STUDY OF RARE EARTH DOPED BNT CERAMIC

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Abstract

We provide an overview of lead-free ferroelectric materials in this paper.Materials with ferroelectric properties exist. Ferro electricity is the ability of a substance to exhibit spontaneous electric polarisation. However, due to their high strain property, $Bi_{0.5}Na_{0.5}Tio_3$(BNT) ceramics are among the most promising lead-free ferroelectrics. Possibility of doping rare earth ions to improve the strain propertyof BNT-based ceramics. Because more than 90% of lead-based ceramics, which typically contain more than 60% of dangerous lead, cause health and environmental issues, lead-free materials have drawn a lot of interest from academics who are concerned about the environment. For BNT-based ceramics, rare earth ions ($La^{3+,}$ $Sm^{3+,}$ $Yb^{3+,}$ $Dy^{3+,}$ $Nd^{3+,}$ $Gd^{3+,}$ and $Pr^{3+)}$ are chosen as doping ions because of their effect on strain enhancement. Due to their versatility and photoluminescence, rare earth doped materials have drawn a lot of interest.

Keywords *BNT-based ceramics, rare earth doping, leadfree, ferroelectric properties*

1.Introduction

The discovery of the ferroelectric phenomena as the cause of the exceptionally high dielectric constant in ceramic barium titanate capacitors in the 1940s gave rise to the field of ferroelectric ceramics. In 1920, Joseph Valasek discovered Ferro electricity in Rochelle salt[1]. Thus, despite the fact that the majority of ferroelectric materials don't include iron, the prefix Ferro, which means iron, was chosen to define the attribute. When a material is electrically polarised, the induced polarisation, P is roughly inversely proportional to the external electric field E that is being applied; Polarisation is a linear function as a result. Linear dielectric polarisation is the term for this. Some substances, referred to as Para electric substances[2] have a more pronounced nonlinear polarisation. The slope of the polarisation curve, which corresponds to the electric permittivity, is a function of the external electric field rather than being constant, as it is with linear dielectrics.Ferroelectric materials exhibit a spontaneous nonzero polarisation in addition to being nonlinear. This is true even when the applied field E is zero. Ferroelectrics are distinguished by the ability of the spontaneous polarisation to be reversed by an appropriately strong applied electric field in the opposite direction. As a result, the polarisation is reliant on both the current electric field and its history, producing a hysteresis loop[3]. They're referred to as ferroelectricsOnly below a particular temperature, known as the Curie temperature (T_C), do materials exhibit Ferro electricity, and above this temperature, spontaneous polarisation disappears and the ferroelectric crystal changes into the Para electric state. Because their Para electric phase possesses a Centro symmetric crystal structure, many ferroelectrics entirely lose their pyro electric characteristics above T_C[4]. Ferroelectric capacitors are utilised to create ferroelectric RAM for computers and RFID cards because the spontaneous function,the hysteresis curve are shown in figure 1. Thin films of ferroelectric materials are frequently utilised in these applications because they enable the field necessary to alter the polarisation to be achieved at a moderate voltage. However, for devices to function consistently when using thin films, a lot of care needs to be paid to the interfaces, electrodes, and sample quality[5].Innovative developments in expansion to advanced living conditions have upgraded admissions of critical amounts of harmful components in to the human body driving to wellbeing issues. Defilement of the environment by distinctive sorts of poisonous inorganic, natural, and organometallic species is one of the foremost genuine issues within the world today. The rare earth gather represents important components found within the environment and got to be considered at more noteworthy profundity to get it their impacts on human wellbeing ,it is shown in figure 3&4.

