Evaluation of thermal testing and X-ray diffraction of $\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3$

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ABSTRACT

The structure of perovskite-based material contained in the niobate and titanate. The fabric was a perovskite crystal structure having the formula $\text{ABO}_3$. Ferroelectric and piezoelectric materials had a perovskite structure. This material could store an electric charge, which was good because of the polarization resulting in a material that was a dielectric. Unleaded piezoelectric material, $\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3$ (KNN), was synthesized using reliable state methods. Synthesis was done by first setting up $\text{K}_2\text{CO}_3$, $\text{Na}_2\text{CO}_3$, and $\text{Nb}_2\text{O}_5$ as a base KNN system. Studies cover X-ray diffraction, thermal analysis TGA-DTA and lattice parameter analysis. From the TGA-DTA analysis obtained for KNN calcination temperature at 700°C for 2 hours can produce a single-phase $\text{ABO}_3$ where $A = (\text{K, Na})$ and $B = (\text{Nb})$. Orthorhombic perovskite structure KNN material owned by P4mm space group with lattice parameters $a = 3.572 \text{ Å}$; $b = 3.570 \text{ Å}$; and $c = 3.565 \text{ Å}$.

Keywords: piezoelectric, perovskite, solid state, $\text{K}_{0.5}\text{Na}_{0.5}\text{NbO}_3$

INTRODUCTION

Known perovskite structure-based material contained in the niobate and titanate (Desmelinda, 2015). It is known that niobate-based material has an advantage and a similar nature of PZT, but more environmentally friendly (Chen, et al., 2013). Perovskite crystal structure is Sebastian having a general formula $\text{ABO}_3$. This structure is based on cubic each cube face having an oxygen atom. Atoms occupy each corner of the cube while the atom $B$ occupies the centre of the hub. The material has a perovskite structure that can have a lattice cube, tetragonal, orthorhombic, and others.

The ferroelectric material is one of several types of materials that have a role in the world of science and industry. Examples of material utilization ferroelectric on electronic circuits such as: variation on the circuit microwave, modular electro-optical, dielectric materials that are good for the capacitor, FeRAM (ferroelectric RAM), ferroelectric tunnel junction, multiferroic materials, piezoelectric transducers, detectors pyroelectric, PTC.
Piezoelectric and ferroelectric materials have a structure that is perovskite. Therefore, the content can store electrical charge properly — the electrical charge storage due to the polarization of the material. Polarization is the result of a cubic phase transition into a tetragonal phase at a specific temperature, which is also called a curie temperature. So that the electric field is relatively small given cation would shift the central grid due to Coulomb interaction. This polarization resulted in distortion of crystal that forms a dipole and the macroscopic scale separation of positive and negative charges or a dielectric material that is called. Ferroelectric has a high dielectric constant when applied to the field of relatively low frequency, for example, at room temperature, or to barium titanate of 5000. Therefore, the capacitor is made of a dielectric material with ferroelectric properties (Callister & Rethwisch, 2012).

Piezoelectricity is a symptom when no force is applied to a material segment that causes the electric charge on the surface of the material sections. A piezoelectric material can alter the mechanical stress into an electrical charge given to him and change the electric field given to him becoming a mechanical stress. The piezoelectric material used as the material to produce electricity cantilever low-power mini electric motors, microphone and medical devices on ultrasonography (Ahda, 2012). Another application is as a base for the manufacture of transducers. The piezoelectric charge coefficient values are in the range of 1-100 PC/N (Saito, 2004). Known piezoelectric materials today are PbZrTiO$_3$ (known as PZT), which are known to have excellent piezoelectric properties and widely applied. But the lead oxide is a toxic material that is high and will increase the danger at high temperatures, especially in the calcining and sintering processes (Mardiyanto, 2010). So that research must be done to make these unleaded piezoelectric material to make it more environmentally friendly.

In the general situation, the unleaded piezoelectric material is a material with a perovskite crystal structure such as BaTiO$_3$ (BT), KNbO$_3$, NaTaO$_3$, and non-perovskite include bismuth layer structured ferroelectric materials (BLSF) and tungsten-bronze ferroelectric materials. According to research conducted by some experts, materials BiNaTiO$_3$ (BNT) is a good candidate to replace the PZT material. The amount of remnant polarization, namely BNT ($P_r$) = 38 μC/cm$^2$ and $E_c$ = 73 kV/cm (Ni et al, 2011). But apparently, this BNT material still has shortcomings that made a dopant to improve the performance of the piezoelectric material.

