IMPEDANCE SPECTROSCOPY OF PURE AND RARE EARTH SAMARIUM(SM)DOPED POTASSIUM NIOBATE SINGLE CRYSTALS

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A B S T R A C T

Dielectric permittivity was studied using an impedance analyser at room temperature for pure(KN); 1wt % Sm(KND-1) &2 wt% Sm (KND-2) doped potassium niobate single crystals from 01 Hz to 10 MHz. Due to Sm doping the capacitance has increased about hundred times. Resistivity has not changed for lower frequency however it has increased ten times for higher frequency. It is also observed that Sm doping has marginally increased Tan δ for higher frequency, reduced the impedance, retaining value of permittivity of pure potassium niobate single crystals for the entire frequency range. The present study has been undertaken to study the effect of rare earth Sm on potassium niobate single crystals at room temperature to investigate it's potential to be used as a capacitor for device applications in the miniature circuits as resonators or filter applications.

Keywords: Rare earth Sm doped potassium niobateDevice applications

1. INTRODUCTION:

ABO_3(A and B are cations and O is the oxygen anion)type perovskites constitute one of the most important classes of ferroelectric materials and are used in several applications in electronic technology.[1-2] Many attentions have been paid to improve the electric & dielectric properties of ABO_3perovskite via partial substitution of either A ions(Pb,Ca,Ba or Sr site doping)or B ions (Ti site doping)[3].So far many new dielectric materials have been developed in recent years due to their interesting properties[4-7]. The best industrial performances are given by ferroelectrics ie. Substances with permanent electric dipoles even in the absence of an external electric field, such as the well-known pervoskite materials $BaTiO_3$, $PbTiO_3$, $KNbO_3$ etc [8]The dielectric property of solids as a function of frequency and temperature gives good insight into various polarization mechanism. According to Debye [9],dielectric polarization is time dependent &relaxation losses are associated with dipolar orientation, ion jump or electron hopping and can occur over a wide range from 10^{-1} to 10^{16} Hz. When selecting a dielectric material for a capacitor, it is also important to consider the effect of frequency on the material's properties. The permittivity that a material exhibits when it is exposed to an electric field is dependent on the frequency of the voltage source. When a material is placed in a static electric field, the permittivity that it exhibits is referred to as static permittivity. The permittivity of a material decreases with an increase in frequency of the voltage source. A primary drive today is towards circuit miniaturisation. Toproduce miniature circuits components with a smaller footprint are required. The dielectric constant of a capacitor determines the capacitance that can be achieved. Dielectric materials with high dielectric constants are used when capacitors with smaller physical sizes are required. Apart from dielectric constant, it is also important to consider dielectric loss and dielectric strength when selecting a dielectric material for a capacitor. The dielectric strength is a measure of the voltage that an insulator will withstand before it allows current to flow through it. The dielectric loss refers to the energy that a dielectric material dissipates when a variable voltage is applied. Application of the Kramers–Kronig relationships show the large measured values of permittivity to be related to the power law changes in conductivity and dielectric loss. The power law dispersions in the electrical responses are consistent with an electrical network model of microstructure. It is concluded that the high apparent values of permittivity are features of the microstructural networks and not fundamental effects in the two perovskite materials Poros PZT &PZT +water [10]

2. EXPERIMENTAL:

Crystals were grown by slow controlled cooling of the melt using ACRT (acceleration crucible rotation technique [11].The crystals in suitable dimensions were selected for the impedance measurements. They were polished, ultrasonically cleaned. Later the crystals were electrode using silver paste& dried on the hot plate. The dielectric permittivity was studied using, high resolution Alpha-A broad band dielectric spectrometer (Novo control GmbH, Aubachstr Germany)in the frequency range of 1Hz to 10MHz at 1Vrms.The actual measurement is then made by balancing the impedance of the crystal with a set of references inside the impedance analyser from this permittivity, capacitance, specific resistance &loss can be calculated. It is possible at the same time to apply a DC bias to the crystal, so the signal is now a small ac ripple superimposed on D C voltage**.**

