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Effect of impurities of ferroelectric Al- doped $KNbO_3$ single crystal

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***Abstract*- The doped $KNbO_3$ single crystal have been prepared using flux method by taking K_2CO_3 and Nb_2O_5 as starting materials, in the molar ratio of 1.2:1 with an impurity of Al_2O_3 (100, 200mg). The good quality single crystals were obtained by this method. The sample are partially transparent suitable for optical properties. The detailed study of structural parameters, dielectric and thermal properties were carried out in this paper. The prepared sample was characterized by X-Ray diffraction method to determine lattice parameters. The material is orthorhombic at room temperature. The dielectric properties shows the dielectric anomaly observed at low frequencies with increasing temperature through dielectric constant measurement. The material has high value of dielectric constant at Curie temperature of about 435°C which is confirmed by DTA curve.**

***Keyword*- Dielectric properties, X-Ray diffraction,**

I.INTRODUCTION

Due to environmental consciousness, lead free ferroelectric material has been recently gaining demand. Such materials are $BaTiO_3$ (BT), $KNbO_3$ (KN), $Ba_5Ti_2O_7Cl_4$ [1] etc. Among these lead free complex perovskite potassium niobate $KNbO_3$ has been investigated widely, both from academic and commercial viewpoints [2]. It exhibits the same Sequence of structural phases as $BaTiO_3$, [3]. It is therefore, highly interesting to compare their physical properties and find out the similarities and differences [4]. But at higher temperatures $KNbO_3$ has an orthorhombic symmetry at room temperature, and undergoes phase transitions at -10, 225, and 425 ºC from rhombohedral → orthorhombic → tetragonal → cubic, respectively [5]. The lead free complex perovskite, KN single crystals are very promising materials for electronics devices & applications. Such as capacitor, actuator, sensors, transducers [6]. Therefore, it is of special interest due to very large electro optic properties& good dielectric properties [7]. The properties of the crystals are strongly affected by the technique of crystal growth as well as by adding external impurities i.e. dopants. The doping may cause colouration of crystals, generation of both point defects and extended defects [8]. This paper reports the effect of impurities i.e. Al_2O_3 on the growth and characterization of $KNbO_3$ singlecrystal

2.EXPERIMENTAL

2.1) Crystal structure determination

The XRD studies of the $KNbO_3$ sample were carried out to characterize the crystal symmetry. The XRD pattern of Al- doped $KNbO_3$ single crystal with different concentration as shown in the figure (1).The sharp and single diffraction peak of XRD pattern suggest the formation of single phase compound; X-ray structure analysis was done using programmed software such as powder-x, check cell, cell151

2.2) Dielectric and phase transition studies:-

The grown crystals were cut in small chips for dielectric studies in to a few $(mm)^2$ areas from 0.2 mm to 0.5 mm thickness. The experiments to determine the dielectric constant were carried out w. r. to temperature at different frequencies i.e. 1 kHz, 10 kHz with impurity 100 mg and 200 mg.

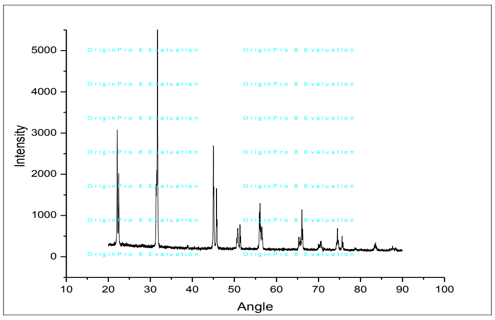
2.3) Thermal analysis

Thermal analysis was carried out by using a thermal analyser, in the temperature range from room temperature to 600°C. The grown crystal was crushed in to fine powder. Then thermal analysis spectra i.e. DTA was recorded in the temperature range from room temperature to 600°C with a heating rate of 10°C / min.

III.RESULTS AND DISCUSSION

3.1) XRD Analysis

Figure 1 Shows the XRD pattern for Al- doped $KNbO_3$ single crystals. It is seen that all the composition possess a single phase perovskite structure and no trace of any secondary phase is detected. The XRD data have been analysed by powder-x programme. It can be seen that the X-ray powder diffraction analysis identified the structure of the as grown crystal shows orthorhombic structure at room temperature.



(a)

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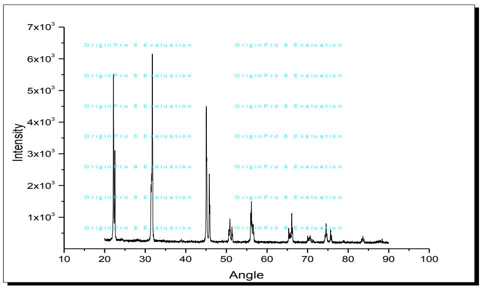
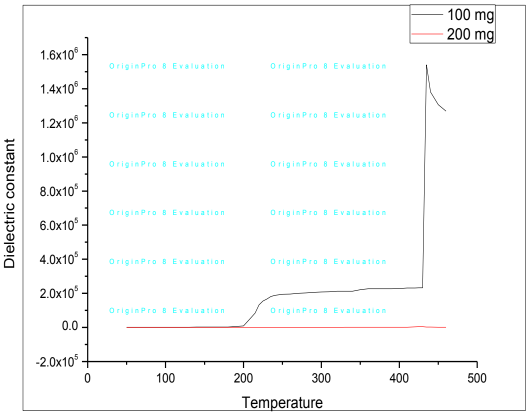


