High strain response and low hysteresis in BaZrO$_3$-modified KNN-based lead-free relaxor ceramics

Jian Zhang
   Nanjing Tech University

Zixuan Liu
   Nanjing Tech University

Tao Zhang
   Nanjing Tech University

Yunfei Liu (✉ yfliu@njtech.edu.cn)
   Nanjing Tech University   https://orcid.org/0000-0002-4397-6607

Yinong Lyu
   Nanjing Tech University

Original Research

Keywords: KNN-based ceramics, BaZr03, high strain, low hysteresis

Posted Date: February 19th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-206598/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

The high driving electric field and the large strain hysteresis was subject to a challenge for piezoelectric actuators’ practical applications. In order to obtain the piezoceramics with giant strain and low hysteresis at small electric field, a ternary solid solution (0.97 - x)(K 0.48 Na 0.52)Nb 0.965 Sb 0.035 - 0.03Bi 0.5 (K 0.18 Na 0.82) 0.5 ZrO 3 - x BaZrO 3 (x = 0 - 0.06) was designed and synthesized by the traditional solid-state reaction method. The relationships among phase transition, microstructure, and electrical properties of the ceramics samples were systemically investigated. Under a low electric field of 4 kV/mm, the ceramic with x = 0.02 obtained a high strain of 0.29 % (S max / E max = 729 pm/V) and a low hysteresis of 13.8 %. The excellent piezoelectric properties are mainly attributed to rhombohedral-orthorhombic-tetragonal (R-O-T) phase boundary and the relaxor-to-ferroelectric phase transition. We believe that our research can not only provide the pathway of achieving KNN-based ceramics with high strain and low hysteresis but also promote the practical application of lead-free piezoelectric actuators.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Tables

Table 1 Comparison of $S_{\text{max}}$, $E$, $d_{33}^*$, and $H_{\text{ys}}$ values of KNN-based and BNT-based ceramics

| Compositions        | $S_{\text{max}}$ (%) | $E$ (kV/mm) | $d_{33}^*$ (pm/V) | $H_{\text{ys}}$ (%) | Ref.     |
|---------------------|----------------------|-------------|-------------------|---------------------|----------|
| BNKT-SBTZ6          | 0.72                 | 11          | 916               | 36.2                | [42]     |
| BNT-2.5Nb           | 0.7                  | 5           | 1400              | 64                  | [28]     |
| BNKT-0.02Sn         | 0.37                 | 8           | 462               | 21.8                | [43]     |
| BNKT-0.02BCZ        | 0.33                 | 6           | 549               | 25                  | [40]     |
| NBST-0.005Mn        | 0.32                 | 6           | 533               | 28                  | [44]     |
| BNT-BKT-0.02BZT     | 0.32                 | 6.5         | 503               | 40                  | [41]     |
| BNKT-9BT            | 0.29                 | 6           | 485               | 23                  | [45]     |
| KNNS$_{0.06}$-SZ-BNZ| 0.15                 | 4           | 375               | 4.3                 | [46]     |
| KNNS-BNKZ-0.02BZ    | 0.29                 | 4           | 729               | 13.8                | This work|

Figures
Figure 1

XRD patterns of KNNS-BNKZ-xBZ ceramics with (a) $2\theta = 10^\circ$-60$^\circ$ and (b) $2\theta = 45$-$47^\circ$, (c) Amplified XRD patterns ($2\theta = 45$-$47^\circ$) of the ceramics with $x = 0, 0.01, 0.02$ where the XRD patterns are fitted by the Gauss method.
Figure 2
Temperature-dependent (-100 to 200 °C) permittivity of the ceramics with x = 0, 0.02, 0.04, 0.06, measured at 10 kHz
Figure 3

Temperature (30-450 °C) dependence of dielectric constant and frequency dependence of dielectric constant for the KNNS-BNKZ-xBZ ceramics, (a) x = 0, (b) x = 0.02, (c) x = 0.04, (d) x = 0.06, (e) ln(1/εr-1/εm)-ln(Tm) curves of KNNS-BNKZ-x BZ ceramics, (e1) x = 0, (e2) x = 0.02, (e3) x = 0.04, (e4) x = 0.06
Figure 4

SEM patterns of KNNS-BNKZ-xBZ ceramics, (a) x = 0, (b) x = 0.01, (c) x = 0.02, (d) x = 0.03, (e) x = 0.04, (f) x = 0.06
Figure 5

(a) P-E loops of KNNS-BNKZ-xBZ ceramics, (b) the variation of Pr and Ec with various BZ content, (c) I-E loops of KNNS-BNKZ-xBZ ceramics

Figure 6

(a) Bipolar S-E curves of KNNS-BNKZ-xBZ ceramics, (b) Smax and d33* curves of KNNS-BNKZ-xBZ ceramics
Figure 7

(a) Unipolar S-E curves of KNNS-BNKZ-xBZ ceramics, and the insets show Srem of x = 0, 0.02, 0.06, (b) Bipolar S-P curves of KNNS-BNKZ-0.06BZ ceramics.
Figure 8

Hysteresis curve of KNNS-BNKZ-xBZ ceramics