

Present Status and Prospects of Lead-free Piezoelectric Ceramics

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Most piezoelectric materials, which have been widely used, are lead-based three-component ceramics including PbTiO_3 - PbZrO_3 (PZT). However, it is very important for environmental protections to use the lead-free components as piezoelectric materials. The use of lead-based materials, for example, lead-based solder etc., will be prohibited by the law in near future for avoidance pollution of the earth. Consequently, it is necessary to search the lead-free piezoelectric material with excellent properties such as PZT system.

In this presentation, trends of the study and development of lead-free piezoelectric ceramics are reviewed. Candidate materials for lead-free piezoelectric ceramics seem to be bismuth perovskites such as bismuth sodium titanate, $(\text{Bi}_{1/2}\text{Na}_{1/2})\text{TiO}_3$ (BNT), bismuth potassium titanate, $(\text{Bi}_{1/2}\text{K}_{1/2})\text{TiO}_3$ (BKT), barium titanate, BaTiO_3 (BT), their based BNT-BKT-BT three component solid solutions and KNbO_3 related. Also bismuth layer-structured ferroelectric (BLSF) family are widely studied on their dielectric, ferroelectric and piezoelectric properties for the special piezoelectric applications.

The Curie temperature, T_c , of BaTiO_3 -based solid solution, $(1-x)\text{BaTiO}_3$ - $x(\text{Bi}_{1/2}\text{K}_{1/2})\text{TiO}_3$ [BTBK-100x] ceramics increases with increasing the amount of x . BTBK-20+ MnCO_3 0.1wt% ceramic shows the high T_c than 200 °C and the electromechanical coupling factor, $k_{33} = 0.35$. In the case of $a(\text{Bi}_{1/2}\text{Na}_{1/2})\text{TiO}_3$ - $b\text{BaTiO}_3$ - $c(\text{Bi}_{1/2}\text{K}_{1/2})\text{TiO}_3$ [BNBK (100a/100b/100c)] solid solution ceramics, the piezoelectric constant, d_{33} and the T_c are 191 pC/N and 301 °C for the BNBK (85.2/2.8/12), respectively.

On the other hand, BLSF ceramics seem to be excellent candidates as piezoelectric sensors for high temperatures and ceramic resonators with high mechanical quality factor, Q_m , and low temperature coefficient of resonance frequency, TC - f_r . Donor-doped $\text{Bi}_4\text{Ti}_3\text{O}_{12}$ ceramics such as $\text{Bi}_4\text{Ti}_{3-x}\text{Nb}_x\text{O}_{12}$ [BITN- x] and $\text{Bi}_4\text{Ti}_{3-x}\text{V}_x\text{O}_{12}$ [BITV- x] show high T_c than 650 °C. The k_{33} value of the grain-oriented (HF) BITN-0.08 ceramic is 0.39 and is able to keep the same value up to 350 °C. $\text{Bi}_3\text{TiTaO}_9$ (BTT) -based solid solution system, $\text{Sr}_{x-1}\text{Bi}_{4-x}\text{Ti}_{2-x}\text{Ta}_x\text{O}_9$ [SBTT2 (x)] ($1 \leq x \leq 2$), displays the high Q_m value (=13500) in (p)-mode at the $x=1.25$ composition.