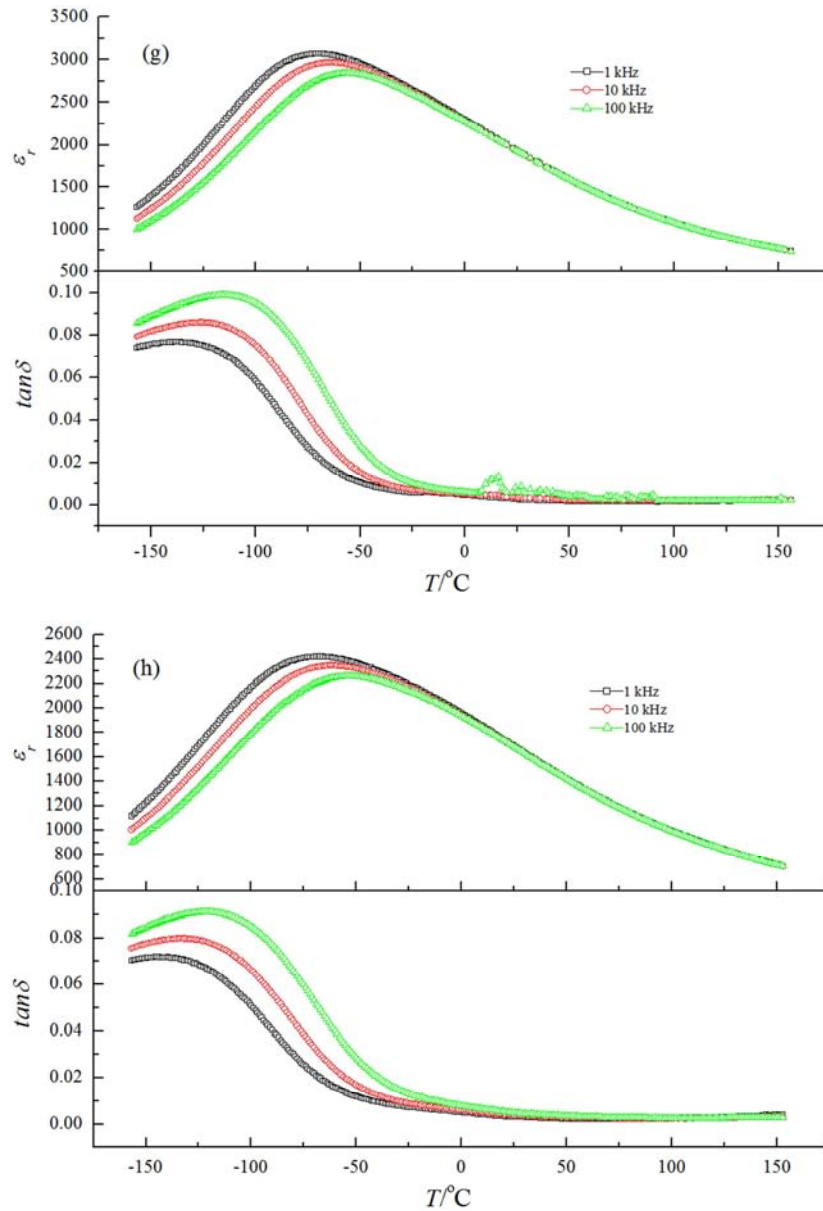
Figure 5 shows the temperature dependence of the relative dielectric constant and dielectric loss at 1kHz~100kHz for  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics. When  $\text{Ho}_2\text{O}_3$  content is higher than 5 wt%, the temperature corresponding to the maximum of relative dielectric constant ( $T_m$ ) for  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics shifts toward higher temperature obviously and the relative dielectric constant (in the  $T < T_m$  range) decreases with the increase of test frequency, which is known as the frequency dispersion [25]. However, as indicated in Figure 5 (a)~(d), the  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics with low  $\text{Ho}_2\text{O}_3$  content do not exhibit permittivity frequency

dispersion. As shown in Figure 5 (c)~(h), the  $\tan\delta$  increases significantly with the increase of test frequency at low temperature; the  $\tan\delta$  is almost unaffected by the test frequency at high temperature, and the  $\tan\delta$  remains at a low

value over a wide temperature range (room temperature~150°C), indicating that Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>)TiO<sub>3</sub> ceramics are promising for the application in capacitors as low dielectric loss dielectrics.

