1. Introduction

Ferroelectric material has important role in the field of electronics. The ferroelectric phenomenon can be characterized by the presence of a hysteresis curve which is a graph of the relation between electric polarization and an electric field [1].

Commonly ferroelectric materials are used for energy storage for example are Barium Titanate (BaTiO$_3$), Titanate Zirconium Bismuth (BZT) and Barium Strontium Titanate (BaSrTiO$_3$) [2]. In this study the ferroelectric material was used Barium Titanate because it has a high dielectric constant (>1000) at room temperature [3]. Barium Titanate has ABO$_3$ perovskite structure [4]. The characteristic of ferroelectric can be modified using A or B ion doping. The selection of ions doping is adjusted with atomic radius at the position of atom A and B.

Barium Titanate can be synthesized with several method such as sol-gel method [5], Chemical Solution Deposition (CSD) [6], co-precipitation, soft chemical process and hydrothermal method [7]. This study use co-precipitation method because it has easier process. The co-precipitation method is carried out by constant stirring, so the solution will be homogeneous and it produces precipitate [8]. Barium Titanate was modified with Lanthanum doping. The addition of a little Lanthanum in a perovskite lattice (0.05 per unit formula) increase the permittivity value and decrease the curie temperature [3]. In this research Lanthanum replaces Ba$^{2+}$ ion because La$^{3+}$ and Ba$^{2+}$ ions have almost same radius, La$^{3+}$ (1.15 Å) and Ba$^{2+}$ (1.35 Å) [9].
2. Experimental

Fabrication of Barium Titanate doped Lanthanum use co-precipitation method. Concentration of mole Lanthanum (x) was varied at 0; 0.01; 0.02; 0.03; 0.04 and 0.05. Barium Hydroxide [Ba(OH)$_2$] (Sigma Aldrich, 95%), Lanthanum Nitrate [La (NO$_3$)$_3$], (Sigma Aldrich, <99%), Titanium Tetrabutoxide [Ti (C$_4$H$_9$O)$_4$] (Sigma Aldrich, 97%), Oxalic Acid (H$_2$C$_2$O$_4$) (Sigma Aldrich) > 99%, Isopropanol [(CH$_3$)$_2$(CHOH)] are raw materials which use for synthesis Barium Titanate doped Lanthanum. Oxalotitanic acid (HTO) solution was made with mixed Titanium Tetrabutoxide in isopropanol (IPA) and Titration Oxalic acid in isopropanol (IPA). Ba(OH)$_2$ and La (x = 0; 0.01; 0.02; 0.03; 0.04 and 0.05) were mixed in HTO solutions. Aquades added in that solution with titration. The final solution was precipitated for 24 hours at room temperature. The solution was washed by ethanol and aquades until it has PH > 5, then the solution was filtered with filter paper.

BaTiO$_3$ and BaTiO$_3$ doped La powder were heated at T= 100 °C for 5 hours and then powder crushed for 1 hour. BaTiO$_3$ and BaTiO$_3$ doped La powder were pressed become bulk. The bulk was sintered for T=1400°C for 4 hours. The bulk BLT was characterized with X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Sawyer Tower method and RCL meter.

3. Result and Discussion

The result of X-Ray Diffraction (X-RD) characterization obtained the diffraction pattern peaks which formed from the graph of the relationship between Intensity (I) and the diffraction angle (2θ). The peaks of diffraction pattern in the Ba$_{1-x}$La$_x$TiO$_3$ sample can be seen as. Figure 1. The peaks of the diffraction pattern matched using the International Center for Diffraction Data (ICDD). ICCD is used to determine the angle shift that occurs between experimental data and theory and it was used to determine the lattice parameters between values a, b and c.

![Figure 1](image-url)

**Figure 1.** The diffraction pattern of the Ba$_{1-x}$La$_x$TiO$_3$ sample with variations in mole and La concentrations.

The peaks of Ba$_{1-x}$La$_x$TiO$_3$ sample diffraction pattern shown in Figure 1. It was matched with the ICDD database pdf # 831880 have Barium Titanat (BaTiO$_3$). The addition concentration of mole La
dopant in Barium Titanate showed diffraction angle shift. $\text{Ba}_{1-x}\text{La}_x\text{TiO}_3$ sample shifts to the right as the concentration of La dopant mole is added in Figure 2.

