CHAPTER I

HISTORY OF FERROELECTRICS
INTRODUCTION :-

Ferroelectric ceramics are widely used in devices for many application such as high frequency pyroelectric sensors, pyroelectric detectors, thermistors and transducer elements. These should have low dielectric constant, low dielectric loss, high pyroelectric coefficient and high Curie temperature. Also over a considerable range of working temperature ceramics with these and other desirable properties can be obtained by suitable modification of known ferroelectrics. Continuous effects in this direction are being made.

Lead titanate has been modified and investigated by a number of investigators [1-5]. These are characterised by high apparent density and small dielectric constant. The dielectric and pyroelectric properties studied by them are found to be good choice for both transverse mode and pyroelectric detector.

It is found that Mn substituted with lead titanate ceramics yield good results for device applications. It is interesting to note that the substitution of B-site cations by divalent, trivalent and pentavalent ions of ABO$_3$ type perovskite compounds yield, a number of complex
compounds, with Curie temperatures, diffuseness and high and low dielectric constant. Because of such behaviour of these complex compounds, some of them are considered to be promising for fabrication of high dielectric capacitors and electrostative transducers elements.

Since the discovery of ferroelectric properties in BaTiO$_3$, a large number of pure or complex oxides having a perovskite structure of ABO$_3$ type have been studied. Pb(Zr$_{1-x}$Ti$_x$)O$_3$ (PZT) perovskite ferroelectric, a solid solution of PbTiO$_3$ (ferroelectric) and PbZrO$_3$ (antiferroelectric), are considered to be attractive piezoelectric materials. In the past, a considerable amount of work has been done to study the effects of various dopands, in varying concentration (X) in A and B-sites of the PZT [6-12] to modify the properties of the materials for different device applications such as non-volatile memory, transducers, phonographic pick-ups etc. Majority of the dopants were isovalent, supervalent and subvalent.

Barium strontium niobate has been studied by Francombe [13]. Jamieseh et al [14] from structural point of view and by Glass [15] as a base for
pyroelectric detection. Jimehez B. [16] studied Br\(_{0.5}\) Sr\(_{0.5}\) Nb\(_2\) O\(_6\) of ceramic with doping Fe\(_2\)O\(_3\) and Fe\(^{3+}\) ions entered in B-site. K.K. Deb [3] shows that \((\text{Pb}_{0.92} \text{La}_{0.06}) (\text{Bi}_{0.02} \text{Ti}_{0.98}) \text{O}_3\) and \((\text{Pb}_{0.74} \text{Ca}_{0.18} \text{La}_{0.06}) (\text{Bi}_{0.02} \text{Ti}_{0.98}) \text{O}_3\) oxide ceramics are useful in I-R sensors and piezoelectric transducer.

K.L. Yadav et al [17] studied on double doping with different alkali ions in Pb site (A-site) percentage of Rb not affected in basic properties of \(\text{Pb}_{0.93}(\text{La}_{1-x}\text{Rb}_x)_{0.07}(\text{Zr}_{0.65}\text{Ti}_{0.35})\text{O}_3\). Some copper containing perovskite \(\text{Ba}(\text{Cu}_{1/3}\text{Ta}_{2/3})\text{O}_3\) and \(\text{Ba}(\text{Cu}_{1/3}\text{Nb}_{2/3})\text{O}_3\) have synthesised by Kapyshnev et al [18], Blasse [19] and Venerstev [20] respectively. Lanthanum doped in \(\text{Ba}(\text{Cu}_{1/3}\text{Ta}_{2/3})\text{O}_3\) Studied by Sambasiva Rao et al [21] and showed resistivity maxima with PTCR behaviour.

Roy Choudhary [22] published an excellent review on PZT ceramics, emphasizing the preparation of PZT composition by ionic substitution, which can mainly be used in piezoelectric and electro-optic devices. Piezoelectric materials provide coupling between electrical and mechanical energy. P.Subramanya Sastry [23] doped strontium in A site
of PZT ceramic which increases dielectric constant and dielectric loss which characterizes the ferro and piezoelectric properties of PZT composition.

Structural disorder upon certain crystallographic sites has long been believed to be responsible for the diffuse phase transition (DPT) in a large group of ferroelectric oxides of complex compositions with structures in the perovskite and tungsten bronze families. The diffuse phase transition is evidenced in many properties associated with the ferroelectric transition, slow change in permittivity and every slow temperature dependence of the spontaneous electric polarization in the realisation range are the examples of the electric characteristics.

