Design and Development of a Lead-Free $BiFeO_3$-$BaTiO_3$ Quenched Ceramics for High Piezoelectric Strain Performance

Authors : Muhammad Habib, Lin Tang, Guoliang Xue, Attaur Rahman, Myong-Ho Kim, Soonil Lee, Xuefan Zhou, Yan Zhang, Dou Zhang

Abstract : Designing a high-performance, lead-free ceramic has become a cutting-edge research topic due to growing concerns about the toxic nature of lead-based materials. In this work, a convenient strategy of compositional design and domain engineering is applied to the lead-fee $BiFeO_3$-$BaTiO_3$ ceramics, which provides a flexible polarization-free-energy profile for domain switching. Here, simultaneously enhanced dynamic piezoelectric constant (d33* = 772 pm/V) and a good thermal-stability (□d33* = 26% over the temperature of 20-180 ^oC) are achieved with a high Curie temperature (TC) of 432 ^oC. This high piezoelectric strain performance is collectively attributed to multiple effects such as thermal quenching, suppression of defect charges by donor doping, chemically induced local structure heterogeneity, and electric field-induced phase transition. Furthermore, the addition of BT content decreased octahedral tilting, reduced anisotropy for domain switching and increased tetragonality (c_t/a_t), providing a wider polar length for B-site cation displacement, leading to high piezoelectric strain performance. Atomic-resolution transmission electron microscopy and piezoelectric force microscopy combined with X-ray diffraction results strongly support the origin of high piezoelectricity. The high and temperature-stable piezoelectric strain response of this work is superior to those of other lead-free ceramics. The synergistic approach of composition design and the concept present here for the origin of high strain response provides a paradigm for the development of materials for high-temperature piezoelectric actuator applications.

Keywords : Piezoelectric, BiFeO3-BaTiO3, Quenching, Temperature-insensitive
Conference Title : ICCSSM 2023 : International Conference on Construction Systems and Smart Materials
Conference Location : Karachi, Pakistan
Conference Dates : December 25-26, 2023