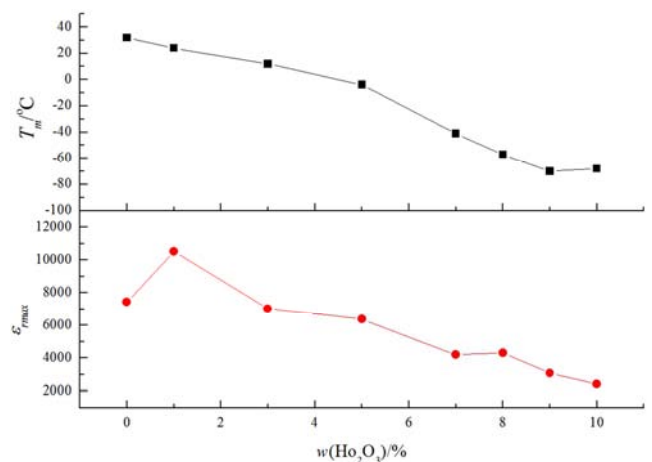






**Figure 5.** Temperature dependence of the relative dielectric constant and dielectric loss of Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics: (a) Ho<sub>2</sub>O<sub>3</sub>=0 wt%; (b) Ho<sub>2</sub>O<sub>3</sub>=1 wt%; (c) Ho<sub>2</sub>O<sub>3</sub>=3 wt%; (d) Ho<sub>2</sub>O<sub>3</sub>=5 wt%; (e) Ho<sub>2</sub>O<sub>3</sub>=7 wt%; (f) Ho<sub>2</sub>O<sub>3</sub>=8 wt%; (g) Ho<sub>2</sub>O<sub>3</sub>=9 wt%; (h) Ho<sub>2</sub>O<sub>3</sub>=10 wt%.

The maximum of relative dielectric constant ( $\epsilon_{rmax}$ ) and the temperature corresponding to this maximum ( $T_m$ ) of (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics with variation of Ho<sub>2</sub>O<sub>3</sub> content are shown in Figure 6. When Ho<sub>2</sub>O<sub>3</sub> > 1 wt%, the  $T_m$  shifts toward lower temperature and the  $\epsilon_{rmax}$  decreases with the increase of Ho<sub>2</sub>O<sub>3</sub> doping content. The local deformation caused by Ho<sub>2</sub>O<sub>3</sub> doping gives rise to the reduction of  $T_m$ . On the other hand, the non-ferroelectric layer in grain boundary of ferroelectric ceramics makes the ferroelectricity decrease, which causes  $T_m$  and  $\epsilon_{rmax}$  decrease. As mentioned previously, the average grain size of Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics decreases with the increase of Ho<sub>2</sub>O<sub>3</sub> doping content, which means that the grain boundary effect [26] is enhanced with the increase of Ho<sub>2</sub>O<sub>3</sub> doping content and consequently makes the  $T_m$  and  $\epsilon_{rmax}$  decrease.



**Figure 6.**  $T_m$  and  $\epsilon_{rmax}$  of Ho<sub>2</sub>O<sub>3</sub> doped (Ba<sub>0.75</sub>Sr<sub>0.25</sub>) TiO<sub>3</sub> ceramics.