It is suggested that crystal exhibiting DPT can be viewed as having composition fluctuation on a microscopic scale and so consisting microvolumes each with a slightly different Curie temperature of the set of ferroelectric polarization [24]. The overall properties result from the distribution of the Curie temperature of these microvolumes.

Expression for dielectric properties have been derived in a statistical treatment by Rolov [25] and Clarke et al [26] have expanded the model to
include a composition dependant parameter. The model of Rolov predicts successfully observed
dielectric properties of ferroelectric relaxors
such as lead magnesium niobate (PMN) and lead zinc
niobate (PZN), but no verification appears yet to
have been given for the direct role of composition
fluctuations. N-Setter [27] studied on
Pb(Sc_{0.5}Ta_{0.5})O_3 and concluded that this complex
perovskite can be ordered on long heat treatment
and also using the annealing.

In solid solutions it has been observed that
as the composition becomes close to that favoring
a homogeneous distribution, the phase transition
sharpness [28,29] and an increase in structural
ordering could explain the observed behaviour but
has not been verified.

Diffuse phase transition from ferroelectric
to paraelectric phases showing a strong broadening
of \(\varepsilon-T\) curve have been reported by numerous
investigators specially in materials having
perovskite (ABO_3) structures with a complex
occupation of the A and/or B-site in the crystal
lattice [30-33].

Relaxor ferroelectrics and other structurally
related compounds are emerging as a technological
important class of materials for use in a wide variety of applications such as multilayer capacitors [34], piezoelectric transducers, electrostrictive actuators, pyroelectric sensors [35,36,37] and microwave resonators [38]. A characteristic feature of these materials is that they contain a compensated mixture of higher (+4) and lower (<4) valence cations on the octahedral B-site sublattice of the perovskite related crystal structure [39,40]. Some examples of relaxor ferroelectrics are Pb(Sc₁/₂Ta₁/₂)O₃, Pb(Mg₁/₃Nb₂/₃)O₃ and Pb(Fe₂/₃W₁/₃)O₃ [41]. The lead based systems are mostly used in high dielectric constant applications such as multilayer capacity. The related barium and strontium compounds have relatively low dielectric constant e.g. 30 for Ba (Mg₁/₃Nb₂/₃)O₃ versus 20,000 of Pb(Mg₁/₂Nb₂/₃)O₃ and more suited for microwave applications.

There are many reports regarding the ferroelectric properties of Pb(Fe₀.₅Nb₀.₅)O₃ and its solid solutions. Recently, the other reported the piezoelectric characteristics of the hot pressed Pb(Fe₀.₅Nb₀.₅)O₃ [42] and Pb(Fe₀.₅Ta₀.₅)O₃ [43] ceramics.
In recent years, dielectric anomalies of oxide ceramics at relatively low frequencies have attracted much attention such as La (Ti,Al)O₃ [44], Ni doped (Ba,Sr)TiO₃ [45], Pb(Yb₀.₅Nb₀.₅)O₃ [46] and (Pb,Sr)(Fe₀.₅Nb₀.₅)O₃ [47].

1.1 INTRODUCTORY REMARK :-

Recently compounds with general chemical formula ABO₃ crystallizing in perovskite structure have attracted wide attention from scientist of the world because of their growing applications as a Ferro-electric, Piezo-electric, pyroelectric etc. Material scientists have tried to prepare the single crystal or polycrystalline compact for getting improved desired properties. The best way of accomplishing this is to get insight into structural property relationship.

Because of industrial utility mixed perovskite and their solid solutions have also been extensively studied by earlier workers. The essential data of such compounds is wide and quite exhaustive. The most important properties of such oxide perovskite are ferro-electricity, ferromagnetism, optical, electrical conductivity, dielectrical constant, melting point, heat of formation, thermal expansion and mechanical
properties. These properties depend upon composition, method of preparation and structure. Hence structure of such compounds will be described at first.

The subject of crystal structure is approached through and based on the concept of the point lattice because the point lattice of a substance is so closely related to its diffraction pattern.

