International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 02 – Issue 09 || September 2017 || PP. 94-98

Effect of Carbon Black added $BaTiO_3$ on dielectric and ferroelectric properties

Wattana Photankham[1,2], Hassakorn Wattanasarn[1,2] and Tosawat Seetawan[1,2,*]

[1]*Program of Physics, Faculty of Science and Technology, 680 Nittayo Rd., Mueang District, Sakon Nakhon Rajabhat University, 47000 THAILAND*
[2]*Piezoelectric Research Laboratory, Center of Excellence on Alternative Energy, Research and development institution, Sakon Nakhon Rajabhat University, 47000 THAILAND*

Abstract: In this work, the sample was detected to structure, dielectric and ferroelectric propertiesof carbon black added BT ceramics. The structure was found that major phase of tetragonal system for all the sample with detected. The dielectric property waschanged as function as CB wt% content. Dielectric loss exhibited stability in the CB added with increases temperature. The addition with CB induced in broadened dielectric constant peaks shifting to lower temperature (about 112 °C) for 2 wt%. All sample show the relaxor ferroelectric behaviors, and decreasing domain size is indicated attempt changed ferroelectric behavior for 6 wt%. The P_r and E_C was obtained good properties around 15.49 μC/cm^{2}and2.13 kV/cm for 10 wt% content.

Keywords: physical property, polarization-electric field loop,structure

1. Introduction

Ferroelectric materials have attracted a lot in the applications in electronic industry [1-3],multilayered ceramic capacitors [15],high dielectric constant materials would torequirements the development high technology [3,8-13]. Generally, the barium titanate ($BaTiO_3$) is ferroelectric materials, with used wide piezoelectric sensors, actuators, transducers and capacitors [1-3,8-15]. Normally, BT is possesses high dielectric constant but relativelylow electrical breakdown strength at high temperature [3,8]. Many efforts have hence been made torelieveshortcoming of dielectric properties of $BaTiO_3$ (BT), inclusive enhancing densification. It is known that carbon black (CB) in the filler fabricated for dielectric properties [4-7]. In addition, CB-filled have a good absorption performance in highfrequency bands [5]. Due to the lowcost is one of the important added in BT base, it can enable reduce sintering process and also promote domain wall motion and dielectric properties [2-5]. Recently, researchers have found that the filler formed by CB was obtained good dielectric properties and enhance the densification [5-7]. However, past of these studies were join with fabrication which support in preparation and properties. Therefore, the present research, CB added BT base were prepared by solid state reaction method, and the structure, dielectric and ferroelectric properties of all the sample ceramics were investigated

2. Materials and Method

Ferroelectric materials of $BaTiO_3$+xCB ceramics was prepared by solid state reaction method, with vary composite x. These samples have been structure, dielectric, piezoelectric and ferroelectric properties in systematics study [1]. All samples were coated with silver paint on surface. The capacitance was carried out using Chen Hwa 1061 LCR–Meter, with dependents on temperature of 30-300 ºC at 100 kHz. Ferroelectric behavior was carried out with polarization-electric field (P-E loop) characteristics, using high voltage AC amplifier (Trek, model 20/20C), applying low field into the sample, connecting to Sawyer-Tower circuit, and transform signal to Picoscope for interpreted hysteresis loop.

3. Results and Discussion

The results obtained structure, microstructure, dielectric, piezoelectric and ferroelectric properties with detected [1]. All the sample shows a single perovskite structure with a tetragonal symmetry is standard BT base [1-3]. The lattice parameter *a* and*c* obtained further increases with CB content increased. As example 8 wt%, it found that higher value become dominant with high tetragonality*c/a* about 1.0159 as display in Figure 1(a). It was indicating to larger lattice parameter *c*. The lattice parameters are changed consistent with the shifted of diffraction peaks in report of TosawatSeetawan et al. [1] as shown in Figure 1(a). The enlargements of the lattices parameter with correspond on diffraction 2θ peak to high the tetragonality. There may be the substitute CB^{4+}(0.77 Å) into B-site of Ti^{4+}(0.68 Å), with affect to expansion of the lattice parameter. Moreover, the

volume gives as strong value for 8 wt% as shown in Table 1. The sintering of CB content on the $BaTiO_3$ exhibited effect is correlated with their densification, grain size, and microstructure improved. CB added material exhibited further increases of the density, and reach a maximum about 5.84 g/cm^3 for 10 wt%.