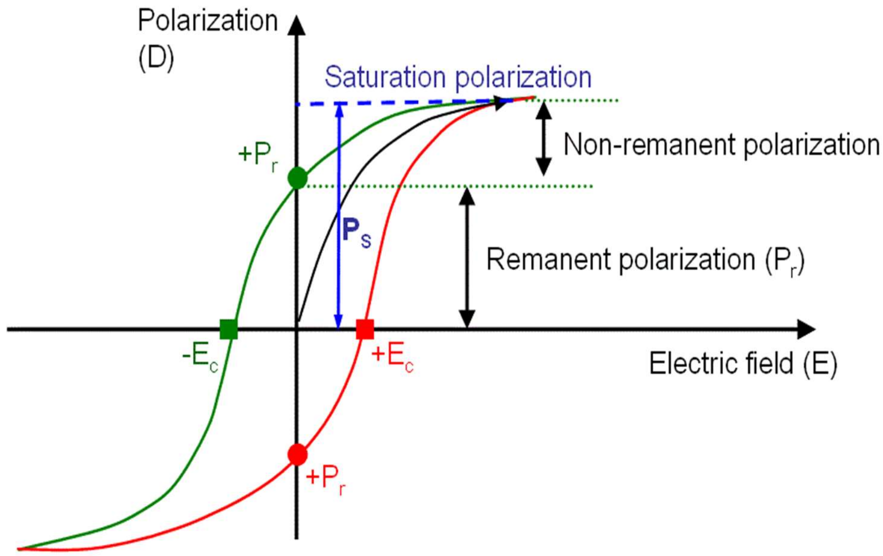


Figure 1 hysteresis curve

Table-1 A summary of the properties of ferroelectric materials

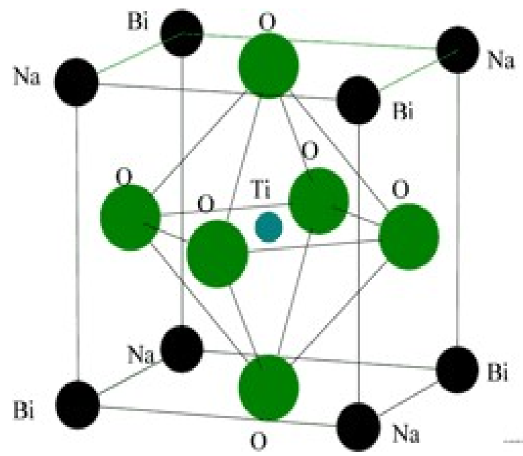
Compound	Chemical formula	Year discovered	Curie temperature Tc(K)	Remanent polarization Ps(μK.cm^2)
Rochelle salt	$KNaC_4H_4O_6.4H_2O$	1921	255and 297	0.25
Potassium dihydrogen phosphate	KH_2PO_4	1935	123	6.1

Lithium niobate	$LiNbO_3$	1949	1,415	10-30
Potassium niobate	$KNbO_3$	1949	400	20-40
Lead zirconate	$PbZrO_3$	1951	503	20-50
Lead titanate	$PbTiO_3$	1950	763	20-96.5
Guanidine aluminium sulphite hexahydrate	$C(NH_2)_3Al(SO_4)_2.6H_2O$	1955	473	0.5
Bismute titanate	$Bi_4Ti_3O_{12}$	1961	953	10-30
Lead bismute niobate	$PbBi_2Nb_2O_9$	1959	833	~3
Barium strontium titanate	$Ba_{0.73}Sr_{0.27}TiO_3$	1960	298	10-30
Strontium bismute tantalate	$SrBi_2Ta2O_9$	1960	600	30-70

By virtue of symmetry considerations, ferroelectric materials must also be piezoelectric and pyro electric. Ferroelectric capacitors are highly helpful, for example, in sensor applications, due to the combination of memory, piezoelectricity, and pyro electricity [6]. Ferroelectric capacitors are used in a variety of devices, including high-quality infrared cameras that can detect temperature differences as small as millionths of a degree Celsius, medical ultrasound machines that generate and then listen for ultrasound pings used to image the internal organs of a body, fire sensors, sonar, vibration sensors, and even fuel injectors on diesel engines.Another concept that has gained attention recently is the ferroelectric tunnel junction (FTJ), in which a contact is created by sandwiching a ferroelectric film only a few nanometres thick between two metal electrodes. The ferroelectric layer's thickness is sufficiently thin to permit electron tunnelling. A giant electro resistance (GER) switching effect may result from the piezoelectric and interfacial effects, the depolarization field, and other factors. Since 1952, when Parravano discovered anomalies in the CO oxidation rates over ferroelectric sodium and potassium niobates close to these materials' Curie temperatures, ferroelectrics have been researched for their catalytic capabilities.Ferroelectric phase transitions are frequently classified as either displacive (such as in the case of $BaTiO_3$) or order-disorder (such as in the case of $NaNO_2$), though frequently phase transitions will demonstrate elements of both behaviours. The surface-perpendicular component of the