3. RESULT & DISCUSSION:

Table I: Rate of detoriation of capacity per decade frequency

FREQUENCY INTERVAL	RATE OF DETORIATION OF CAPACITY PER DECADE FREQUENCY		
	KN	KND-1	KND-2
10^0-10^1Hz	$8.7X10^{-10}$F/Hz	$1.0X10^{-6}$ F/Hz	$8.9X10^{-9}$F/Hz
10^1-10^2Hz	$2.5X10^{-11}$F/Hz	$3.1X10^{-8}$F/Hz	$9.1X10^{-10}$F/Hz
10^2-10^3Hz	$8.7X10^{-11}$F/Hz	$8.0X10^{-9}$F/Hz	$9.0X10^{-10}$F/Hz
10^3-10^4 Hz	$2.5X10^{-12}$F/Hz	$5.5X10^{-9}$F/Hz	$9.0X10^{-10}$F/Hz
10^4-10^5Hz	$8.3X10^{-12}$F/Hz	$9.4X10^{-9}$F/Hz	---
10^5-10^6Hz	$4.1X10^{-13}$F/Hz	$5.5X10^{-11}$F/Hz	$8.9X10^{-10}$F/Hz
10^6-10^7Hz	$1.1X10^{-12}$F/Hz	$09.1X10^{-11}$F/Hz	

