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STUDY OF ENVIRONMENT FRIENDLY PIEZOELECTRIC MATERIAL

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INKING INNOVATIONS

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Abstract:

Piezoelectric materials possess wide range of applications in present day technologies for sensors and actuators. This is because of their unique ability to change electric polarization in response to the mechanical stress developed due to an applied electric field. Most common piezoelectric materials contain more than half weight percent of lead (Pb). Lead based piezoelectric materials have been in forefront of industry since decades due to their excellent properties. Despite all advantages Pb-based materials are facing global restrictions due to their high toxicity to the environment as well as the human society. To be more precise, in the lead oxide based materials, the lead oxide vaporizes during processing but the lead remains in the environment for a very long time. Biological observations have revealed that if lead remains in the environment for a longer time then there is a chance for it to get accumulated in the human body and cause damage to the brain and the nervous system. Due to harmful effects of lead there is a strong need to study and find out new lead free materials which can be used as replacement for lead containing piezoelectric materials. In the present paper, we have studied BZT-BCT (Ba(Zr0.2Ti0.8)O3-x(Ba0.7Ca0.3)TiO3) material which is a good substitution for lead containing piezoelectric materials. This material was synthesized by sol-gel route with three different concentrations. The samples were calcined at 1100°C for 6 hours. As-prepared samples were characterized by X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). The size of particles was determined by using Debye-Scherrer formula and was found to be about 42 nm. The SEM images show a uniform distribution of particles having cubical morphology.

Keywords:

Environment friendly, lead free, piezoelectric, nano materials.

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Introduction:

Environment friendly materials are of keen interest for researchers. Most of the methods of synthesis in common use are hazardous and the handling and applications of such materials leads to several environmental issues like toxicity. Thus there is need to synthesize environment friendly materials. Less pollutant materials are of prime importance because of emerging environmental conditions such as global warming and soil pollution. Basically, piezoelectric materials were listed amongst the pollutant materials due to lead content in them.

Piezoelectricity (pressure electricity) was discovered by Nobel laureates Pierre and Jacques Curie in 1880 [1] during their study of the effects of pressure on the generation of electrical charge by crystals such as quartz, tourmaline and Rochelle salt. Piezoelectric materials are the materials which show unique property of changing electric polarization in response to the mechanical stress developed due to an applied electric field [9]. Piezoelectric materials possess wide range of applications. Traditional piezoelectric materials are mostly made up of lead. Lead based piezoelectric materials have been in the forefront of industry since decades due to their excellent properties. Lead zirconate titanate [PZT] materials are traditional piezoelectric materials [4]. PZT materials are widely used in sensor and actuator industries.[5,7,8] These materials contain more than 60% lead of its total weight, however lead [Pb] affects the human body as well as the ecosystem. Lead affects the central nervous system of animals and inhibits their ability to synthesize red blood cells. Large lead content creates hazards during processing (lead volatilizes and is released into the atmosphere), limits applications (e.g., in vitro), and is potentially environmentally toxic during disposal [11,2,10]. Lead content in PZT materials is of prime disadvantage from the environmental point of view. Since, there is no proper replacement for PZT material; this has been used in various applications with its risk of hazardous effects.

Many attempts were made to synthesize lead free piezoelectric materials; suitable lead-free piezoelectric materials are still being developed as no single composition has been proposed with properties that are comparable to that of PZT. For lead free piezoelectric materials researcher proposed single, binary and ternary component systems among which binary and ternary component systems are often useful for lead free piezoelectric materials.[3] Barium is a good option for making Pb-free piezoelectric ceramic material. Apart from being environment friendly, Barium also shows a high piezoelectric coefficient. Moreover ternary component systems mostly show low Curie temperatures (Tc) of about 150° C as compared to binary systems with high Tc values of about 270° C [6]. Thus, in the present work we have carried out the synthesis of a lead free binary component system BZT-BCT. Such systems have been synthesized by solid state route. We have carried out synthesis by a simple Sol-Gel method that does not involve large and costly instrumentation, and can be carried out at low temperatures. Moreover we have obtained nanoparticles of the BZT-BCT system which have the potential to show enhanced piezoelectric properties.

Material and Methods:

Method of synthesis:

For the synthesis of BZT-BCT nanoparticles, we carried out Sol-Gel method. The Sol-Gel Method which is also known as chemical solution deposition is a wet chemical technique. It is mostly used with precursors like metal alkoxides and chlorides.

The sol-gel process involves the evolution of inorganic networks through the formation of a colloidal suspension (sol) and gelation of the sol to form a network in a continuous liquid phase (gel). The precursors for synthesizing these colloids consist usually of a metal or metalloid element surrounded by various reactive ligands. The starting material is processed to form a dispersible oxide and forms a sol in contact with water or dilute acid. Removal of the liquid from the sol yields the gel, and the sol/gel transition controls the particle size and shape. Calcination of the gel produces the oxide (figure 1).

