**RESEARCH PROPOSAL**

**TITLE**: - To study, synthesize and characterize lead free piezoelectric perovskite material for piezoelectric energy harvesting applications at high temperatures.

**ABSTRACT**: -

In this highly technological advanced world, today the most obvious problem which we have to acknowledge keeping our future generations, environment and social externalities in mind is energy scarcity. In order to have sustainable development we have to focus on how can we consume the ambient energy present in our surrounding and convert it into useful energy. To this problem one solution is piezoelectric energy harvesting. Piezoelectric energy harvesting is a technique in which devices made up of suitable piezoelectric material depending on the type of application, are used to capture the ambient energy typically vibrational energy and convert it into usable electrical energy. These devices are self-powered, have extended lifetimes and can be used in remote places. After the discovery of PZT (Lead Zirconium Titanate), it took over the industry due to its excellent piezoelectric properties. Since then it has been used extensively in almost every field be it electronic industry, defence, medical, research and development, information technology, optoelectronic technology and so on. But the toxicity of lead is alarming for both human and environment. Elimination of lead from already commercialized applications is quite challenging but researchers have been working to find substitute for lead based piezoelectric materials from last two decades and lead free piezoelectric perovskite materials have attracted a lot of attention due to the appreciable progress in their properties. Despite of knowing numerous lead free perovskite systems the commercialization of only a handful have been possible till now this is due to several reasons few of them are

* Lack of reproducibility and large scale production have made it difficult to satisfy demands of electronic devices because the electrical properties are sensitive to compositions, sintering conditions and poling conditions.[1]
* Temperature sensitivity of electrical properties because of the structural and domain issues which leads to narrow temperature usage range for piezoelectric devices. For good application balance between piezoelectricity and temperature stability is essential.
* Good fatigue stability and frequency stability are also required for device application and it can be improved by controlled measurement conditions (temperature, electric field, frequency, electrodes etc.) and material properties (crystallographic structure, microstructure etc.).[1]
* Due lack of literature available it is necessary to ascertain the relationships among final performance which includes electrical properties and microstructure analysis, raw materials (purity and morphology) and synthesis processes (reaction kinetics and sintering mechanism). Also there is no clear explanation of structural and physical origins of high piezoelectricity.[1]
* Intrinsic characteristics of phase boundaries is not completely explored.[1]

Hence the main aim of this research is to synthesize and characterise lead free piezoceramic for high temperature energy harvesting applications.

**LITERATURE REVIEW**: -

Piezoelectric effect was first discovered by Jacques and Pierre Curie, in 1880 for quartz crystal, which is basically appearance of an electric potential (a voltage) across the sides of crystal when subjected to mechanical stress. One of the elusive characteristics of this effect is reversibility. The lead free piezoceramics which includes sodium potassium niobate (KNN), barium titanate (BT), bismuth sodium titanate (BNT) and bismuth ferrite (BFO) have attracted a huge attention owing to their promising improvement in electrical, physical and compositional properties.

In 2004, Saito et al. reported high piezoelectricity in textured KNN based ceramic with orthorhombic- tetragonal phase boundary prepared by reactive template grain growth (RTGG) method. [2] Since then there has been significant efforts in enhancing the piezoelectric properties of KNN based materials. Piezoelectric properties of KNN based ceramics can be improved by designing new phase boundaries, composition modification and texturing. Poor temperature stability is hindering the practical implications of KNN based ceramics. [3]

In 2009, Ren et al. observed a large piezoelectric effect in BT based ceramics with a R-T phase boundary. [10] In 2017, giant d33 of 755pC/N and d33\* of 2027pm/V were obtained in highly textured BCTZ ceramics. [11] Ion substitution plays an important role in tuning the phase transition temperature of BT-based ceramics. [4-9] Low Curie temperature for BT based ceramics is main drawback present currently.

In 2007, Zang et al. reported a large strain value S= 0.45% for BNT-BT-KNN ternary ceramic due to antiferroelectric to ferroelectric phase transition. [12] In 2016, Tan et al. obtained superior strain value (S=0.7%) in Sr and Nb co-modified BNT based ceramics. [13]Large strain values are important for actuator applications. The main longstanding obstacle in the practical applications of BNT based ceramics is low depolarization temperature and large hysteresis of BNT which limits the temperature usage range. [14-17] Even when temperature usage range is widened using composition modification the piezoelectric coefficient remains inferior for practical purpose. [18-20]

In 2015, by modifying preparation process (conventional solid state method with quenching sintering) large piezoelectric charge coefficient of 402pC/N and high Curie temperature (Tc= 454°C) were obtained for BiGaO3 modified BFO-BTO based ceramics with a R-T phase boundary. [21] BFO based ceramics are suitable candidates for high temperature applications as they possess high Curie temperature and have good electrical properties. Phase boundaries do not play a critical role in enhancing the electrical properties of BFO ceramics with ion substitution however their magnetic properties can be improved. Since BFO shows multiferroic properties so it is very much possible that the BFO based materials can be used in areas where we can derive more than one application from single material. In BF-BT solid solution the structure and properties can be effectively tailored by changing BT content. The piezoelectric and ferroelectric properties can be effectively strengthened by composition modification induced phase boundaries.

**METHODOLOGY**: -

To enhance electrical properties several approaches have been taken including certain additive oxides (MnO2, CuO etc.), ion substitution at A or B site or both at A or B, elements (Ga, La, Co) and other additional ABO3 compounds. Microstructural parameters such as grain size and degree of densification of BF-BT ceramics also depends on doping level.[22] For enhancing the properties of BF-BT based system the type of processing method used, optimizing conditions such as poling, calcination and sintering plays very pivotal role. Among numerous of processing method available out there conventional solid state reaction method is still very popular one due to its simplicity, also its economic compared to other methods which can be very beneficial from commercialization and reproducibility point of view. So after going through literature and researching for a while I have decided to use solid state route first for preparation of my sample with certain modification in sintering techniques where I will go for water quenching under optimized conditions to prevent thermal shocks. Also I want to experiment more with different quenching techniques, processing method and see how they are effecting the properties of given sample. For crystal structure, phase transformation, microstructural morphology, electrical, dielectric loss and magnetic characterization XRD, SEM, TEM, d33 measurement, impedance analysis, P-E measurement, strain analysis will be done. After the synthesis and characterization a piezoelectric device will be fabricated for energy harvesting applications.

**IMPACTS**:-

The purpose of the research proposal is to design a material for piezoelectric energy harvester in high temperature applications like space technology, industrial application, aviation industry, remote areas and many other possibilities.

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