Strategies to Improve Physical Properties in Eco-Friendly Materials through Cation Engineering

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Abstract

Bulk ferro/piezoelectric ceramics are the backbone for several components utilized in communication systems, industrial automation, medical diagnostics, information-technology, energy storage and harvesting. From the application point of view, ferro/piezoelectric materials should have high piezoelectric coefficients, high remnant polarization (P_r), low coercive field (E_C), wide temperature stability and good mechanical strength [1]. In most of the high performance piezoelectric applications, the material of choice is ultimately based upon lead based materials such as PZT (i.e., $Pb(Zr, Ti)O_3$). Even though PZT has excellent piezoelectric properties suitable for device applications, the prime concern is about lead (Pb) which is highly toxic and hazardous in nature. Hence, it has become a serious threat for environmental protection during the waste disposal and also it indirectly induces health related issues. In this regard, worldwide environmental considerations are demanding the elimination of lead-based materials from all consumer items [2].

In orderto replace PZT based systems, new lead free systems have to be developed for specific applications based on their piezoelectric performance. In the recent years perovskite based A-site disordered (i.e., A-site being shared equally by two cations) lead free ferroelectrics such as $Na_{0.5}Bi_{0.5}TiO_3$ (NBT), $Bi_{0.5}K_{0.5}TiO_3$ (BKT), $K_{0.5}Na_{0.5}NbO_3$ (KNN) and their solid solutions have been actively studied for lead free piezoelectric ceramics. Among them NBT and its derivatives has received much attention because of their stable ferro/piezoelectric properties. At room temperature the parent NBT system exhibits a remanent polarization P_r = 38 $\mu C/cm^2$ along with a large coercive field of $E_C \cong 63$ kV/cm. The piezoelectric charge coefficients (d_{33}) for NBT vary from 70-100 pC/N.

The physical properties of the materials can be tuned with different approaches. Here, the chemical modification through site specific cation engineering and solid-solution approaches have been used to tune the physical properties. The grain size variation at nano-scale and their refinement have also shown interesting observations in properties [3]. Since structure of the materials also plays crucial role to modify the properties, structural-property correlation has been also addressed [4-6].

References

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