

SYNTHESIS AND FABRICATION OF [(K_{0.5}Na_{0.5})_{0.935}Li_{0.065}]NbO₃ ADDED WITH Mn FOR PIEZOELECTRIC MODULE

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ABSTRACT

Piezoelectric ceramic was directly manipulated to change oscillation to electricity and electric to oscillation. The KNNL–Mn ceramic was synthesized from K₂CO₃, Na₂CO₃, Li₂CO₃, Nb₂O₅, and MnO₂ (1.5 mol %) materials by conventional mixed oxide method. The crystal structure of sample was identified by X–Ray diffraction technique, and the microstructure was observed by using a scanning electron microscope. The XRD patterns of the KNNL–Mn ceramics with various Mn content showed the tetragonal structure. The crystal size of sample was mean 34 nm and lattice parameters were a = 1.29 nm, c = 0.41 nm. The Vickers hardness values of the KNNL–Mn ceramics was found to be 352 N mm⁻², theoretical density of 90.70 %. The dielectric constant and dielectric loss of KNNL–Mn yielded 574.48 and 0.28, respectively at room temperature. The mean piezoelectric constant at 94 pC N⁻¹ and the module showed an electrical voltage of 0.21 V.

KEYWORDS: KNNL–Mn, crystal structure, piezoelectric materials, dielectric constant

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INTRODUCTION

The potassium sodium niobate (KNN) has good ferroelectric properties. The crystal structure of KNN shows Perovskite general formula of ABO₃ [1-4]. The KNN compound produces anti-ferroelectric properties, and anti-ferroelectric, which have a molecular structure and polarization in the opposite direction. The KNN compound structures are orthorhombic at a room temperature and change when the temperature is higher [5-7]. The structure, changing from orthorhombic to tetragonal and cubic respectively will affect the electrical properties. In addition, the KNN compound has a Curie temperature of about 693 K which works well at a high temperature. The electrical terminals can also be arranged easily under a low electric field of approximately 5 kVcm⁻¹ and the piezoelectric coefficient of approximately of 80

pC N after the low intensity of the electric field [8,9].

In this study, the properties and performance piezoelectric module [(K_{0.5}Na_{0.5})_{0.935}Li_{0.065}]NbO₃ added with Mn 1.50 mol% (KNNL–Mn) are investigated. The piezoelectric properties are appropriate to develop efficient modules for the diversion of electricity.

MATERIALS AND METHODS

The KNNL–Mn ceramic was synthesized through solid-state reaction method, from the precursor's powder (K₂CO₃, Na₂CO₃, Nb₂O₅ with purity of 99%, 99.80% and 95% respectively, was produced by Tianjin Fuehen Chemical Reagents Factory in China). The Li₂CO₃ with 99% purity was produced by Sigma–Aldrich, USA. The MnO₂ (1.50 mol %) with 99% purity was produced by Carlo Erba Reagents, France. The synthesis process starts from the balancing of

chemical equations. Then, the precursor of all proportion to the scale of the calculation of the equation, then K_2CO_3 , Na_2CO_3 , Li_2CO_3 put the beaker and then use a paper foil off the small hole in the beaker and then placed on the oven at 373 K for 30 min. Then the substrate was put into the bottles with a ball mill mixed by ball-milling for 6 h, the sintering temperature was at 1073 K for 4 h and to ensure the purity of the increase. The powder felted pressure 300 MPa diameter of 0.015 m by mixing with 1.50% PVA after burning out PVA and burns them on the sintering at 1343 K for 2 h. The crystal structure of sample was analyzed by X-ray diffraction (XRD, SHIMADZU 6000, Japan) and Fourier transforms infrared spectroscopy (FTIR, SHIMADZU 8900, Japan). The micro structure of sample was observed by scanning electron microscopy (SEM; JSM-6301F, JEOL, Germany). The density of sample was measured by Density Kit (MS204, METTLER TOLEDO, Switzerland). In addition, we study hysteresis loop distribution dielectric constant, dielectric loss according to frequency and temperature into ceramic KNNL-Mn (1.50mol %). Then attach terminals to detect the conjugate of electrical ceramics KNNL-Mn (1.50mol %).

RESULTS AND DISCUSSION

The structure of the ceramic KNNL-Mn was prepared through solid state reaction powders calcined at 1123 K for 4 h and sintered at 1343 K for 2 h. The XRD patterns were shown in fig 1. The analysis found that the structure of the KNNL-Mn ceramic was consistent with KNN ceramic, and was contaminated from the substrate with Li_2CO_3 and MnO_2 . When the sintering of KNNL-Mn ceramics were more symmetrical, the XRD patterns in the range of 2θ from 45 to 47 show (200)/ (020) splitting peak and confirming its tetragonal symmetry.

