Study of Ferroelectric Properties of Lead free KNN Ceramics with Temperature

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ABSTRACT

The attractive lead free $K_{0.5}Na_{0.5}NbO_3$ (KNN) ceramics are prepared by solid state reaction method with pure perovskite structure. The materials show high Curie temperature and high dielectric constant with two phase transitions. The ferroelectric properties are studied by recording P-E hysteresis loops. P-E hysteresis loops are recorded at 20 Hz frequency at different temperature ranging from 30-70^{0}C. The width of P-E loops and coercive field is found to have strong dependency on temperature. The squarness ratio i.e. P_r/P_s ratio is also calculated at all the temperatures. The results reveal the good ferroelectric properties of KNN even at higher temperatures.

Keywords: KNN; Perovskite; Ferroelectric Properties.

1. INTRODUCTION

Ferroelectrics are highly studied among the smart materials due to the existence of mobile domain structure. Firstly, Barium Titanate has become one of the most important electroceramics materials among all the ferroelectric materials because of its versatility in multilayer ceramic capacitors, ferroelectric random access and electro-optic devices [1-2].

Many Lead based ceramics also show interesting piezoelectric, pyroelectric and opto-electronic properties. The evaporation of lead during sintering of these ceramics is not environment friendly. With the raise of environmental consciousness, excellent lead free ceramics have been attracting attention worldwide as new material replacing of lead based piezoelectric ceramics. There are several candidates for lead free ceramics, such as bismuth based compounds and alkaline niobate compounds. Potassium sodium niobate [$K_{0.5}Na_{0.5}NbO_3$, KNN] ceramic is an attractive material that has been thoroughly investigated as a result of its high Curie temperature, strong piezoelectricity and ferroelectricity [3-4].

In this paper, P-E hysteresis loops of KNN are recorded at 20 Hz frequency at different temperature ranging from 30-70^{0}C for observing the effect of temperature on ferroelectric properties. After

observing all results, it is concluded that lead free piezoelectric ceramic KNN shows good ferroelectric properties even at higher temperature.

2. EXPERIMENTAL PROCEDURE

Sample Preparation

In this work, $K_{0.5}Na_{0.5}NbO_3$ (KNN); were synthesized by solid state reaction method with oxides and carbonates. Highly pure sodium carbonate, potassium carbonate and niobium pentaoxide in the required amount were used as precursors. The powders were mixed and milled in Ethanol for 3 h using high energy planetary ball mill. The powders were mixed properly by using zirconia balls as the grinding medium. The mixed slurry was dried in oven at 200^0C temperature. The dried slurry was calcined at 850^0C for 4hrs in oxygen rich environment. The calcined powders were reground and then fine powders of KMNN pressed into discs with 15mm in diameter and about 1.5 mm in thickness. The green discs finally pellets sintered in air at 1050^0C for 3hrs and cooled in the furnace.

Characterization

To study the ferroelectric properties, electrodes were made on the surfaces of discs by firing of silver paste at 500^0C for 30 min. The polarization – electric field (P-E) hysteresis loops were obtained by using Swayer – Tower circuit by applying a sinusoidal input signal at frequency of 20 Hz from room temperature (30^0C) to higher temperature (up to 70^0C).

3. RESULTS AND DISCUSSIONS

Structural Properties

XRD pattern of calcined sample show the pure perovskite structure with orthorhombic symmetry at room temperature with defined planes which is already reported by the authors [5].

Ferroelectric Properties

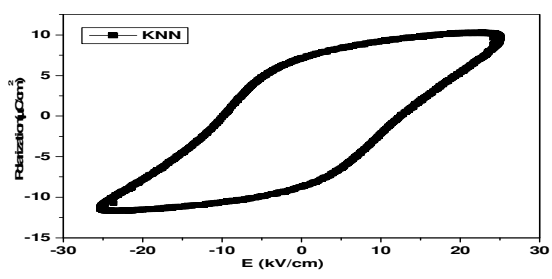

Figure 1. P-E loop of KNN at room temperature.

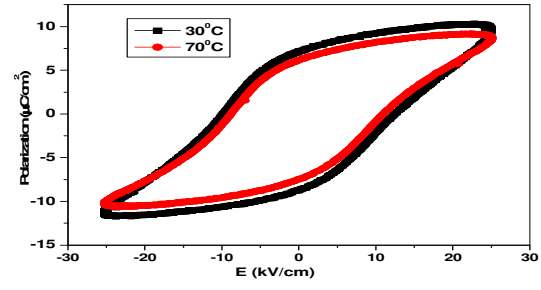

Figure 2. Comparison of P-E loop of KNN at 30^0C and 70^0C temperature.