Materials:

Appropriate molar concentrations of various precursors namely, Barium acetate (Ba(CH3 COO)2), Zirconyl nitrate hydrate (ZrO(NO3)2.H2O), Calcium acetate (Ca(CH3COO)2), Titanium isopropoxide (C12H28O4Ti) and 2-Methoxy ethanol were taken. The required amounts of Barium acetate and Calcium acetate were dissolved in 60 ml of Acetic acid and stirred for half an hour till the solution became transparent. The solution of ZrO(NO3)2.H2O was prepared in 2-Methoxy ethanol and was added to the earlier transparent solution of Ba(CH3COO)2 and Ca(CH3COO)2. Titanium isopropoxide (C12H28O4Ti) was pipetted to the above solution. This solution was continuously stirred and heated for about 4 hours till the formation of the gel. The remnant lumps were removed by simple grinding for 10 minutes. The sample was calcined in a furnace for 1100°C for 6 hours. The lumps formed during calcination process were also grinded. By varying the concentrations of precursors, we synthesized three different combinations of BZT-BCT material as 48BZT-52BCT, 50BZT-50BCT, 52BZT-48BCT. The powder was mixed with 4% PVA (polyvinyl alcohol) as an organic binder to increase the strength of pellets. The pellets were formed by applying a pressure of 5 tones and to remove the binder the pellets were heated for 1 hr at 400°C. The structural and surface morphology of the pellets were analyzed by XRD and SEM respectively. CuKα X-rays with wavelength of 1.54 Å were used for XRD.

Results and Discussion:

From the diffracted peaks obtained in the XRD spectrum (figure 2), the average grain size of the synthesized BZT-BCT particles is determined with the help of the Debye-Scherrer formula. The values of interplaner spacing (d spacing) were calculated by using Bragg's relation and were compared with the JCPDS data (36-0019) (T-1). The matching between the two is excellent. Thus, proper phase of BZT-BCT is formed.

SEM data (figure 3) shows the formation of cubical morphology of the particles.

Conclusions:

i. We have successfully synthesized nanoparticles of BZT-BCT for the first time.

ii. All the three compositions show approximately the same size of about 42 nm at 1100°C. However 48BZT-52BCT material shows a few small extra peaks in the XRD spectrum. We are investigating the cause of this extraneous feature.

iii. Testing of the piezoelectric properties of BZT-BCT nanoparticles are in progress.

Acknowledgement :

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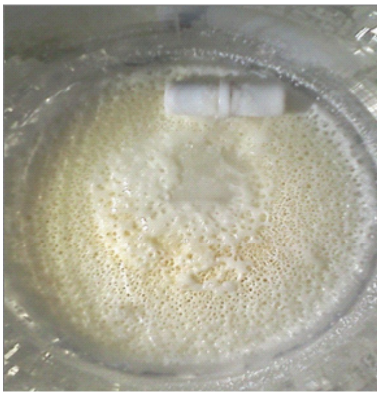

Figure 1:
Gel formation during Sol-Gel method.

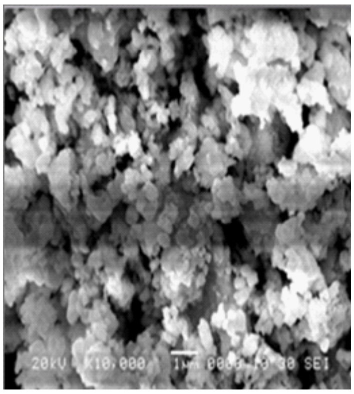

Figure 3:
SEM of BZT-BCT nanoparticles
(Magnification 10000, 20kV)

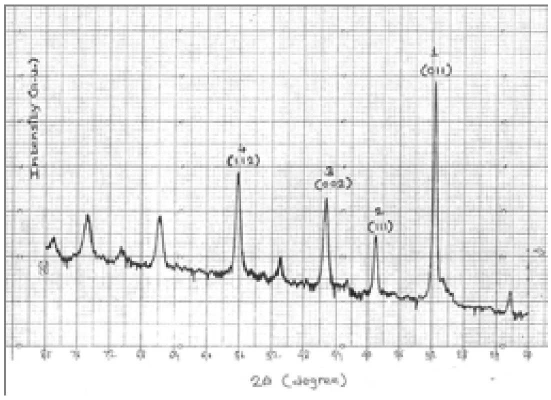

Figure 2:
XRD of BZT-BCT nanoparticles.

Peak No	*Experimental Data*		*JCPDS data (36-0019)*	
	Grain Size (nm)	**d spacing (nm)**	**d spacing (nm)**	**(hkl)**
1	*41.20*	*0.2831*	*0.2865*	*(011)*
2	*42.10*	*0.2321*	*0.2339*	*(111)*
3	*43.06*	*0.1997*	*0.2026*	*(002)*
4	*45.03*	*0.1636*	*0.1654*	*(112)*

Table 1: The values of grain size and d spacing.

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