High strain response and low hysteresis in BaZrO₃-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

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

Compositions	$S_{\max}$ (%)	E (kV/mm)	d_{33}^* (pm/V)	H_{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) $2\theta = 10^\circ\text{--}60^\circ$ and (b) $2\theta = 45\text{--}47^\circ$, (c) Amplified XRD patterns ($2\theta = 45\text{--}47^\circ$) 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 $^{\circ}\text{C}$) permittivity of the ceramics with $x = 0, 0.02, 0.04, 0.06$, measured at 10 kHz

Figure 3

Temperature (30-450 $^\circ\text{C}$) 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) $\ln(1/\epsilon_r - 1/\epsilon_m) - \ln(T - T_m)$ 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 P_r and E_c 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) S_{max} and d_{33}^* curves of KNNS-BNKZ-xBZ ceramics

Figure 7

(a) Unipolar S-E curves of KNNS-BNKZ-xBZ ceramics, and the insets show S_{rem} 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