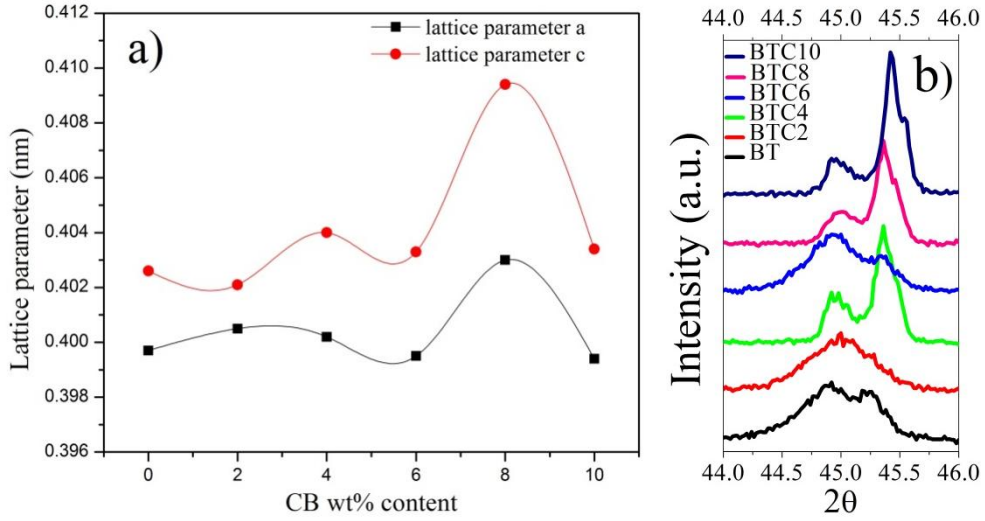

Figure 1:(a) the lattice parameter *a* and *c* compared with CB wt% content of $BaTiO_3$+xCB sintered at 1200 °C, and (b) the XRD pattern corresponding expanded in the 2θCuKα from 44° to 46° (report withTosawatSeetawan et al. [1]).

Table 1: Physical and structure of $BaTiO_3$+CB with sintering at 1200 °C for 2 h (reported with TosawatSeetawan et al. [1]).

Sample	Density (g/cm^3)	Phase structure	% Phase perovskite	Volume (pm^3)	Grain size (nm)
BT	5.657	tetragonal	88.33	64.318(0)	0.58
BTC2	5.776	tetragonal	89.67	64.495(1)	2.49
BTC4	5.784	tetragonal	89.97	64.689(1)	2.67
BTC6	5.797	tetragonal	90.73	64.363(9)	2.38
BTC8	5.793	tetragonal	90.43	66.493(8)	1.68
BTC10	5.842	tetragonal	91.46	64.346(3)	1.34

The $BaTiO_3$+xCB ceramics exhibits the temperature dependent dielectric properties of the sintered ceramics measure at 100 kHz as display in Figure 2. The BT base ceramic had a sharp dielectric constant (ε_r) peak around 164 °C, indicating a classic ferroelectric behavior. The ε_r peak maximum was as high as 8603, and also broadened peak significantly. With increasing the added content of CB as display in Figure 2(a), the peaks were shifting markedly, with around 112, 192, 148, 204 and 200 °C for 2, 4, 6, 8 and 10 wt%, respectively. Meanwhile, the ε_r peak of 2 wt% shifted to lower temperature, also severed decreased with increasing the temperaturesignificantly. Moreover, the ε_r peaks became flatter in the CB content increase, become of a dielectric property on carbon black. This phenomenon is clearly attributed to the structures formed by CB doping, and exhibited insulating propertiesdue to clusters of charged and limited conductance [4-7]. The particles cation of CB^{4+} ions likely diffuse into the lattices to substitute Ti^{4+} ions due to the very similar radii according to the Goldschmidt tolerance factor [2]. The formations of microstructures by CB doping were also obtainedby SEM, as shown in research work with TosawatSeetawan et al. [1]. Which dielectric loss ($\tan\delta$) obtained rose increases temperature for 0 and 2 wt% as given in Figure 2(b). As further increases, the $\tan\delta$ wereremarkable stability to increased temperature. This behaviorwas good reasonable on the capacitor materials.