The transition in barium titanate, a typical displacive ferroelectric, can be explained in terms of a polarisation catastrophe, in which the force from the local electric fields caused by the ions in the crystal increases faster than the elastic-restoring forces if an ion is slightly displaced from equilibrium. As a result, the equilibrium ion locations shift asymmetrically, and a permanent dipole moment results. The relative position of the titanium ion within the oxygen octahedral cage is the subject of the ionic displacement in barium titanate. Despite having a structure that is somewhat similar to that of barium titanate, lead titanate, another prominent ferroelectric material, has a more complicated mechanism for Ferro electricity, with interactions between lead and oxygen ions playing a significant role. Each unit cell in an order-disorder ferroelectric has a dipole moment, but at high temperatures, the direction of the dipoles is random. The dipoles inside a domain order, all pointing in the same direction, as a result of the phase transition and temperature reduction[8].Lead zirconate titanate (PZT), a component of the solid solution generated between ferroelectric lead titanate and anti-ferroelectric lead zirconate, is a crucial ferroelectric material for applications. PZT with a composition closer to lead titanate is preferred for memory applications, whereas piezoelectric applications use the diverging piezoelectric coefficients linked to the morphotropic phase boundary that is found close to the 50/50 composition.Similar to ferromagnetic crystals, ferroelectric crystals frequently exhibit multiple transition temperatures and domain structural hysteresis. It is still unclear what causes the phase transition in some ferroelectric crystals[9].Ferroelectric liquid crystals were predicted by R.B. Meyer using symmetry considerations in 1974[10], and the prediction was quickly confirmed by a number of observations of ferroelectric behaviour in chiral and tilted smectic liquid crystal phases. The development of flat-screen monitors is made possible by technology. Canon carried out mass production between 1994 and 1999. Reflective LCoS (Liquid crystal on silicon) is produced using ferroelectric liquid crystals.In 2010, David Field discovered that common chemical films, like those made of propane or nitrous oxide, had ferroelectric characteristics. In addition to having potential uses in electronics and nanotechnology, this novel family of ferroelectric materials exhibits "spontelectric" features that may have an impact on the electrical makeup of interstellar dust.Triglycine sulphate, polyvinylidene fluoride (PVDF), and ultimotantalate are further ferroelectric materials that are utilised.[11] Pure bismuth can be used to make a ferroelectric monolayer that is just one atom thick. [12]At room temperature, it should be able to create materials with simultaneous ferroelectric and metallic characteristics.[13] Researchers were able to create a "two-dimensional" sheet of shown in figure 2, according to research that was published in Nature Communications in 2018[14].

Medicinal ultra-sonic composites are one of the more recent developments in the field of ferroelectric ceramics.Thin and thick films, photo restrictors etc.Ferroelectric materials are classified as dielectricmaterials whose polarisation persists even when the applied electric field is removed.Example: Rochelle salt,



$BaTio_3$[15]. Certain non-conducting crystals or dielectrics with Ferro electricity exhibit spontaneous electric polarisation.As the shift is made from a passive to an electrically active "smart" and very smart material, ferroelectric ceramics are already bright and continue to get even brighter.Smolenski et al. published the initial study on BNT in 1960. Due to their strong strain properties, $Bi_{0.5}Na_{0.5}Tio_3$(BNT) ceramics are among the most promising lead free ferroelectrics[16]. BNT lead-free ceramics have a high curie temperature (Tc=320°C) and a good ferroelectric constant, however the high temperatures (1200°C) required to produce dense BNT-based ceramics make production less efficient and more difficult.Significant loss of bismuth occurs at 1200°C.Ceramics made from BNT have a rhombic structure, polarisation of 38μc/cm^2, and depolarization temperature of 200°C[17].