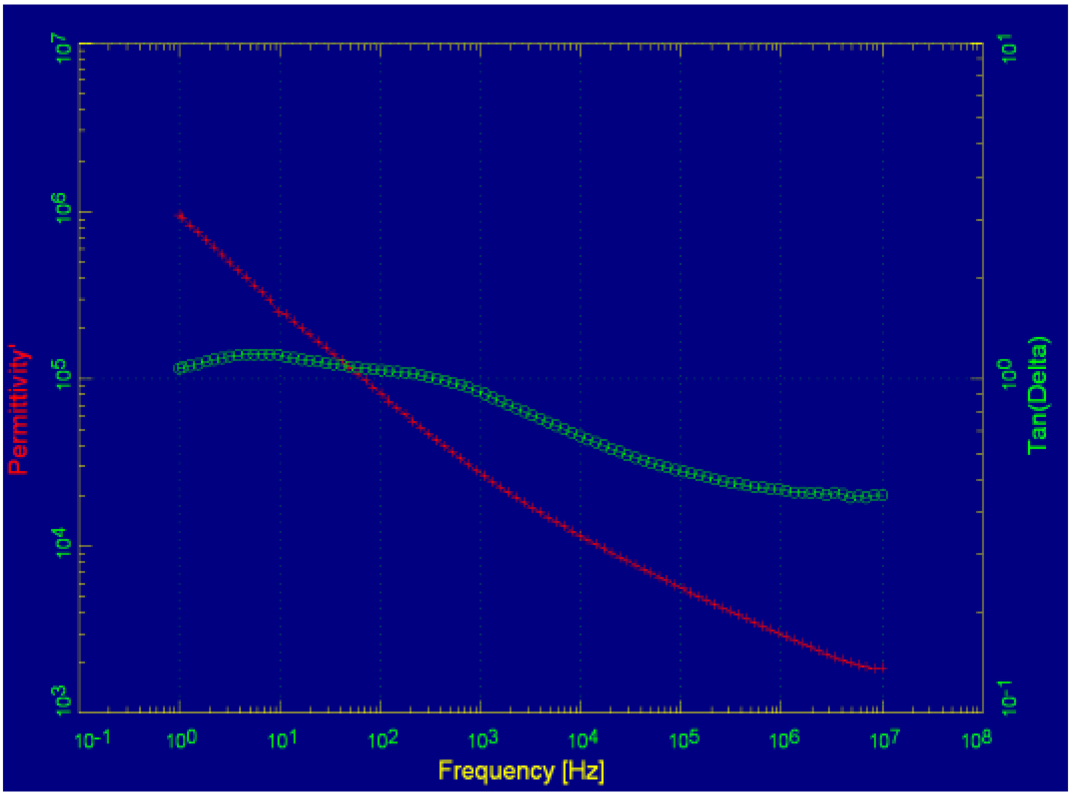

FIG 1 : PERMITTIVITY VS FREQUENCY FOR KN

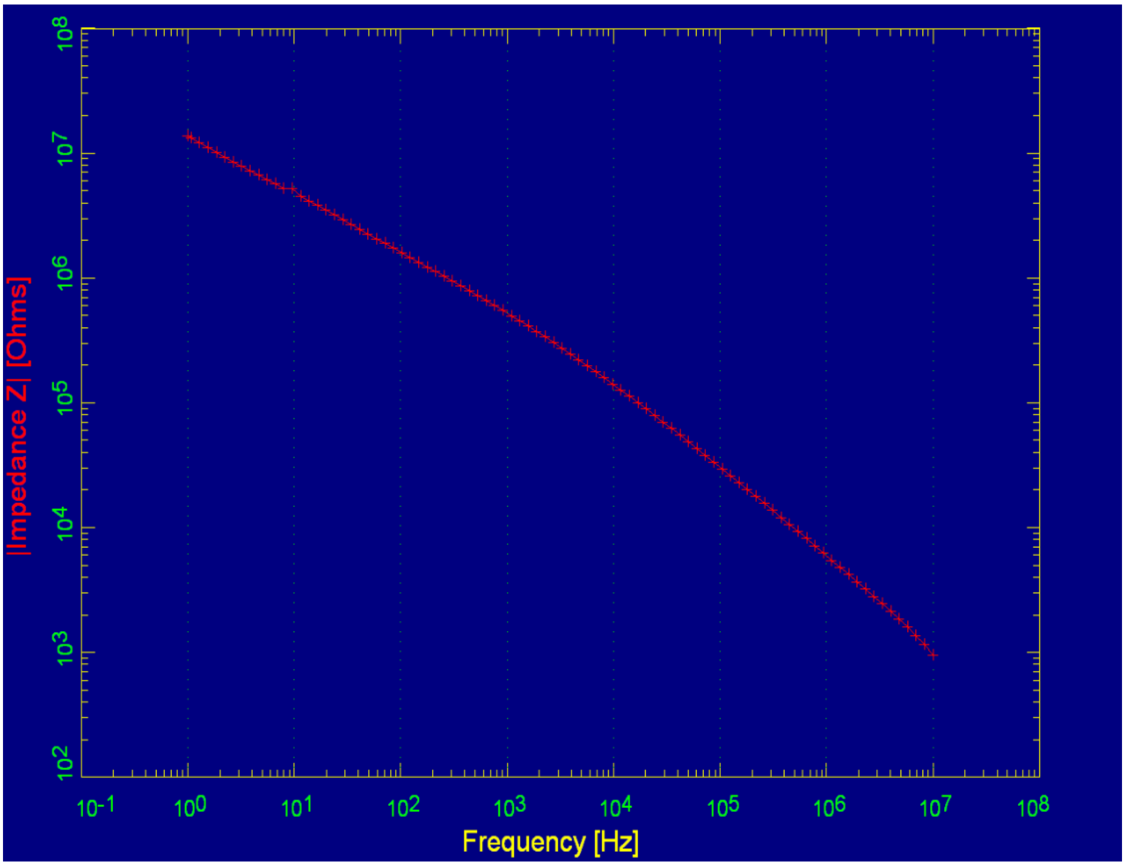

FIG 2 : IMPEDANCE VS FREQUENCY FOR KN

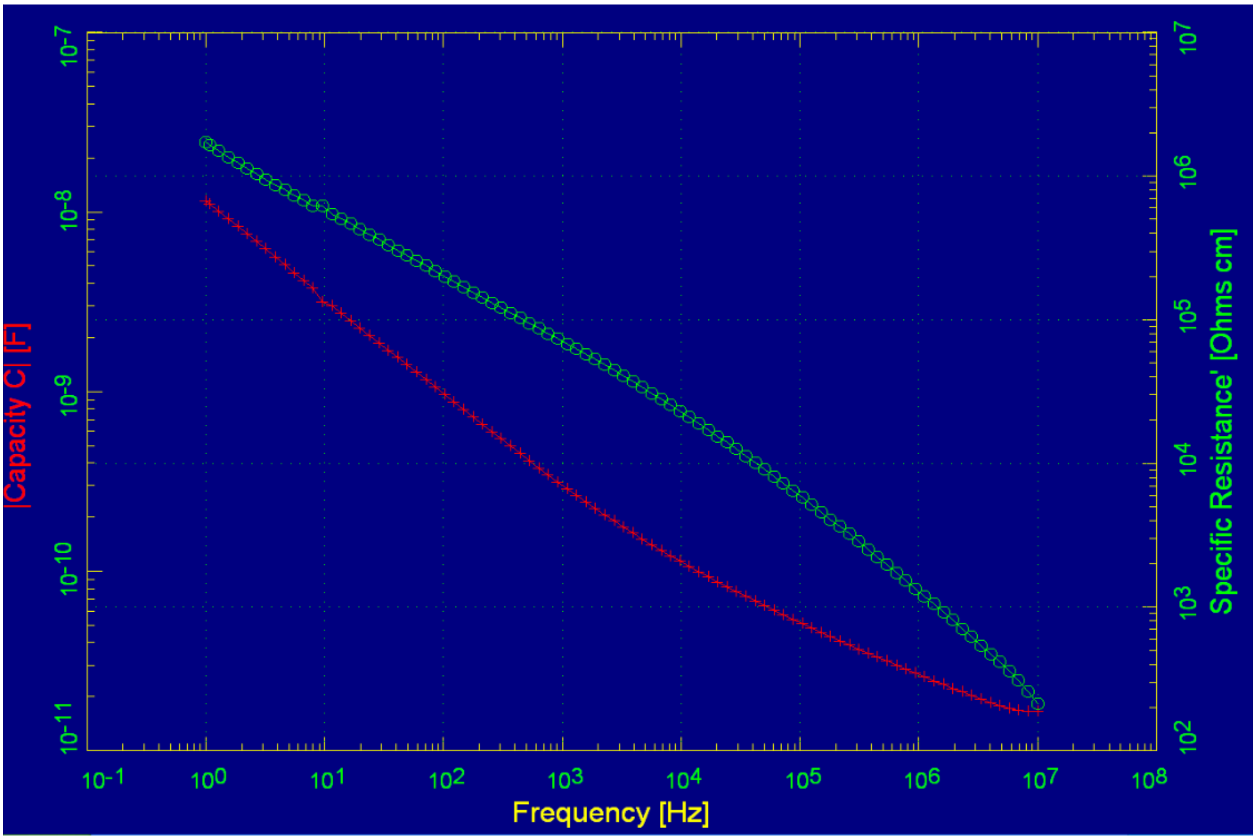

FIG 3 : CAPACITY& SPECIFIC RESISTANCE VS FREQUENCY FOR KN

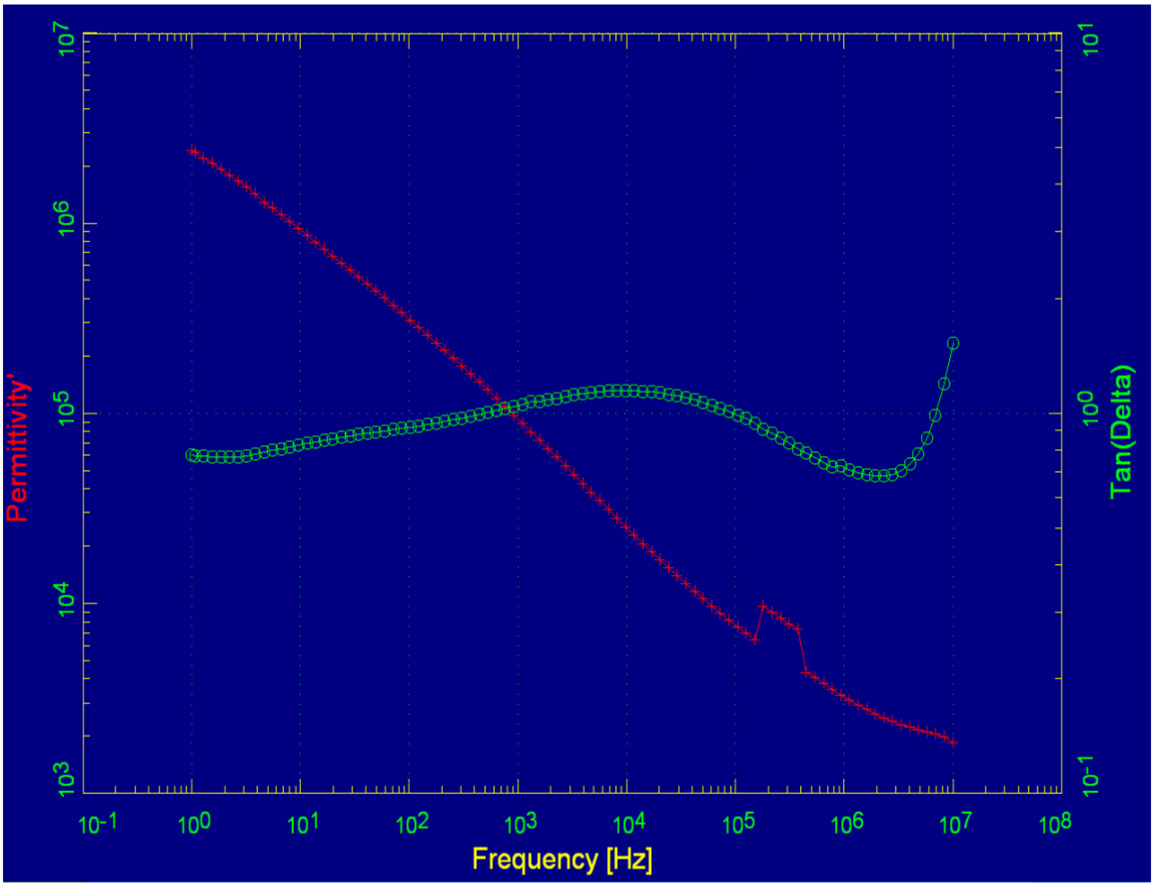

FIG 4 : PERMITTIVITY & TANDELTA VS FREQUENCY FOR KND-1