1.2 CRYSTAL STRUCTURE OF PEROVSKITE :-

In ferro-electric, there is important group known as the perovskites from the mineral perovskite CaTiO$_3$. In fact it is itself disordered perovskite structure. The perfect perovskite structure denoted by ABO$_3$ compound where A is monovalent or divalent metal and B-site is a tetravalent or pentavalent. The atomic arrangement in the perovskite structure, with A atoms at the cube corners, B atoms at the body centres and the oxygen at the face centres. This atomic structure was first found in CaTiO$_3$ in which calcium atoms at corner of a cube and Ti atoms at centre and oxygen at centre of the faces. Which is shown in figure 1.1.

The space group of cubic perovskite is Pm$_3$m (221). It has centered cubic structure [48] and
FIGURE 1.1 PEROVAKITE STRUCTURE, ABO$_3$. 
atomic positions with (m3m) as origin.

<table>
<thead>
<tr>
<th>Number of Positions</th>
<th>Wyckoft Notation</th>
<th>Point Symmetry</th>
<th>Co-ordinates</th>
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<tr>
<td>1</td>
<td>a</td>
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<td>0, 0, 0.</td>
</tr>
<tr>
<td>1</td>
<td>b</td>
<td>m3m</td>
<td>1/2, 1/2, 1/2.</td>
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<td>3</td>
<td>c</td>
<td>4/mmm</td>
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Generally, solids are in regular behaviour, known as crystal structure, to study the properties of it. The study of crystal structure is very important in a solid state physics. It can be studied by using X-ray diffraction technique. X-ray diffraction is a tool for the investigation of the internal structure of matter. At first, X-ray diffraction was used only for the determination of crystal structure. Now a days X-ray diffraction is applied not only to structure determination but another method such as chemical analysis, structure measurements to study of phase equilibrium, the measurement of particle size, to the determination of the orientation of one crystal or ensemble of orientation in a polycrystalize aggregate also. It has been found that, very few perovskite type oxides have the simple cubic structure at room
temperature, but many $\text{ABO}_3$ types assume this ideal structure at elevated temperature. Only in perovskite structure the A cation is co-ordinated with twelve oxygen ions and the B cation with six. The A cation is normally, found to be some what larger than the B cation. In order to have contact between A, B and O ions, $R_A + R_B$ should be equal $\sqrt{2}(R_B+R_O)$, where $R_A, R_B$ and $R_O$ are ionic radii. Goldschmidt has shown that the cubic perovskite structure is stable only if a tolerance factor 't' defined by

$$R_A + R_B = t \sqrt{2} (R_B + R_O)$$

has an approximate range of $0.8 < t < 0.9$ and a some what larger range for disordered perovskite structure.

The ternary perovskite type oxides are divided into $A^{+1}B^{5+}O_3$ types and oxygen and cation deficient phases. The oxygen and cation deficient phases may be regarded as those which contain considerable vacancies and not those phases which are only slightly non-stoichiometric. Many of these contain B ions of one element in two valence states.

The complex perovskite type compounds containing two types of B ions such as $A (B'_z B''_y)O_3$
FIGURE 1.2 THE $(\text{NH}_4)_3 \text{FeF}_6$ STRUCTURE: CUBIC ORDERED PEROVSKITE-TYPE $A(B'_0.5B''_0.5)O_3$. 
be divided into three groups.

(01) One with thrice as much lower valence state element as higher valence state element, A (B_{0.67}B_{0.33}) O_3.

(02) Those which contain twice as much of the higher valence state element A (B_{0.33}B_{0.67}) O_3 and

(03) Those which contain the two B element in equal amount A(B_{0.5}B_{0.5}) O_3 (Figure 1.2) and also oxygen deficient phase A(B_xB_y)O_{3-x}. Due to ferroelectric properties of the oxides A^{1+}B^{5+}O_3 type have a great importance. e.g. potassium niobate (KNaO_3) or the rhombic with unit cell a = 3.974 0Å, b = 5.6946 0Å and c = 5.7203 0Å. Where b and c are equal approximately \sqrt{2} a or the length of face diagonals of the simple perovskite cell. The sodium niobate (NaNaO_3) structure also can be described by an orthorhombic unit cell but it is antiferroelectric. The unit cell is pseudo-tetragonal at 420°C, tetragonal at 560°C and cubic at 640°C unlike the structure of niobate. The KTaO_3 is orthorhombic structure has cubic unit cell. The structure of NaTaO_3 is orthorhombic with the space group P_{cnm} and all the atoms are placed in the unit cell in position [49].