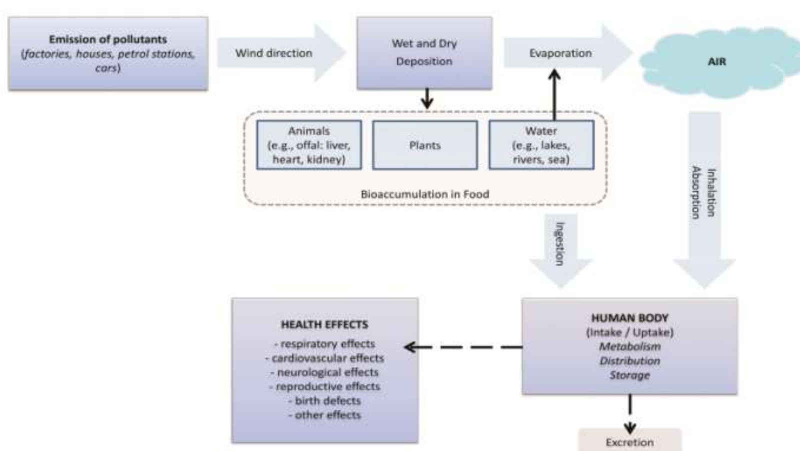


Figure 3 effect of rare earth on human body

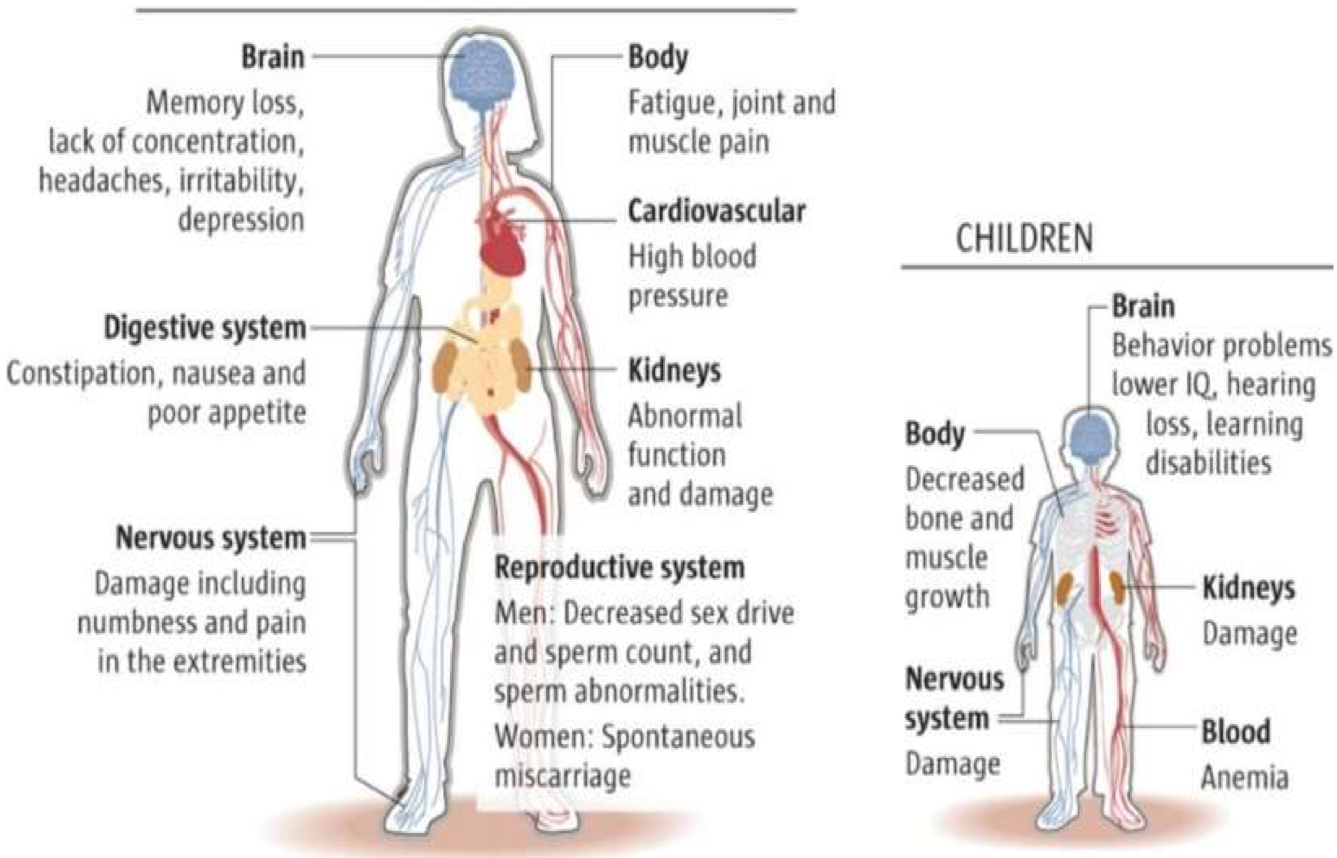


Figure 4 effect of rare earth elements on human body

According to reports, BNT-based lead-free crystals have excellent electric properties, a wide band gap, and a high near-visible light absorption coefficient[18].Pure BNT ceramics display several issues like strong conductivity and a significant cohesive field, which frequently cause issues during the poling process.BNT-based ceramics, however, also show considerable promise in the fields of energy storage and energy conservation due to their high Ferro electricity.Transducers, capacitors, electro-acoustic transformers, signal processing devices, etc. are only a few examples of the diverse applications for BNT[19].The relaxer ferroelectrics with the common formula ABO3 are revealed by the dielectric research of BNT[20].There are 17 members of the rare earth element family that is shown in figure 5, including 15 lanthanides that exhibit rare earth doping in ferroelectric materials.Rare earth ions have exceptional optical, electrical, magnetic, and nuclear properties and contain rich structures and energy levels.Studies reveal that solid solution, sol gel methods, or doping solutions with large dielectric losses and high sintering temperatures, such 1200°C, can considerably improve the overall characteristics of the BNT system.This finding suggests that the addition of rare earth ions can boost electrostatic coefficient, particularly at the ergodic relaxation state, and optimise strain properties by creating non-ergodic relaxation stages[21].

Number		
21	Scandium**	Sc
39	Yttrium	Y
57	Lanthanum	La
58	Cerium	Ce
59	Praseodymium	Pr
60	Neodymium	Nd
61	Promethium*	Pm
62	Samarium	Sm
63	Europium	Eu
64	Gadolinium	Gd
65	Terbium	Tb
66	Dysprosium	Dy
67	Holmium	Ho
68	Erbium	Er
69	Thulium	Tm
70	Ytterbium	Yb
71	Lutetium	Lu

Figure 5 Rare earth elements

2. RESULTS AND DISCUSSION

2.1 Gd^{3+}doped BNT