Figure 3 show the relation between dielectric constant and dielectric loss of $BaTiO_3$+xCB ceramics as function as CB content measured at 100 kHz. As BT base, it exhibited classic ferroelectric behavior according reported with Yan Yan et al. [2,3,13-15]. In addition of CB content, it was little changed the $\tan\delta$, because electrical of carbon blackwith the conductance. But, the ε_r wasinfluence capabilitywill be rapidly decreased of the dielectric constant.

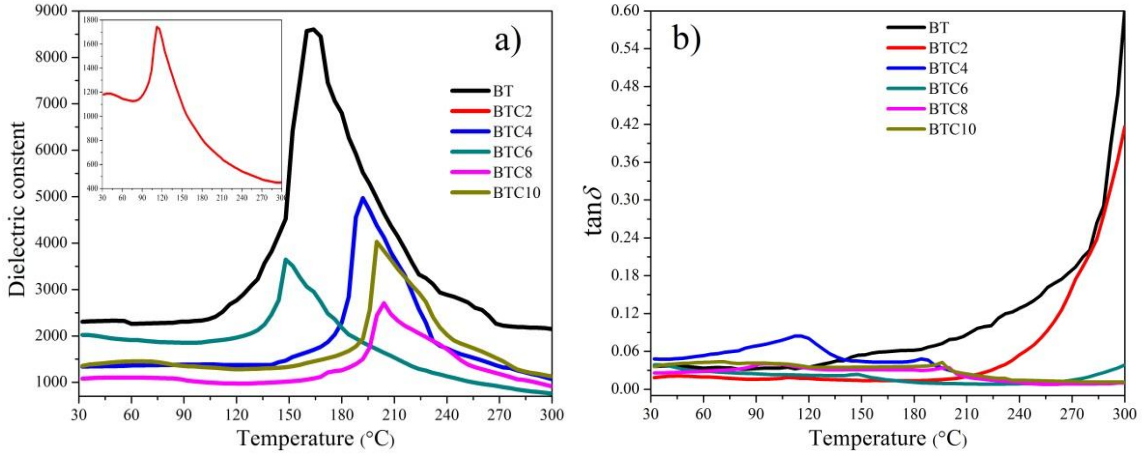

Figure 2: The dependent temperature on dielectric properties of $BaTiO_3$+xCB ceramics as function of CB content measured at 100 kHz, (a) dielectric constant and (b) dielectric loss.

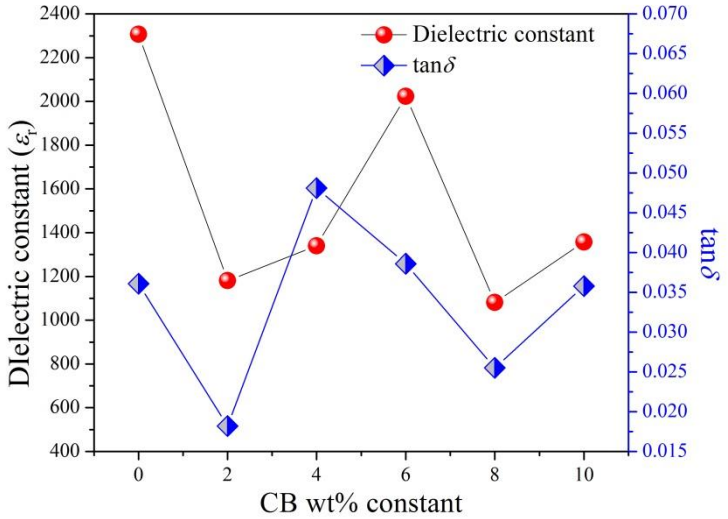

Figure 3: the relation on dielectric constant and dielectric loss of $BaTiO_3$+xCB ceramics as function as CB content measured at 100 kHz, (a) dielectric constant and (b) dielectric loss.