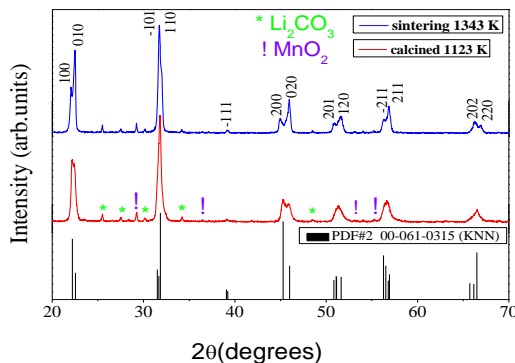


Fig. 1. XRD patterns of Mn = 1.50 mol% added with $[(K_{0.5}Na_{0.5})_{0.935}Li_{0.065}]NbO_3$ ceramic

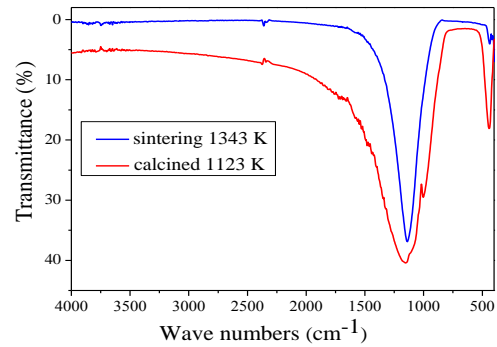


Fig. 2. FT-IR of Mn = 1.50 mol% added with $[(K_{0.5}Na_{0.5})_{0.935}Li_{0.065}]NbO_3$ ceramic of powders calcined and sintering

Figure 2 shows that FT-IR changed as a result from temperature change while calcining and sintering. The peak, during high wave numbers 500 and 900, was reduced when the calcination temperature increased.

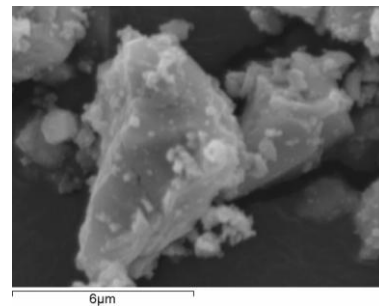


Fig. 3. SEM image of Mn = 1.50 mol% added with $[(K_{0.5}Na_{0.5})_{0.935}Li_{0.065}]NbO_3$ ceramic of powders sintering

The peak at the wave numbers 1000 also disappeared when the temperature increased. In addition, the height of the peak decreased as the temperature increased. The analysis also found that the structure of the material was more symmetrical when a sintering temperature increased.

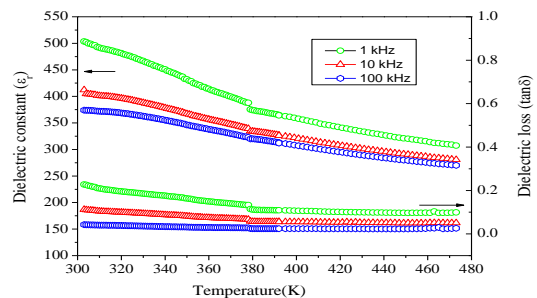


Fig. 4. Dielectric constant (ϵ_r) and Dielectric loss ($\tan \delta$) of Mn = 1.50 mol% added with $[(K_{0.5}Na_{0.5})_{0.935}Li_{0.065}]NbO_3$ ceramic

Figure 3 shows SEM processing identifying grain shape and features, which was similar to a cluster of tiny crystals sticks to the surface of grain shaped like a triangle. The change of the structure shows that MnO_2 had spread into the structure of KNNL. This trend can be explained through the differences in ionic radius as the range of Mn ions are +2, +3, +4, with the size of the ion radius of 0.67, 0.64 and 0.53 Å respectively [10-13], which are smaller than the radius of the ion K^+ Na^+ and Li^+ ions [14]. The crystal size of samples, added Mn = 1.50 mol%, is 34 nm and plane a = 1.29 nm, c = 0.41 nm, the theoretical density of 90.70 %. The Vickers hardness values were found at 352 N mm^{-2} .

Figure 4 shows dielectric constant (ϵ_r) and dielectric loss ($\tan \delta$) of KNNL ceramic added with Mn = 1.50 mol%. They were measured in the frequency range of 1 kHz–100 kHz, beginning at 298 K–473 K. The figure IV revealed that dielectric constant (ϵ_r) and dielectric loss ($\tan \delta$) decreased when the temperature increased. The maximum value of dielectric constant (ϵ_r) was 574.48, and dielectric loss ($\tan \delta$) was 0.28 at a temperature of 298 K, and had a frequency of 1 kHz. The reduction of dielectric constant (ϵ_r) and dielectric loss ($\tan \delta$) occurred when the temperatures and the frequency increased. This would cause the electrons in a grain moved up, and collided with more whole grain and the grain boundary area.