BNT with added Gd content showed a shift of the peak towards greater angle indicating decreasing the peroveskite unit cell lattice parameter[22].The information of a smaller ionic radius of Gd^{3+} as compare to Na^{+} and Bi^{3+} may be the reason for the shifting of the peak position in XRD spectrum.$(Bi_{1-x}Gd_x)_{0.5}Na_{0.5}Tio_3$System was found to decrease with increasing Gdconcentration due to lasser radii Gd^{3+}(0.938Å)as compared to Bi(1.03Å).Raman spectra of pure BNT and Gd doped BNT ceramics for composition formed in the range from 100 to 1000cm^{-1}[23].it is fact that with Gd-doped BNT ,Gd served as a growth inhibitor .Gd-inhibits grains growth due to its slower rate of diffusion then that of bi ions.Gd-doped BNT ceramics have curie temperature-19°C and tetragonal and cubic structure. dielectricis 310°C[24].Grain size is 28µm to 15µm.sintered at 1500°C and having Td-198°C(rhombohedral to tetragonal)[25].

2.2 La^{3+}doped BNT

All the ceramics present the normal perovskite structure with out secondary phase diffraction peaks, indicating that rare earth La^{3+}can well get into BNTbased matrix Asite.This phenomenon may result from the medium ionic radius of La^{3+}(1.36Å)among Bi^{3+}(1.17A](̊26].All the ceramics present dense micro structure and possess similar shape of grains. addition of rare earth La^{3+} the average grain size of ceramics gradually decreasing 1.70µm to 1.52µm.Rare earth $La^{3+}$is well merged into the BNT based matrix and also indicates on the grain growth of BNT based ceramics .La-doped BNTceramics have coercive field-35.7kv/cm,remnant polarization

200k[27].

2.3 Sm^{3+}doped BNT

Environmental lead free piezoelectric ceramics with great property and high thermal stability.Sm^{3+} modified lead free ceramics are prepared[28]. The piezoelectric properties are improved with the introduction of $Sm^{3+}$$d_{33}$(optical property)is 325pc/N,d_{33}* is 384pm/v are the samples shows good thermal stability such as the d_{33}*decreases less than 20%when the temperature raised from 30 to 180°C.These result shows that the ceramics are good for further application even high temperature[29].The rear earth Sm^{3+} doped BNT the remanantpolarisation Pr and piezoelectric coefficients d_{33} and d_{33}* were improved with the introduction of Sm^{3+} ions[30].Whered_{33} of 325pc/N,d_{33}* of 384pm/v,Pr is 11.19μC/cm^2,Tc is 180°C it is good for high temperature[31].