Figure 4 show characteristicthe polarization-electric field (P-E) hysteresis loops of $BaTiO_3$+xCB ceramics measurement at room temperature. All samples possess a ferroelectric behavior from P-E hysteresis loop. The characteristic of P-E hysteresis loops had exhibiting relaxor ferroelectric, moreover, indicated to the domain size. As 6wt% sample, it observing attempt in change ferroelectric behavior, cause of CB^{4+} substituted due to B-site of Ti^{4+}. Therefore, the behavior that have been affected to decrease the spontaneous polarization (P_S), as display in Figure 4(a). Thus, the domain size was rapidly decreased, and then increasing with the content 8 wt%.Figure 4(b), illustrates the several of the remnant polarization (P_r) and coercive field E_C for the $BaTiO_3$+xCB at different content. The P_r of BT show higher value around 12.11 pC/cm^2, while lowthe E_C at 3.8 kV/cm. With 8 and 10 wt% added, the sample exhibited high P_r value of 14.86 and 15.49 μC/cm^2, respectively. Moreover, there sample was obtained good E_C value with 1.79 and 2.13 kV/cm for 8 and 10wt% content, respectively, this result indicating that the ceramic obtain expedient to pole and effect has higher piezoelectric properties.

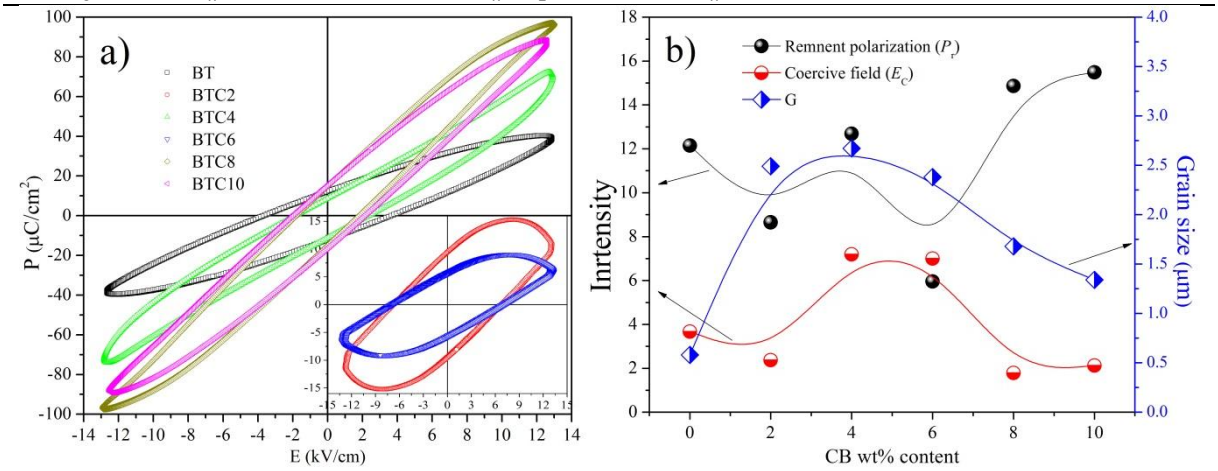

Figure 4: (a) The characteristicP-E hysteresis loops of $BaTiO_3$+xCB ceramics obtained at room temperature,(b) The remnant polarization and coercive field of $BaTiO_3$+xCB ceramics as function as CB content.

4. Conclusion

We have investigated structure, dielectric and ferroelectric properties for effect carbon black in $BaTiO_3$. All sample show major phase with tetragonal phase of BT base.With increasing CB addition, the lattice parameter was found enlarge increased to enhance the tetragonality. In CB addition, the dielectric property was fabricated electrical conductance of carbon black. The dielectric constants were little decreases,while the dielectric loss exhibited rose stability with increases temperature. The ferroelectric properties of samples exhibited relaxor ferroelectric at room temperature. The electrical properties were good P_r and E_C for 8 and 10 wt%.

5. Acknowledgements

This work is financially supported by Scanning Electron Microscope (SEM) results from National Metal and Materials Technology Center (MTEC).

References

[1]. TosawatSeetawan, WattanaPhotankham, HassakornWattanasarn, SuntiPhewphong, "Influence of nano carbon black added $BaTiO_3$ on physical and dielectric properties", Materials Today: Proceedings, 4, 6472–6477, 2017.

[2]. Yan Yan, Chao Ning, ZongziJin, Haoran Qin, Wenting Luo, Gang Liu, "The dielectric properties and microstructure of $BaTiO_3$ ceramics with ZnO-Nb_2O_5 composite addition", J. Alloy. Compd., 646, 748-752, 2015.

[3]. Yun Yang, Kaihua Liu, Xiaokui Liu, Gang Liu, Chengjie Xia, Zhanbing He, YanYan, "Electrical properties and microstructures of (Zn and Nb) co-doped $BaTiO_3$ ceramics prepared by microwave sintering". Ceram.Int., 42, 7877–7882, 2016.