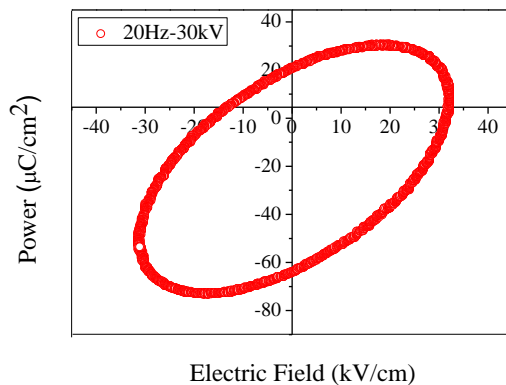


Fig. 5. Hysteresis loop of KNNL ceramic added with Mn = 1.50 mol%

Figure 5 shows hysteresis loop of KNNL ceramic added with Mn = 1.50 mol% which measured the voltage 30 kV and a frequency of 30 kHz. The results shown from the graph revealed the characteristics of the trend are oval to oval. Typically, P–E loop looks like an oval at the top end, and the bottom is pointed. The

samples were applied in a 50 kV cm^{-1} field with a temperature of 353 K for 15 minutes. The samples were cooled at a room temperature in the electric field. The measure d_{33} is a value 94 pC N^{-1} , and the stick for terminals is fabricated into module.

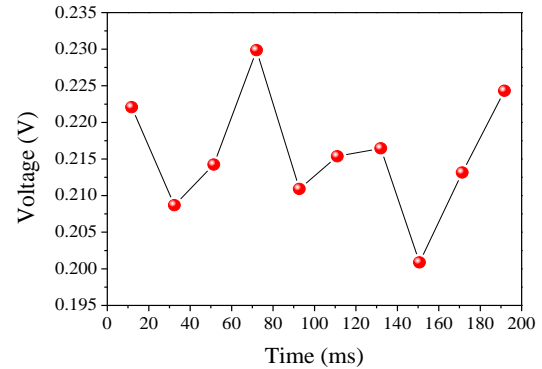


Fig. 6. Shows voltage from the electrical conjugated of KNNL–Mn module.

Figure 6 shows the maximum voltage of each frequency from the conjugated electricity of Piezoelectric module of KNNL–Mn. Necessitating, the conjugate of electricity piezoelectric modules frequency will depend on the mechanical impact of modules. The piezoelectric Module is a module type of ceramics. The frequency of the desired effects of mechanical force low frequency, thus you can make piezoelectric module average voltage values at 0.21 V.

CONCLUSION

The results of synthetic piezoelectric material of $[(K_{0.5}Na_{0.5})_{0.935}Li_{0.065}]NbO_3$ added with Mn = 1.50 mol% (KNNL–Mn). The Perovskite structure indicated tetragonal symmetry, and showed dielectric constant (ϵ_r) dielectric loss ($\tan \delta$), and hysteresis loop at nice. When directed to the module it can deviate from mechanical to electrical current.

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REFERENCES

- [1] L. Jing-Feng, W. Ke: *J. Eur. Ceram. Soc.* 96(12), **2013** 3677–3696.
- [2] L. Jing-Feng, Z. Yuhua, Z. Bo-Ping, Z. Li-Min. W. Ke: *Ceram. Int.* 34(4), **2008** 783–786.
- [3] P. Xuming, Q. Jinhao: *Ceram. Int.* 38, (2012). 2521–2527.
- [4] H. Jigong, Z. Xu: *Mater. Des.* 31, **2010** 3146–3150.
- [5] H. E. Mgbemere, R.-P. Herber, G. A. Schneider: *Am. Ceram. Soc.* 29, **2009** 1729–1733.
- [6] S. Wongsanmai: *Curr. Appl. Phys.* 12, **2012** 418–421.
- [7] L. Lu, G. Yue-Qiu, G. Lun-Jun, D. Hui, Y. Xi-Feng, Z. Xue-Jun: *Mater. Des.* 33, **2012** 362–366.
- [8] U. Flückiger, H. Arend. H. Oswald: *Am. Ceram. Soc. Bull.* 56(6) **1977** 575–577.
- [9] R.E. Jaeger, L. Egerton: *J. Eur. Ceram. Soc.* 45, **1962** 209–213.
- [10] T. Liu, A. L. Ding, X.Y. He, X. S. Zheng, P. S. Qiu, W. X. Cheng: *Phys. Status Solidi.* 203(15), **2006** 3861–3867.
- [11] J. H. Moon, H. M. Jang, B. D. You: *J. Mater. Res.* 8(12), **1993** 3184–3191.
- [12] Y. Guo, K. Kakimoto, H. Ohsato: *Mater. Lett.* 59(2–3), **2005** 241–244.
- [13] Y. Saito, H. Takao, T. Tani, T. Nonoyama, K. Takatori, T. Homma, T. Nagaya, M. Nakamura: *Nat.* 432, **2004** 84–87.
- [14] R.D. Shannon : *Acta Crystallogr.* (32), **1976** 751–767.