2.4 Nd^{3+}doped BNT

Nd^{3+} doped BNT lead free piezoelectric ceramics were successfully prepared using a concentration the phase assemblage of BNT gradually transformed from pseudocubic phase.Where Pr~36.6μC/cm2,Ec ~33.6kv/cm,d_{33} is 190pc/N,d_{33}* is 33pm/v[32].All peaks could be attributed to a single perouskite phase indicating that a stable solid solution was formed in the studied range 20°–70°Diffraction peaks shifted to a higher diffraction angle with increasing Nd concentration,consistent with smaller relative ionic radius Nd^{3+} ions compared to that of Bi^{3+} ions in matrix compositions.The decrease in remanent polarization(P_r) d_{33} with increase in Nd concentration can be attributed to the coexistence of ferroelectric and relaxon phases[33].

Nd doped lead free ceramics were preaped by a conventional sintering technique and composition and temperature dependency of ferroelectricity and strain investigated[34].

2.5 Pr^{3+}doped BNT

Rare-earth-doped perovskite complex oxides, especially Pr-doped ABO_3-type compounds, have been extensively studied over the past few decades due to their potential applications as red emitting phosphors in display devices.Accordingly, there has been a great deal of effort invested in developing Pr^{3+}doped perovskite compounds with high luminescence emission intensity[35]. Very recently, Baoreported excellent photoluminescence (PL) properties in Pr^{3+}-doped lead-free $Bi_{0.5}Na_{0.5}TiO_3$ (BNT)compounds. The red emission of the compound is attributed to the valence–conduction transitions of the intervalence charge transfer (IVCT) band and subsequent effective energy transfer from the host to Pr^{3+} ions[36]. The BNT-BCST-Pr ceramics also exhibit strong red photoluminescence emission at 610 nm. The piezoelectriceoptic responses can be modulated by electric fields. The disappearance of luminescence induced by polarization may be attributed to the weak optical activity and the decreased binding energy of self-trapped excitons in the highelectric-induced phase structure[37]. This phenomenon is caused by the reduced distortion and stiffness of the octahedral, enhanced crystal symmetry, lattice expansion, energy barrier, and domain structure in the photoluminescence properties of BNT-based ceramics under an external stimulus.We observed that ferroelectric remanent polarization remarkably enhances the PL intensity of Pr^{3+}þdoped $(Bi_{0.5}Na_{0.5})TiO_3$ ceramic samples, indicating that ferroelectric poling is an effective way to enhance the PL intensity of rare-earth doped ferroelectric ceramics[39]. The PL emission intensity can be enhanced by 35% for a Pr^{3+} doping concentration of 0.5%. We anticipate that there is great potential to monitor ferroelectric remanent polarization of BNT:xPr ceramics through measuring the PL spectra intensity of Pr^{3+} ions in the future. We also found that the threshold for Pr^{3+} concentration quenching increased in the poled BNT:xPr^{3+} ceramic sample[40].

2.6 Yb^{3+}doped BNT

$Bi_{0.5}Na_{0.5}TiO_3$ (BNT) ceramics with Yb doping were studied for their microstructure, phase transition, and dielectric characteristics[41]. It has been discovered that ytterbium encourages the densification and development of ceramic grains, while the appearance of Ti-rich impurities results from the compensation of Ti-vacancy[42]. The use of ytterbium significantly increased the dielectric operating temperature range of ceramics with a 15% tolerance up to 500°C. In the meantime, as doping Yb levels rise, the diffuseness of the diffuse phase transition also rises[43]. A potential material for use in high-temperature capacitors, BNT ceramics with 3 mol% Yb doping exhibits near-plateau dielectric behaviour over a wide temperature range of 147 to 528 °C and a low dielectric loss (0.025) from 154ºC to 356°C. Using the traditional mixed-oxide approach, $(Bi_{0.5}Na_{0.5})_{1-x}Yb_xTiO_3$ (BNT-xYb) ceramics with x = 0.00, 0.015, 0.03, 0.05, and 0.08 were created. High purity Bi_2O_3, Yb_2O_3, TiO_2, and carbonate Na_2CO_3 were blended in the beginning ingredients in accordance with the stoichiometric BNT-xYbcomposition[44]. The slurry was dried after being ball-milled in alcohol for 24 hours, and it was then calcined for two hours in an enclosed space at 900°C in air. Investigations have been made on the structure, dielectric characteristics, and relaxation behaviour of $(Bi_{0.5}Na_{0.5})_{1-x}Yb_xTiO_3$ (x=0-0.08) ceramics. BNT ceramics' densification and grain development can both be aided by ytterbium. Although the excess Ti content in the BNT ceramics system allows the doping Yb to perform a donor role, the Ti-vacancy prefers to play a potential role as defect compensation. Antiferroelectric-paraelectric dielectric peak intensity is reduced by Yb doping, and the phase[45]**.**