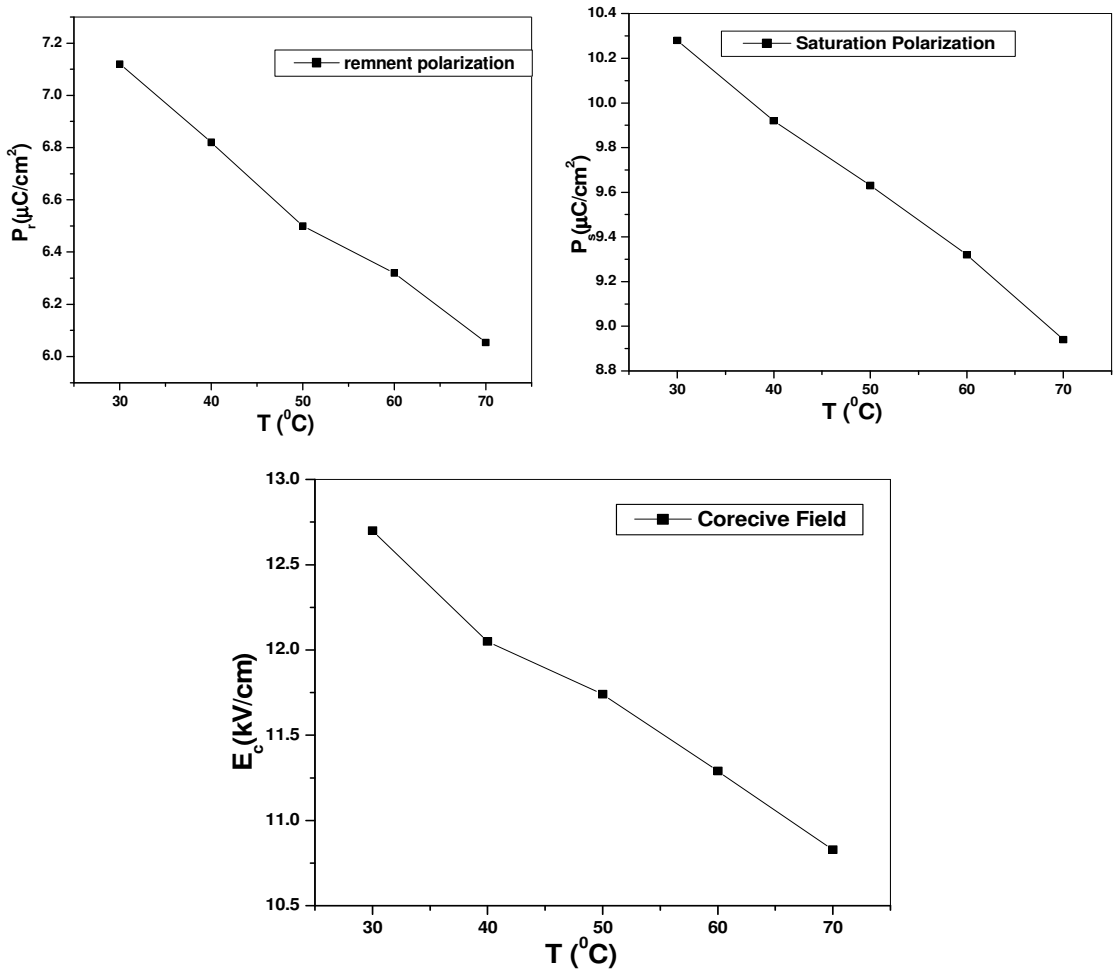

Figure 3. Variation in P_r, P_s and E_c of KNN with temperature.

The width of P-E loop is found to decrease with increase in temperature. The decrease in P_r, P_s and E_c with increase in temperature is shown in Fig.3. The decrease in E_c indicates that the material gets softness on heating [6]. The P_r/P_s also shows the decreasing behavior with temperature which indicates that squarness of P-E loop of KNN decrease with heating [7].

4. CONCLUSION

With pure perovskite structure, KNN ceramics have well defined ferroelectric behavior. Temperature plays an important role for change in ferroelectric properties of these ceramics. Remnant polarization, coercive field and squarness of KNN decrease with increase in temperature. These results conclude that material gets softness on heating.

References

[1] K. Uchino, Ferroelectric Devices, Marcel Dekker, New York, 2000.
[2] G. H. Haertling, J. Amer. Ceram. Soc., 82 (1999) 797.
[3] P. Zhao, B. Zhang, J. Li, Appl. Phys. Lett., 90 (2007) 242909.
[4] J. Tellier, B. Malic, B. Dkhil, D. Jenko, J. Cilencek, M. Kosec, Solid Stat. Sci., 11 (2009) 320.
[5] A. Dahiya, O. P. Thakur, J. K. Juneja, IEEE 7th Int. Con. Sens. Tech., (2013) 383.
[6] P. Kumar, S. Singh, J. K. Juneja, C. Prakash, K. K. Raina, Physica B 404 (2009) 1754.
[7] P. Kumar, S. Singh, J. K. Juneja, C. Prakash, K. K. Raina, Mate. Chem. Phys., 125 (2011) 660.