![Diffraction angle peaks](image1)

**Figure 2.** Magnification of the diffraction angle peaks [202] of the $\text{Ba}_{1-x}\text{La}_x\text{TiO}_3$.

![Dielectric constant vs frequency](image2)

**Figure 3.** The dielectric constant for each frequency at mole doping variation La (x).

The dielectric constant of $\text{Ba}_{1-x}\text{La}_x\text{TiO}_3$ sample was measured by the RCL meters. RCL meter measurements obtained capacitance values. Measurement use $V_{rms} = 1$ Volt and the frequency of 0.01 kHz - 100 kHz. The relations between frequency and dielectric constant of $\text{Ba}_{1-x}\text{La}_x\text{TiO}_3$ sample can be seen in Figure 3. The dielectric constant decrease when frequency 0.01 kHz to 10 kHz and the
dielectric constant were more stable at frequency of 10 kHz to 100 kHz. When the frequency is low, dielectric constant is high because the dipole follows the shape of the field and the dielectric permittivity value equals in the static field [10].

![Figure 4. Dielectric constant of BaTiO\textsubscript{3} doped La.](image)

The dielectric constant increase as the number of mole La dopant was added increase (Figure 4), this is because the radius of the La atom (1.15 Å) is smaller than the Ba atom (1.35 Å) so that the grain size to be small. The small grain size cause unit cell volume become small. The volume of small cell units cause large polarization, because the volume of cell units is inversely proportional to polarization. The large polarization on sample cause a large dipole moment so that the stored charge gets bigger, because the dipole moment and charge are directly proportionial. The more stored charge in a sample, the capacitance becomes more large so that the dielectric constant is large because of the capacitance with the dielectric constant is directly proportionial.

The results of characterization using SEM on Barium Titanate doped Lanthanum (Ba\textsubscript{1-x}La\textsubscript{x}TiO\textsubscript{3}) sample such as morphology, roughness and grain size. The morphology of Ba\textsubscript{1-x}La\textsubscript{x}TiO\textsubscript{3} can be seen in Figure 5.

![Figure 5. Photo SEM Ba\textsubscript{1-x}La\textsubscript{x}TiO\textsubscript{3} (a) x=0 and (b) x=0.01.](image)
The influence of variations in the number mole La dopant cause small grain size, because the La atom will be replaced Ba atom position which the atomic radius of La is smaller than the Ba atom. The roughness of BLT sample was calculated using WSxM 4.0 Beta 9.0 software. The results of roughness calculations with software can be see Table 1. The influence of variations concentration mole La dopant causes the sample roughness level to be smaller. The grain size and Roughness of the Ba$_{1-x}$La$_x$TiO$_3$ can be seen in Table 1.

**Table 1**. Grain size in Ba$_{1-x}$La$_x$TiO$_3$ samples.

| La mole in Ba$_{1-x}$La$_x$TiO$_3$ | Grain Size ($\mu$m) | Roughness   |
|-----------------------------------|---------------------|-------------|
| $x=0$                             | 5.17                | 597.367     |
| $x=0.01$                          | 3.03                | 509.140     |
| $x=0.02$                          | 2.60                | 383.633     |
| $x=0.03$                          | 1.84                | 367.202     |
| $x=0.04$                          | 1.50                | 286.348     |
| $x=0.05$                          | 0.41                | 256.064     |

4. Conclusion

The influence of the variation concentration dopant mole of Lanthanum in BaTiO$_3$ causes the diffraction angle shifts to the right and crystal size to smaller. The dielectric constant increase as the concentration dopant mole of Lanthanum was added in BaTiO$_3$ increase. The grain size and roughness to smaller as the concentration of mole La dopant was added in Barium Titanate there more.
Acknowledgement
The authors would like to thank PUPT UNS Grant of 2018.

References
[1] Takayama R Y, Tomita K, Ijima and Ueda I 1996 \textit{J. Appl. Phys.} 61 4011-15
[2] Jamaluddin A, Susilowati E, Budiawanti S and Iriani Y 2014 \textit{Adv. Mater. Res.} 896 358362
[3] Morrison F D, Derek C S and Anthony R W 2001 \textit{Int. J. Inorg. Mater.} 3 1205-10
[4] Pradhan S and Roy G S 2013 \textit{Researcher} 5 63
[5] Iriani Y, Saputri D F, Hadiati S, Ramelan A H and Variani V I 2014 \textit{Adv. Mater. Res.} 91 205-9
[6] Setyadhani R T, Iriani Y and Jamaluddin A 2014 \textit{Adv. Mater. Res.} 896 229-32
[7] Vijayalakshmi R and Rajendran V 2010 \textit{J. Nanomater. Biostruct.} 5 511-17
[8] Khollam Y B, Bhoraskar S V, Deshpande S B, Potdar H S, Pavaskar N R, Sainkar S R and Date S K 2002 \textit{Mater. Lett.} 57 1871-79
[9] Wang Y, Cui B, Liu Y, Zhao X T, Hu Z Y, Yan Q Q, Wu T, Zhao L L and Wang Y Y 2014 \textit{Scripta. Mater.} 90-91 49-52
[10] Sonia, Chandrasekhar M and Kumar 2016 \textit{J. Ceram. Int.} 42 10587-92