2.7 Dy^{3+}doped BNT

xDy_2O_3-$Bi_{0.5}(Na_{0.82}K_{0.18})_{0.5}$Ceramics made of TiO_3(0-0.4wt%) were created using traditional solid-state methods[46]. The tetragonal and rhombohedral phases co-existed in the Dy_2O_3 doped $Bi_{0.5}(Na_{0.82}$K0.18$)_{0.5}TiO_3$ ceramics from x = 0.05 to 0.4 wt% Dy_2O_3, according to an X-ray diffraction pattern. According to SEM pictures, doping Dy_2O_3 encourages the development of ceramics with uniform microstructures and high density. After the addition of Dy_2O_3, the $Bi_{0.5}(Na_{0.82}K_{0.18})_{0.5}TiO_3$ ceramics maintain their diffuse phase transition behaviour[47]. By adding an appropriate proportion of Dy_2O_3, the electrical characteristics of BNKT ceramics can be enhanced, with the best values being 1765 (1 kHz) at x = 0.10, 152 pC/N, and 32.5 C/cm^2 at x = 0.15, respectively. By creating dysprosium-doped bismuth sodium titanate (Dy^{3+}-BNT) ceramics, Watcharapasorn et al. were able to produce extremely dense ceramics with relatively little constant is too small for practical use[48]. A high piezoelectric constant of 170 pC/N and the dielectric constant of 1900 (at a frequency of 1 kHz) were observed in our earlier study when Dy^{3+} was doped in $(Bi_{0.5}Na_{0.5})_{0.94}Ba_{0.06}TiO_3$ systems. With varying amounts of Dy_2O_3, Lee et al. revealed dual effects on the piezoelectric and dielectric properties of Dy^{3+}, which were likewise studied in the $BaTiO_3$ system. [49]. In the current work, Dy_2O_3 was added to $Bi_{0.5}(Na_{0.82}K_{0.18})_{0.5}TiO_3$ (BNKT) ceramics in order to better understand Dy_2O_3 doped BNT-based ceramics. The piezoelectric, dielectric, and ferroelectric characteristics of a variety of Dy_2O_3- doped (0.05–0.4wt%) BNKT ceramics were discussed. $Bi_{0.5}$ $(Na_{0.82}K_{0.18})$0-0.4 wt% $0.5TiO_3$ ceramics Conventional solid-state techniques have been used to create Dy_2O_3[50]. Research using X-ray diffractograms demonstrates that Dy_{3+} penetrates the A-site of the perovskite structure and the Dy_2O_3-doped $Bi_{0.5}$ $(Na_{0.82}K_{0.18})$ $_{0.5}$Rhombohedral and tetragonal phases coexist in TiO_3 ceramics, maintaining their single-phase perovskite structure[51]. Dy_2O_3 doping encourages the development of BNKT ceramics with uniform microstructures and high density while preventing the ceramics' grain growth. At x = 0.15, the $Bi_{0.5}$ $(Na_{0.82}K_{0.18})_{0.5}TiO_3$ ceramics doped with Dy_2O_3 showed a remarkable increase in piezoelectric constant and remanant polarisation: d_{33} = 152 pC/N, r = 1765 (1 kHz), and Pr =.32.5 C/cm^2 (1.0 Hz)[52].