Smith and Welch [50] found that potassium
iobate KIO$_3$ and thallous iobate TlIO$_3$, also adopt the perovskite structure. The large number of perovskite type compounds are described by the general formula A$^{2+}$B$^{4+}$O$_3$ where the A cations are alkaline earth ions cadmium or lead and the B$^{4+}$ ions include Ce, Fe, Pu, Sr, In, Th, Hf, Ti, Zr, No and U. The strontium titanate is cubic. The space group is P$m_3m$ and its atoms are in following positions in the unit cells.

A$^+$ Sr

B - Ti : 1/2 1/2 1/2.

O - O : 1/2, 1/2, 1/2 ; 1/2, 0, 1/2 ; 0, 1/2, 1/2.

Barium titanate and Lead titanate are of more interest because the atomic displacements in their structure produce ferroelectric properties. Neutron diffraction studies show that the displacements are greater in lead titanate than they are in barium titanate. For barium titanate, the atoms in the unit cell are in the following positions.

Ba: 0 0 0

Ti: 1/2, 1/2, 0.512

O : 1/2, 1/2, 0.023; 1/2, 0, 0.486; 0, 1/2, 0.486.

The large number of A$^{3+}$B$^{3+}$O$_3$ type compounds were found by Geller and Wood [51] to have an orthorhombic structure (Fig.1.3) similar to that of
GdFeO$_3$. The space group for those compounds are P$_{bmn}$. The classification of these compounds are based upon their ionic radii. In these compounds A and B ions are small, the compounds have the corundum or ilmenite type structure. When A and B ions are large the phases from La$_2$O$_3$ type structures while none of the A$^{3+}$B$^{3+}$O$_3$ type compounds have the 'ideal' cubic pervoskite structure the rhombohedral pervoskites, such as, LaAlO$_3$ are only slightly disordered. The well known non-stoichiometric ternary oxides are the tungston bronzes. The phases Na$_x$WO$_3$ have been found to have the cubic pervoskite structure in the range $0.3 < x < 0.956$ and the phases Li$_x$WO$_3$ in the range $0.35 < x < 0.57$ [52]. The lattice constants of these materials vary linearly with increasing amounts of alkali metal ions. A smaller range of non-stoichiometry exists in the strontium niobium bronzes [53]. Where the alkaline earth metal ion mole fraction can vary from 0.7 to 0.9 and in La$_x$VO$_3$ where $0.66 < x < 1$.

Rooksby et al [54] reported the preparation of a group of pervoskite type rare earth niobates and tantalates. The structure of these A$_{0.33}$BO$_3$ type compounds was tetragonal, orthorhombic or
monoclinic.

The structure of compounds $\text{A}^{2+}(\text{B}^{3+}0.67\text{B}^{6+}0.33)\text{O}_3$ type contains twice as many $\text{B}^{3+}$ ions as $\text{B}^{6+}$ ions are not well established. Fresia et al [55], who prepared one of the first compounds of this type $\text{Ba(Sc}_{0.67}\text{W}_{0.33})\text{O}_3$ felt that it probably had an ordered perovskite structure.

The two different B ions alternate at the corners of the simple cubic unit cell of the perovskite structure so that the cell edge has to be doubled. The space group is $\text{F}_{m3m}$. Roy [56] studied the compound $\text{Ba(Sr}_{0.33}\text{Ta}_{0.67})\text{O}_3$ had a new ordered perovskite structure, based on space group $\text{P}_{3m1}$.

If the perovskite structure is described as close-packed layers of A and oxygen ions perpendicular to (1,1,1) direction with the small B-ions in the the octahedral holes between the layers than the B ions Sr and Ta, each forms planes of atoms. These planes are parallel to the close packed layers and since there are twice as many tantalum ions, strontium ions, the repeat scheme is two layers of tantalum ions and a one of strontium ions. It is interesting that the ordered structure of $\text{A(B}^{'0.5}\text{B}'^{'0.5})\text{O}_3$ type compounds when
observed in the same way in the [1,1,1] direction, consists of alternating layers one of which contains B' ions and other B'' ions.