Since the diffuse phase transition is generally characterized by broadening in the dielectric constant ( $\epsilon$ ) versus temperature ( $T$ ) curve, the full-width of half-maximum (FWHM) of  $\epsilon_r$ - $T$  curve is here calculated and listed in Table 1. It is notable that the FWHM increases from 31°C to 222.8°C when  $\text{Ho}_2\text{O}_3$  content increases from 1wt% to 10wt%. In other words, the Curie peaks of high  $\text{Ho}_2\text{O}_3$  concentration ceramics

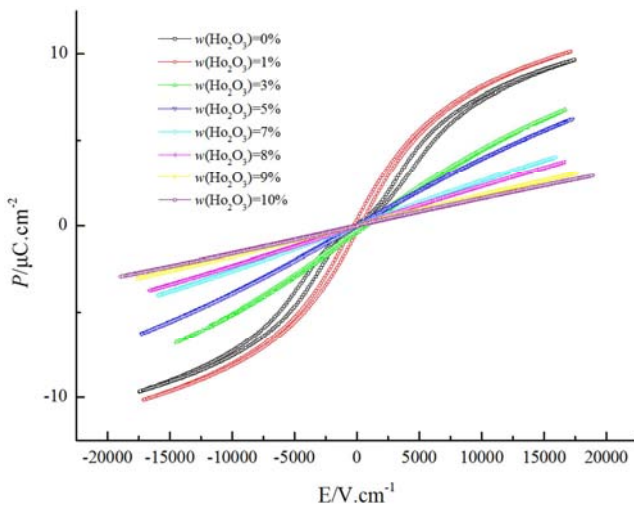
are more diffused and broadened than that of low  $\text{Ho}_2\text{O}_3$  concentration ones. Since the typical diffuse phase transition and frequency dispersion of dielectric constant occurred in the  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics with high  $\text{Ho}_2\text{O}_3$  content, it can be concluded that with the increase of  $\text{Ho}_2\text{O}_3$  doping content,  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics are transformed into a relaxor-like ferroelectrics.

**Table 1.** The FWHM of  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics.

$W(\text{Ho}_2\text{O}_3)/\%$	0	1	3	5	7	8	9	10
FWHM/°C	41.1	31	56.1	65.9	159	166.9	197.8	222.8

### 3.5. Ferroelectric Properties

Figure 7 shows the  $P$ - $E$  hysteresis loops of  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics with different  $\text{Ho}_2\text{O}_3$  doping content measured at room temperature. The typical  $P$ - $E$  hysteresis loops can be found for undoped and 1 wt%  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics. Especially, compared with the undoped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics, the ferroelectricity of the 1 wt%  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics is enhanced, which exactly explains that the  $\epsilon_{r\text{max}}$  of the 1 wt%  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics achieve the maximum as shown in Figure 6. With the increase of  $\text{Ho}_2\text{O}_3$  doping content, the  $P$ - $E$  relationships turn out to be straight lines, implying the paraelectric phase for  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics with high  $\text{Ho}_2\text{O}_3$  content.



**Figure 7.**  $P$ - $E$  hysteresis loops of  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics.

## 4. Conclusions

The  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics were prepared by solid state reaction method and their crystalline structure, surface morphology, dielectric and ferroelectric properties were investigated. The results show that:

- (1) The proper  $\text{Ho}_2\text{O}_3$  doping content is beneficial to obtaining fine grain structure. When  $\text{Ho}_2\text{O}_3 > 8$  wt%, ceramic samples are multi-phase compounds with typical perovskite structure.
- (2)  $\text{Ho}^{3+}$  ions enter the A and B site of perovskite lattice, causing lattice distortion of the system and affecting

the relative dielectric constant and dielectric loss at room temperature. In addition, the electrons and oxygen vacancies produced in the substitution process also have a certain effect on the dielectric loss.

- (3) The diffuse phase transition and frequency dispersion of dielectric constant reveal a relaxor characteristic of high  $\text{Ho}_2\text{O}_3$  doped  $(\text{Ba}_{0.75}\text{Sr}_{0.25})\text{TiO}_3$  ceramics.
- (4) According to the  $P$ - $E$  hysteresis loops, the ferroelectricity is increased and then decreased with the increase of  $\text{Ho}_2\text{O}_3$  doping content.

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