K$_{0.5}$Na$_{0.5}$NbO$_3$ or commonly abbreviated as KNN is an excellent candidate to make unleaded piezoelectric material for piezoelectric properties and a strong ferroelectric. According to Saito (2004), a composition is having a high $d_{31}$ values obtained in the phase between orthorhombic and tetragonal. KNN widely studied is a compound made of the carbonate such as K$_2$CO$_3$, Na$_2$CO$_3$, and Nb$_2$O$_5$. KNN that have been hot press having $d_{31} \sim 160$ pC/N (Desmelinda, 2015). Analysis of the structure and morphology of the piezoelectric material is performed using X-ray diffraction (XRD).

X-ray diffraction is a test to determine the crystal system in materials. This test also can explain the existence of the lattice parameters, the type of structure, the difference in the arrangement of atoms in the crystal, the crystal is not perfect, and the amorphous form in the material. X-rays produce electrons spread if the particle strikes a metal at high speed in a state of vacuum tubes. X-ray beam using a crystal to diffraction because of the order of X-ray wavelengths have the distances between atoms is nearly equal or smaller in a glass (Zulianingsih, 2012).

XRD testing utilizing the diffraction of X-rays. High voltage generator to function as power generating X-ray source in the x-ray tube. Samples that have been compressed powder form placed over a container that can be positioned. Then the X-ray beam strikes an example and is diffracted by the sample, into the tool counter. X-ray diffraction intensity captured by the detector and translated in the form of curves.
In addition to analysis using X-ray diffraction, testing the other is by thermal analysis. Thermal analysis is the measurement of the physical properties and chemical as a function of temperature. Thermal analysis has two analytical techniques that thermogravimetric analysis (TGA) and differential thermal (DTA). Thermogravimetric analysis (TGA) can measure the change in weight of the sample. In contrast, the thermal differential analysis (DTA) can measure the temperature difference between the sample with inert reference material as a function of temperature. DTA is used for the study of the structure of the glass, the determination of the phase diagram, the phase transition polymeric, kinetic energy, heat capacity, enthalpy, and decomposition.

The robust reaction method is a method for making ceramics made in the solid-state. It occurs at temperatures above 1000°C. Method with less solid-state synthesis is used to create a unique composition and morphology needed to produce desirable properties in crystals, piezoelectric, and other advanced materials. In general, the solid-state reaction is stoichiometric reaction powders at high temperatures. Keuntungan of this method is simple, in the sense that everyone can do it, but can be tricky, for instance, at a temperature and atmosphere used.
in 99% alcohol for 1 hour. Then dried using a rotatory evaporator to obtain the KNN powder while maintaining the homogeneity of the mixture. Once it is done, thermal analysis (TGA-DTA) to determine the reactions indicated by the presence of mass reduction and both endothermic and exothermic phenomena that accompany the specific range of temperatures that can be known calcination temperature. 650°C to 750°C is possible because the CO₂ released from carbonate of approximately 11.17%.

After the temperature over 750°C, there was found no decrease in mass. From the results of the thermal analysis test it is believed that at temperatures around 650°C to 750°C the reaction occurs in the formation of KNN material.

**Test Results X-ray Diffraction**

After the thermal analysis is carried out, the powder mixture of K₂CO₃, NaCO₃ and Nb₂O₅ is calcined at a temperature that is expected to form the KNN reaction at 700°C with a holding of 2 hours. Then powder XRD results calcination testing to determine the phases present in the KNN powder. Figure 5 is an XRD pattern of results from the software origin calcined at a temperature of 700°C for 2 hours. The results of the XRD pattern shows that when a temperature of 700°C, KNN powder has been formed due to the phase generated only a single step and no secondary phase.

To clarify the evidence that there is only a single phase of this material can be analyzed using software match. Figure 6 is a picture of mountains owned by KNN calcined material 700°C for 2 hours. The Figure shows that the single-phase already obtained. Determining the type of TiO₂ phases are generated based on the location of the summit accord angle (2θ) with an individual specific datasheet.

ICSD data show that KNN orthorhombic crystal structure at room temperature. To find...
CONCLUSION

Perovskite structure without timbale material synthesized by reliable reaction method. Their calcination at a temperature of 700°C for 2 hours is able to produce a single-phase ABO₃ where A = (K, Na) and B = (Nb). KNN material has a perovskite structure orthorhombic with P4mm space group and lattice parameters a = 3.572 Å; b = 3.570 Å; and c = 3.565 Å.

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