A study of Ba(B^{2+}0.33Ta^{5+}0.67)O_{3} compounds showed a decrease in the ordering as the difference in the size of B^{2+} and B^{5+} ions become smaller [57]. The results were confirmed in a latter investigation of Ba(B^{2+}0.33Ta^{5+}0.67)O_{3} compounds [58]. In some cases the ordering lines in the X-ray patterns were annealed at high temperatures. This observation was attributed to the existence of small ordering domains which grew at higher temperatures. Thus the X-ray patterns of some of the compounds which might be expected to be ordered because of the large size difference of the B' and B'' ions did not show the ordering linear if they could not be annealed at high temperatures because of low melting points. The largest group of complex perovskite type compounds has the general formula A(B'_{0.5}B''_{0.5})O_{3}. When the structure of these compounds is ordered and most of them are, they adopt the structure shown in Figure 1.3. It was postulated by Galasso et al [59] that an ordered distribution of the B ions is most probable when a large difference existed in either their charges or
ionic radii. A study of $\text{Ba}(\text{M}^{3+}_{0.5} \text{Nb}^{5+}_{0.5})_3$[60] type compounds indicated that the critical percentage difference in ionic radii between B ions which cause ordering lies between 7% to 17%.

The first compounds with this ordered structure were reported by Roosky[54] who found that a number of alkaline earth tungstates and molybdates of the $\text{A}(\text{A}_{0.5}\text{B}_{0.5})_3$ type where A is an alkaline earth ion and B is Mo, Cr, W have this structure. The structures of $\text{Ba}(\text{Ca}_{0.5}\text{W}_{0.5})_3$ and $\text{Ba}(\text{Ca}_{0.5}\text{Mo}_{0.5})_3$ were reported to be cubic at room temperature. While $\text{Ba}(\text{Sr}_{0.5}\text{W}_{0.5})_3$ structure was distorted and becomes cubic only after heating to $500^0\text{C}$. Fresia et al [55] found that other ions such as $\text{Zn}^{2+}$, $\text{Fe}^{2+}$, $\text{Co}^{2+}$ and $\text{Ni}^{2+}$ could be used as B ion in the ordered perovskite structure without distortion. However, when compounds were prepared with strontium in the A position. The structures where distorted Sleight and Ward [61] in a study of $\text{A}(\text{B}^{2+}_{0.5}\text{U}_{0.5})_3$ type perovskite also found that all of the compounds containing strontium in the position had distorted structures. The unit cell were pseudomonoclinic but powder patterns were indexed on a smaller orthorhombic unit cell.

The compound $\text{Ba}(\text{Na}_{0.25}\text{Ta}_{0.75})_3$ and
Sr(\(\text{Na}_{0.25}\text{Ta}_{0.75}\))O\(_3\) would be ordered because of the large charge difference in the B ions. But no superstructure lines were observed in the X-ray patterns of these two compounds [62].

1.3 FERROELECTRIC PROPERTIES OF PEROVSKITE:

Extensive investigations were carried out particularly on titanates by Von Hipple et al [63]. The war time investigations showed that barium titanates exhibits a ferroelectric behaviour. A ferroelectric has been defined as a dielectric with reversible spontaneous polarization. Therefore it is obvious that the structure must be polar with lack of center of symmetry. In changing the direction of the polar axis the structure must pass through an intermediate non polar stage, and the polar structure is a distortion of this more symmetrical form. The structure of ferroelectric materials becomes less distorted as the temperature increases and undistorted at and above a temperature called Curie temperature point. Some of that titanates, niobates, zirconates, tantalates and their solid solutions have been widely investigated. As the data is large and scattered it is not possible and essential to have recourse of it for complete understanding for new
compounds. However some elementary ideas may be discussed in nutshell. The most important and widely investigated compound is BaTiO$_3$ due to its important ferroelectric properties. The compound is cubic above Curie point and teragonal for the temperature below Curie point and is orthorhombic at about 0°C and becomes tetragonal again at -90°C. In short barium titanates has four different types of symmetry between different temperature ranges. The changes in dielectric constant with respect to temperature are shown in figure 1.4. High dielectric constant of the compound makes it useful in an energy convertor and capacitor applications. The high dielectric constant has been further increased by certain metal additives, barium titanates, lead titanates are also ferroelectric with a tetragonal distortion of perovskite structure. Strontium titanates is cubic perovskite and is not ferroelectric at room temperature though it has quite high dielectric constant. There are some conflicting reports on the possibility of being ferroelectric at lower temperature calcium titanates is orthorhombic at room temperature. Then barium and lead titanates are ferroelectric while the calcium strontium
FIGURE 1.4
titanates are not ferroelectric at room temperature, like titanates, niobates are also ferroelectric. Potassium niobates transformed from rhombohedral to orthorhombic at \(-12^\circ C\), orthorhombic to triagonal at \(22^\circ C\) and tetragonal to cubic at \(412^\circ C\). The loss tangent at transition is ten times much than \(\text{BaTiO}_3\). Sodium niobate is not ferroelectric but an antiferroelectric, it has also several transformations at \(20^\circ C\), \(390^\circ C\), \(420^\circ C\), \(560^\circ C\) and \(640^\circ C\). Similarly tantalate, zirconate, hafnates, exhibit similar trend of behaviour. The solid solution of the perovskite have also been studied for different concentration, composition, temperature ranges.