[4]. ManindraTrihotri, U.K. Dwivedi, FoziaHaque Khan, M.M. Malik, M.S. Qureshi, "Effect of curing on activation energy and dielectric properties of carbon black–epoxy composites at different temperatures", J. Non-Cryst. Solids., 421, 1–13, 2015.

[5]. OmedGh. Abdullah, Gelas M. Jamal, Dana A. Tahir, and Salah R. Saeed, "Electrical Characterization of Polyester Reinforced by Carbon Black Particles", Int. J. Appl. Phys. Math., 1,2,2011.

[6]. Ahmad Ghasemi-Kahrizsangi, HomeiraShariatpanahi, JaberNeshati, EsmaeilAkbarinezhad, "Corrosion behavior of modified nano carbon black/epoxy coatingin accelerated conditions", Appl. Surf Sci., 331, 115–1262015.

[7]. M. El Hasnaoui, A. Triki, M.E. Achour, M. Arous, "Modelling of dielectric relaxation processes of epoxy-resin filled with carbon black particles",Physica B, 433, 62–66, 2014.

[8]. Shoufu Shao Jialiang Zhang, Zhong Zhang, Peng Zheng, Minglei Zhao, Jichao Li and Chunlei Wang, "High piezoelectric properties and domain configuration in $BaTiO_3$ ceramics obtained through solid-state reaction route", J. Phys. D: Appl. Phys., 42, 189801, 2009.

[9]. Yu Huan, Xiaohui Wang, Jian Fang, and Longtu Li, "Grain Size Effects on Piezoelectric Properties and Domain Structure of BaTiO3 Ceramics Prepared by Two-Step Sintering", J. Am. Ceram. Soc., 96[11], 3369–3371, 2013.

[10]. Ahmed I.Ali, Chang Won Ahn, Yong Soo Kim, "Enhancement ofpiezoelectricandferroelectricpropertiesof$BaTiO_3$ceramics byaluminumdoping", Ceram.Int., 39, 6623–6629, 2013.

[11]. Wei Chen, Xia Zhao, Jingen Sun, Lixue Zhang, LishengZhong, "Effect of the Mn doping concentration on the dielectric and ferroelectric properties of different-routes-fabricated $BaTiO_3$-based ceramics", J. Alloy. Compd., 670, 48-54, 2016.

[12]. Yu Huan, Xiaohui Wang, Jian Fang, Longtu Li, "Grain size effect on piezoelectric and ferroelectric properties of $BaTiO_3$ ceramics", J. Eur. Ceram. Soc., 34, 1445–1448, 2014.

[13]. Wei-Gang Yang, Bo-Ping Zhang, Nan Ma, Lei Zhao, "High piezoelectric properties of $BaTiO_3$–xLiF ceramics sintered at low temperatures", J. Eur. Ceram. Soc., 32, 899–904, 2012.

[14]. Yan Yan, Lin Liu, Chao Ning, Yun Yang, Chengjie Xia, Yuetong Zou, Shiyuan Liu, Xiaoxue Wang, Kaihua Liu, Xiaokui Liu, Gang Liu, "Improved electrical properties of SiO_2-added $BaTiO_3$ ceramics by microwave sintering", Mater. Lett., 165, 135–138, 2016.

[15]. P. Zheng, J.L. Zhang, Y.Q. Tan, C.L. Wang, "Grain-size effects on dielectric and piezoelectric properties of poled $BaTiO_3$ ceramics",Acta Mater., 60, 5022–5030, 2012.

[16]. Enwei Sun, Wenwu Cao, "Relaxor-based ferroelectric single crystals: Growth, domain engineering, characterization and applications",Prog. Mater. Sci., 65, 124–210. 2014.

[17]. Lianyun Yang, Xinyu Li, ElshadAllahyarov, Philip L. Taylor, Q.M. Zhang, Lei Zhu, "Novel polymer ferroelectric behavior via crystal isomorphism and the nanoconfinement effect". Polymer, 54, 1709-1728, 2013.

[18]. Nan Ma, Bo-Ping Zhang, Wei-Gang Yang, Dong Guo, "Phase structure and nano-domain in high performance of $BaTiO_3$ piezoelectric ceramics J. Eur. Ceram. Soc., 32, 1059–1066, 2012.