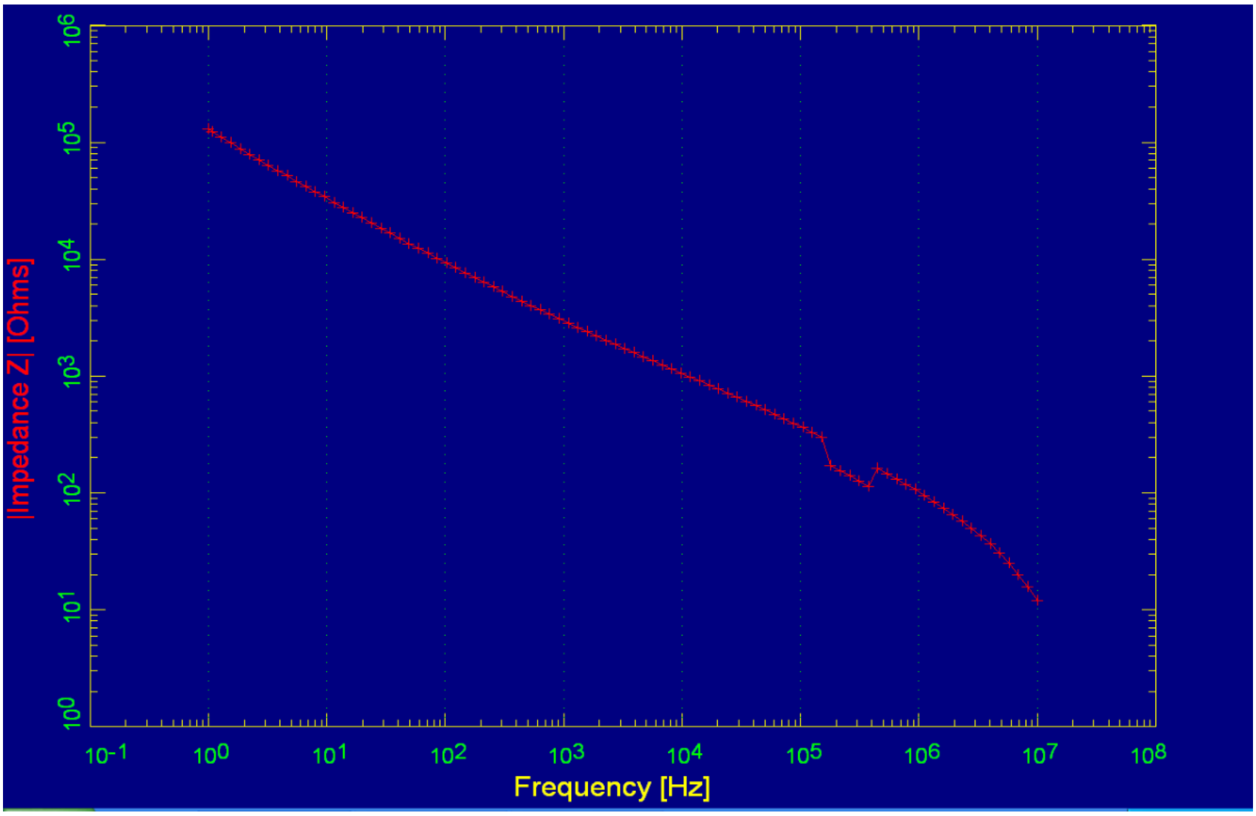

FIG 5 : IMPEDANCE VS FREQUENCY FOR KND-1

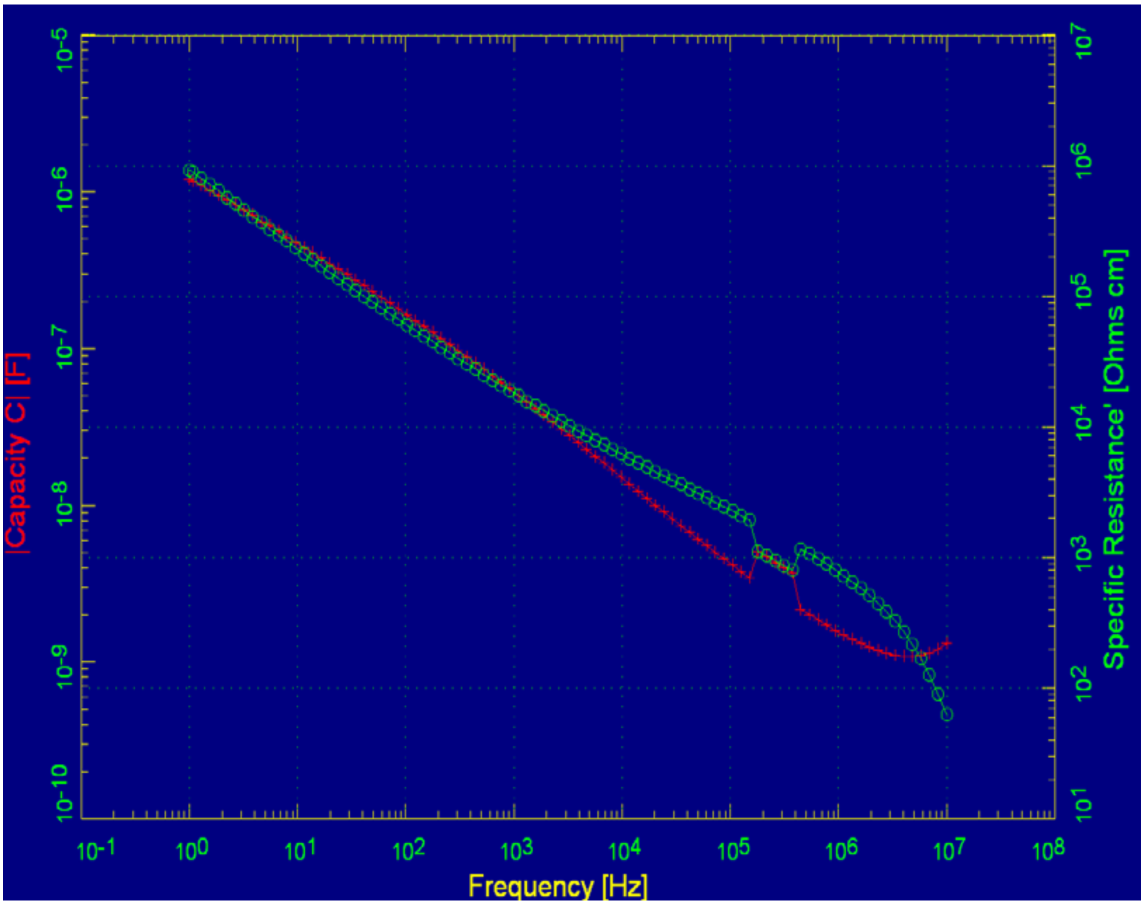

FIG 6 : CAPACITY & SPECIFIC RESISITANCE VS FREQUENCY FOR KND -1

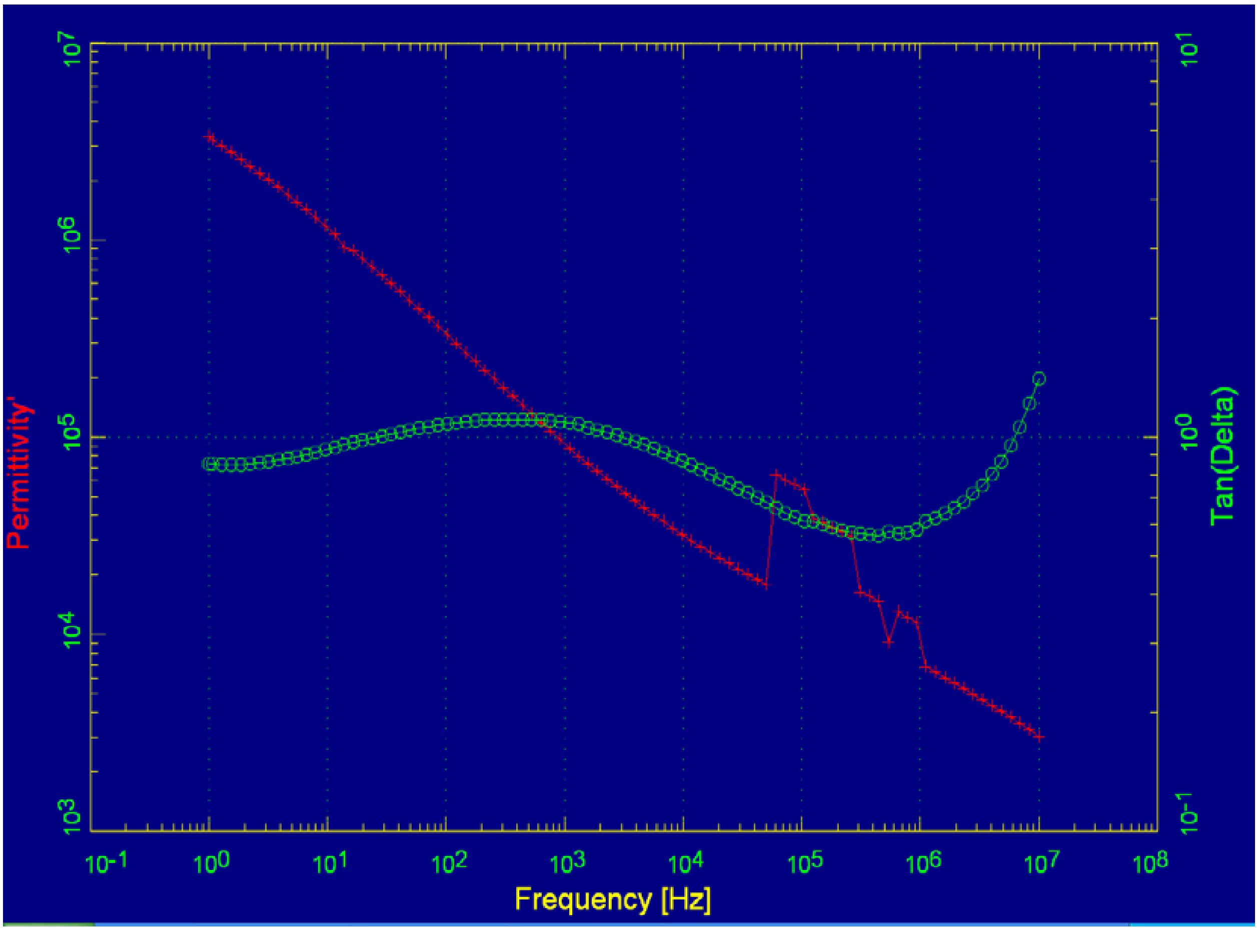

FIG 7 : PERMITTIVITY & TANDELTA VS FREQUENCY FOR KND-2

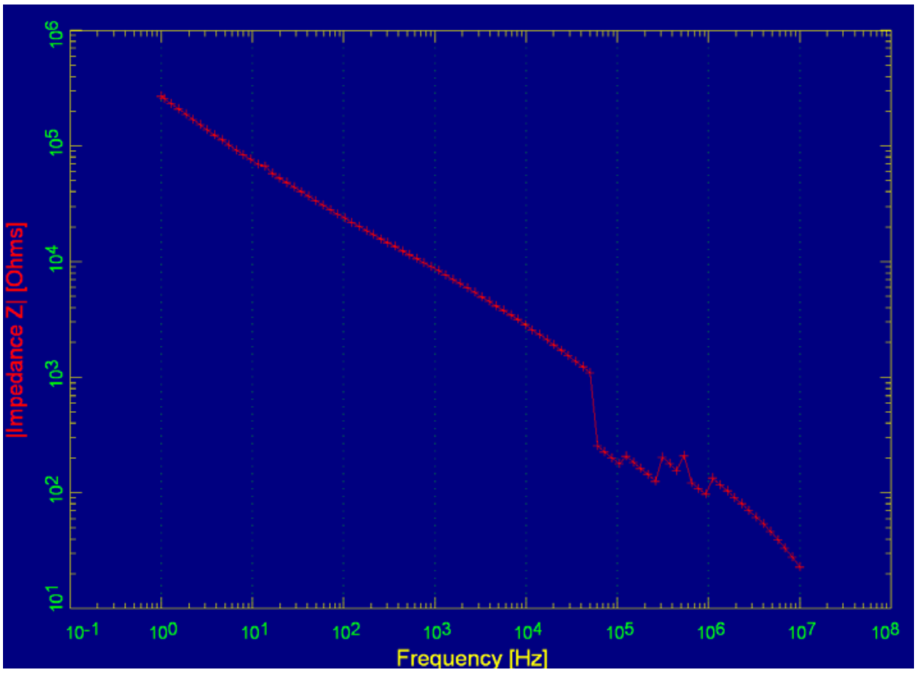

