

Design and Development of a Lead-Free BiFeO₃-BaTiO₃ 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-free BiFeO₃-BaTiO₃ ceramics, which provides a flexible polarization-free-energy profile for domain switching. Here, simultaneously enhanced dynamic piezoelectric constant ($d_{33}^* = 772 \text{ pm/V}$) and a good thermal-stability ($\Delta d_{33}^* = 26\%$ over the temperature of 20-180 °C) are achieved with a high Curie temperature (TC) of 432 °C. 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/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