1.4 APPLICATION OF PEROVSKITE COMPOUNDS:

Perovskite compounds have wide applications [64,65] in electronic. Due to self adjusting capacities with temperature of the material, it is used as a dielectric amplifier, varactor, thermistors, the high dielectric constants and ferroelectric behaviour of perovskite type compounds are probably the most important properties which they exhibit.

The dielectric constant of barium titanate can be raised by the addition of strontium
titanate at room temperature. It lowers the Curie temperature to date most of these ceramic capacitors have been used at low voltage as a bypass capacitors. The hysteresis loop of ferroelectric compounds make them of potential use for information storage in electronic computers.

The international telephone and telegraph corporation recently reported a new use for ferroelectric for producing high voltage ac or dc power was based on the fact that the dielectric constant of a ferroelectric is sensitive to temperature at the Curie point. The capacitor is held at the Curie point and then heated, lowering the dielectric constants since the charge can not decrease because of a diode in the circuit, there must be a rise in capacitor voltage. This scheme has been proposed for use in a space vehicle which spins so it alternately faces towards and away from the sun.

1.5 AIM OF THE PRESENT WORK :-

Ferroelectricity is one of the interdisciplinary fields of research which needs to be tackled in physical science, engineering and technology. Although ferroelectric have been extensively studied in theory and in experiment,
during the last six decade owing to their important device application, they continue to arouse interest among the research workers. Specially because they hold promise in diverse new areas of technology and their understanding is not yet complete. The scope of ferroelectrics is even further broadened in view of the significance of the related phenomena such as ferroelectricity, magnetoelectricity, electro-optics, non linear dielectric and liquid crystals.

Hippel and many workers have studied perovskite compounds in much details still there are some perovskite left unnoticed. The detailed study of perovskite compounds is therefore needed for understanding their behaviour. Most of the workers had studied perovskite compounds from different aspects.

A survey of literature shows that B site substituted perovskite were not studied in much detail. Titanates and niobate with $\text{ABO}_3$ formula have perovskite structure of which barium titantes and strontium titanates have been widely studied due to their interesting industrial properties. Similarly, potassium and sodium niobates find much scope in the industry, with this view in mind some
workers have tried to combine barium and niobium oxides along with other oxides and in some cases they were successful.

On the parallel lines we thought to prepare barium and strontium pervoskites, containing niobium along with iron in B cations of lower valency for charge compensation. In this entire study the other types of ions chosen are trivalent and therefore, their percentage is same as that of pentavalent niobium making the average charge on the B-site as four.

The study of non-linear dielectric has been subjected to considerable interest in modern physics. Their wide range of practical application in ceramic and engineering industry and the recent development in quantum electronic have stimulated the investigation of the materials which have high non linear properties in the optical range.

In the past a considerable amount of work has been done to study the effects of various dopants in varying concentration (x) in A site and B site of the PZT to modify the properties of the materials for different device applications. Majority of the dopants were isovalents, supervalents and subvalent. But little work is done
with Ba and Sr containing Nb perovskite. Therefore we have taken the \((Ba_xSr_{1-x})(Fe_{0.5}Nb_{0.5})O_3\) compound for study where \(X = 1, 0.8, 0.6, 0.5, 0.2\). In recent years ferroelectric ceramic materials have become important as substitutes for single crystals in various device applications because their low cost and easy of fabrication. This ceramic specimen is easily compared with others.

Resistivity of Ba \((Fe_{0.5}Nb_{0.5})O_3\) is less as compared to PZT and BaTiO\(_3\) ferroelectrics. The Fe is known to be present as di and trivalent ions simultaneously in oxide ceramics.
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