FIG 8 : IMPEDANCE VS FREQUENCY FOR KND-2

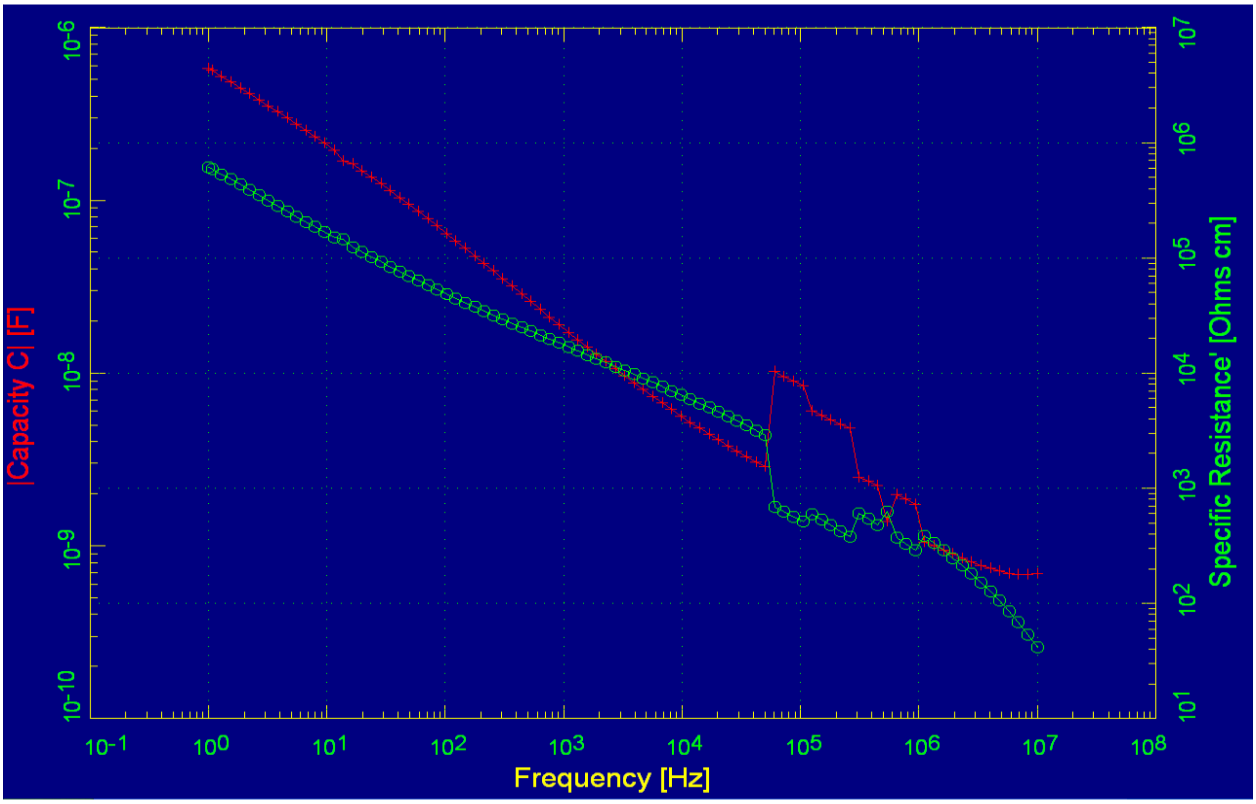

FIG 9 : CAPACITY & SPECIFIC RESISTANCE VS FREQUENCY FOR KND-2

The observed data of impedance against frequency is recorded automatically from 10Hz to 100 MHz at room temperature. The data has been plotted using origin 8 software.

From the Figures of KN, KND-1 and KND-2 . It is seen that due to Sm doping the impedance has reduced by two orders of magnitude. From the relative permittivity & tan δ curve, it is observed that due to Sm doping relative permittivity has increased marginally however tan δ has not changed significantly over the entire range of frequency. Lastly the specific resistance has not changed due to Sm doping for the entire frequency range at room temperature. In our case Sm doping has improved ferroelectric properties of potassium niobate single crystals.

4. CONCLUSIONS:

In this study it is being observed that, Capacitance, Specific resistance, Impedance & permittivity shows a linear decrease relation as a function of frequency almost in the entire frequency range. The high value of capacitance; low loss;rate of detoriation of capacity slowest as well as no increase in specific resistance at room temperature due to Sm doping in potassium niobate crystals suggest the suitability as a dielectric for capacitor worth for resonator or filter applications.

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