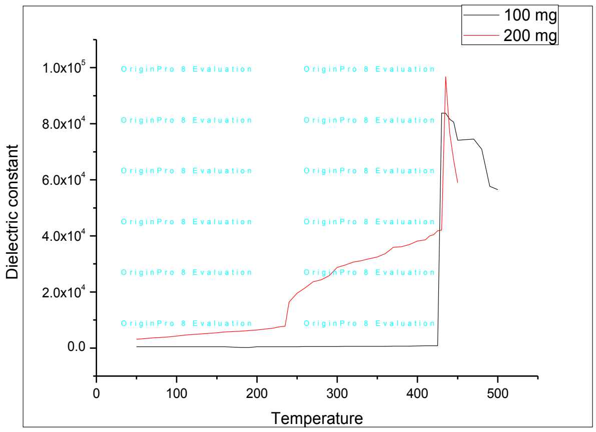
(b)

Fig. 1: XRD pattern of doped $KNbO_3$ single crystal (a) Al_2O_3 (100 mg) (b) Al_2O_3 (200 mg).

3.2) Dielectric constant:-

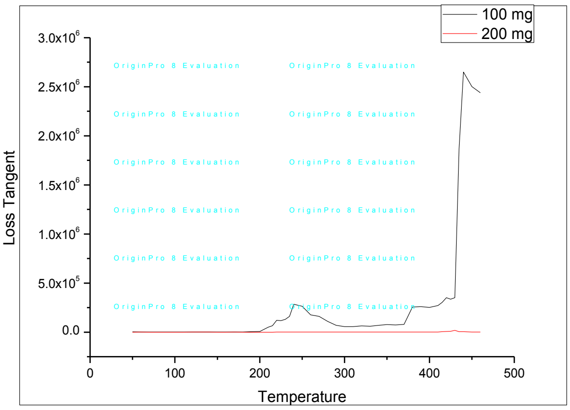
The variation of dielectric constant w. r. t. temperature at different frequencies has been shown in figure 2 (a and b). The high value of dielectric constant equal to 1.6×10^5 at 1 kHz of the impurity 100 mg and 1×10^4 at 10 kHz of the impurity 200 mg was found at Curie temperature (Tc) of about 435°C which is Equal to the value of Tc of KN single crystals i.e. 435°C, it was also observed that the value of dielectric constant increases with increasing temperature [9]. The value of dielectric constant decreases with increasing impurity. The dielectric curve shows no effect of frequency on the Curie temperature[10]. Figure 3 show that the loss tangent varies exponentially for 1 kHz, whereas the same is varying randomly for 10 kHz, but the large variation around 225°C and 435°C confirms the possibility of phase transitions.



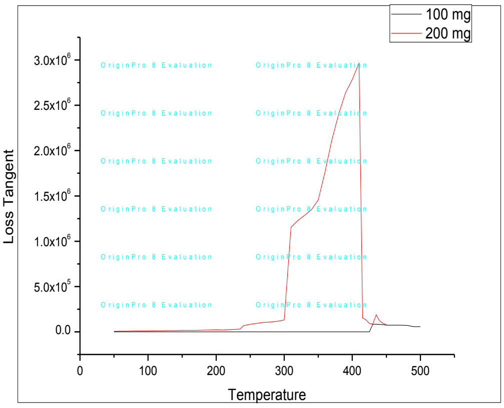


(a)

Fig. 2: Variation of dielectric constant w.r.to temperature at (a) 1 kHz (b) 10 kHz.



(a)



(b)

Fig. 3: Variation of loss tangent w.r.to temperature at (a) 1 kHz (b) 10 kHz respectively

3.3) Thermal analysis

Figure 4 shows DTA curve for Al_2O3 doped $KNbO_3$ single crystal. DTA shows very small endotherm at 210°C and another smallendotherm at 440°C.These two endotherms correspond to phase transitions. Since the peaks are observed without loss in mass, they can be attributed to phase transitions.

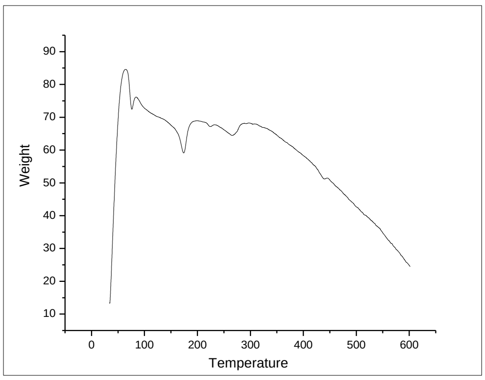


Fig. 4: DTA curve of Al_2O_3 doped KNbO3 single crystal

IV.CONCLUSION

Al – doped $KNbO_3$ single crystal was successfully grown by flux method. The good quality large single crystal was obtained. The calculated lattice parameters of the as-grown crystals are: a = 5.69399 Å, b = 3.96801 Å and c = 5.71852 Å. The present material is orthorhombic at room temperature. The materials have high value of dielectric constant at the Curie temperature of about 435°C it is confirm by DTA curve. The further careful and systematic studies, with varying compositions and preparative conditions, appropriate materials for different industrial and technological applications can be developed

V. ACKNOWLEDGEMEN

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