2.8 Rare-Earth Doped BNT-BT Ceramic

2.8.1 La doped BNT-BT

BNT-BT ceramic is one of the most widely used lead-free piezoelectric ceramics. The piezoelectric constant d_{33} increased from 117 to 125 pC/N in the BNT-6BT ceramics doped with one at% La, but the thick electromechanical coupling coefficient kt decreased slightly from 0.43 to 0.38[53] due to the high Curie temperature and good piezoelectric constant (d_{33}> 100 pC/N). The BNT-6BT ceramics doped with 0.4 wt% CeO_2 outperformed pure BNT-6BT ceramics in terms of performance. BNT-6BT ceramics with la dopants. After 0.6 wt% La_2O_3 doping, the ceramics have good piezoelectric properties (d_{33} 167 pC/N, kp 0.30)[54]. Excellent photoluminescence properties can also be seen in BNT-BT ceramics doped with rare earth elements.The planar electromechanical coupling coefficient kp and the piezoelectric constant d_{33} of the 2.5 mol% Dy doped BNT-6BT ceramic can both go close to 190 pC/N and 0.372, respectively. Additionally, the ceramics stimulated at 426 nm had notable emissions at 478 and 575nm[55].

2.8.2 Sm doped BNT-BT

The piezoelectric constant d_{33} and thick electromechanical coupling coefficient kt of the doped ceramics are 120 pC/N and 0.52, respectively, of the Sm doped BNT-6BT ceramics, which have excellent electric properties[56]. Additionally, nd doping can improve the electric properties of BNT-6BT ceramics. The ceramics' coupling coefficient k_p and piezoelectric constant d_{33} both increased to 202 pC/N and 0.3, respectively. The piezoelectric constant d_{33} and planar electromechanical coupling coefficient k_p of ceramics can both become close to 175 pC/N and 0.31, respectively[57].

2.8.3 Dy doped BNT-BT

ceramics, indicating a potential application in electro-optic devices[58]. Under 980 nm stimulation, the Er-doped BNT-7BT ceramics displayed visible up-conversion luminescence at 532, 540, and 600 nm as well as broadband down-conversion luminescence in the near infrared (1440-1660 nm) and mid-infrared (2620-2840nm) ranges. Li created a strong orange luminescence in the Sm-doped BNT-12BT ceramics when triggered by blue light, and the emission intensity is greatly influenced by the doping concentration[59].

Table 2 Comparison of Ɛ, tanδ, Tc of Lead zirconatetitanate(PRZT) compounds

Rare earth element(R)	$Ɛ_{RT}$	$tanδ_{RT}$	$Ɛ_{max}$	$tanδ_{max}$	T_c(°C)	Reference
La	3413	0.072	18924	0.016	156	[60]
Nd	2148	0.005	6577	0.007	182	[60]
Sm	737	0.071	5594	0.051	284	[60]
Gd	187	0.098	12864	0.064	337	[60]
Dy	528	0.085	12673	0.014	368	[60]
Yb	194	0.089	_	0.086	_	[60]

Table 3Comparison ofE_a,P_r,$E_e$and *d_{33}* of PRZT compounds

Rare earth element(R)	E_a(eV)	P_r(μC/cm^2)	E_e(kV/cm)	d_{33}(pC/N)	Reference
La	0.53	21.90	6.65	569	[60]
Nd	0.25	8.84	6.61	269	[60]
Sm	0.18	7.58	5.51	151	[60]
Gd	0.63	8.31	3.11	_	[60]
Dy	0.33	6.75	3.97	84	[60]
Yb	_	_	_	_	[60]

3.Conclusion

We learned from the aforementioned literature review that the dielectric and ferroelectric properties are included in the rare earth element doping of BNT ceramics.Additionally, we came to the conclusion that the rare earth metal can reduce the conductivity of the material and, as a result, the oxygen vacancy. Therefore, rare-earth doping is a useful technique for creating materials with many functions. The following are the research and development prospects for rare-earth doped piezoelectric materials. Lead-free piezoelectric materials that function superbly can replace conventional lead-based ceramics while being more environmentally benign. Due to their improved electric characteristics, rare-earth doped piezoelectric single crystals outperform typical piezoelectric ceramics in situations involving considerable strain and high energy conversion efficiency. In order to address the needs of ever-more-demanding applications, single crystal growth conditions and characteristics will be optimised in future development.A form of integrated materials.

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