Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Niobate Based Lead-Free Piezoceramics: Diffused Phase Transition Boundary Leading to Temperature-Insensitive High Piezoelectric Voltage Coefficient

Qing Liu,[a] Jing-Feng Li,*[a] ,Lei Zhao,[a] Yichi Zhang,[a] Jing Gao, [a] Wei Sun,[a] Ke Wang and Longtu Li, [a]

[a.] State Key Laboratory of New Ceramics and Fine Processing, School of Materials Science and Engineering, Tsinghua University, Beijing, 100084, P. R. China

*Email: jingfeng@mail.tsinghua.edu.cn (Jing-Feng Li)

I. Phase structure

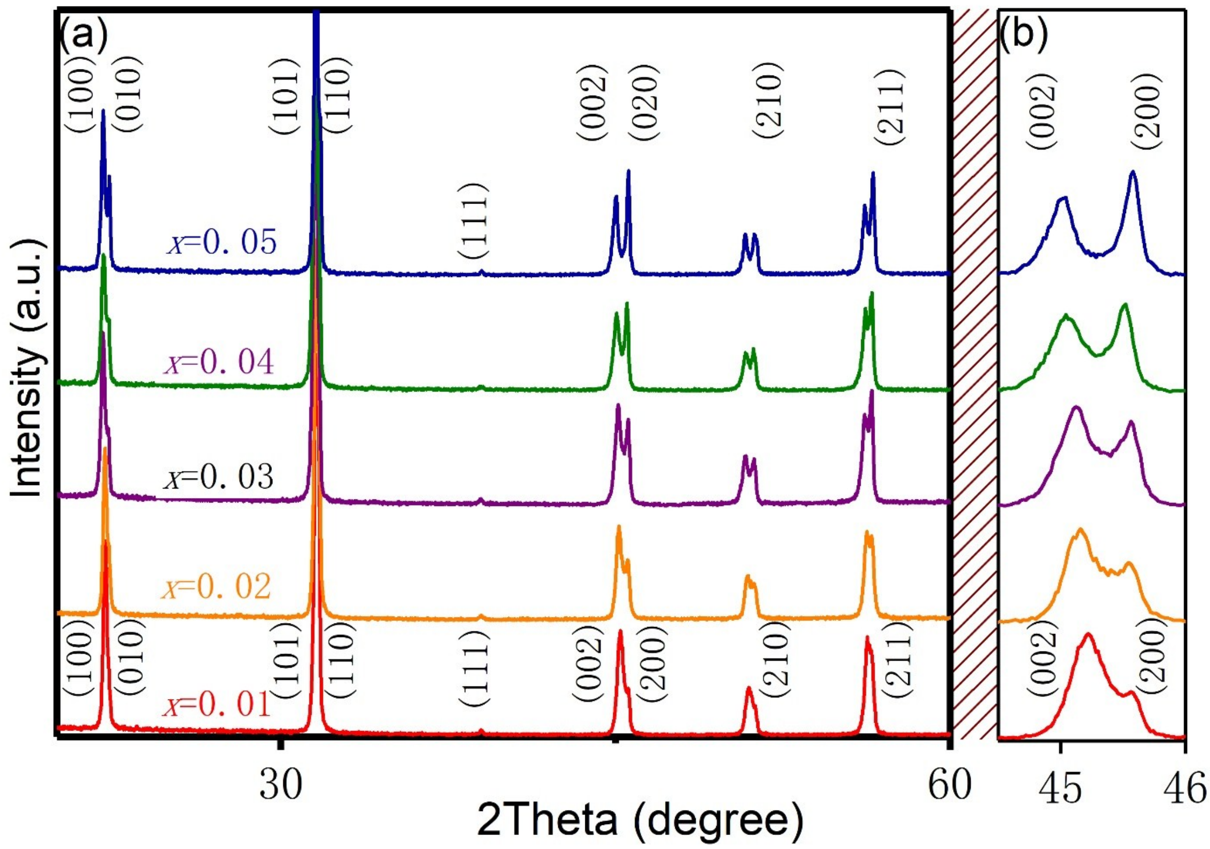

Fig. S1 Room temperature XRD patterns of the L_xKNN-6.5BZ-1BNT samples

II. Mechanical property of $L_{0.02}KNN$-6.5BZ-1BNT sample

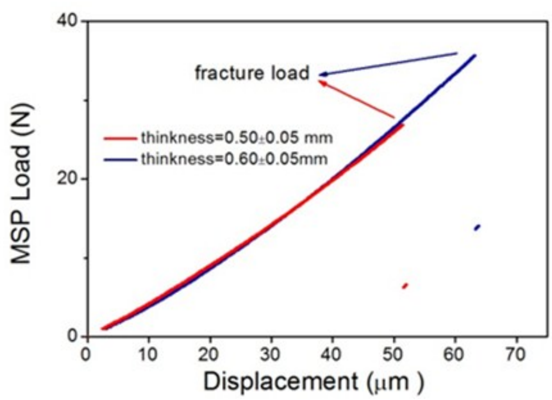

Fig. S2 MSP load-displacement curves for $L_{0.02}KNN$-6.5BZ-1BNT sample.

It makes sense if the lead-free piezoelectric ceramics exhibit both considerable piezoelectricity and good mechanical property. And it is considered according to the experimental data as listed in Table 1 that the high density of the L_xKNN-6.5BZ-1BNT favors the high k_p value. The mechanical property is considered to be highly related to the microstructure. A modified small punch (MSP) method was used to evaluate the mechanical strength according to the following **Equation S1**:

$$\sigma_f = \frac{3P}{2\pi t^2}\left[1 - \frac{1-v^2}{4} \times \frac{b^2}{a^2} + (1+v) \times \ln\frac{a}{b}\right] \qquad (S1)$$

where P is the fracture load, t is the thickness of the sample, *v* is the Poisson ratio, 2a is the diameter of the load-supporting hole of the lower die, and 2b is the diameter of the cylinder-shaped pressure head. The samples exhibit brittle fracture behavior. The fracture load P could be identified as an abrupt load decline occurs, before which a linear dependence of displacement is observed for the MSP load. The MSP fracture loads are P_1=26.8 N with t_1=0.50 mm, P_2 =35.6 N with t_2=0.60 mm. The two observed MSP σ_f values are expected to be similar and are calculated to be 81MPa and 78MPa, respectively, which are larger than the previous reported KNN-based ceramics.[1]

III. Translucent feature of $L_{0.02}$KNN-6.5BZ-1BNT sample

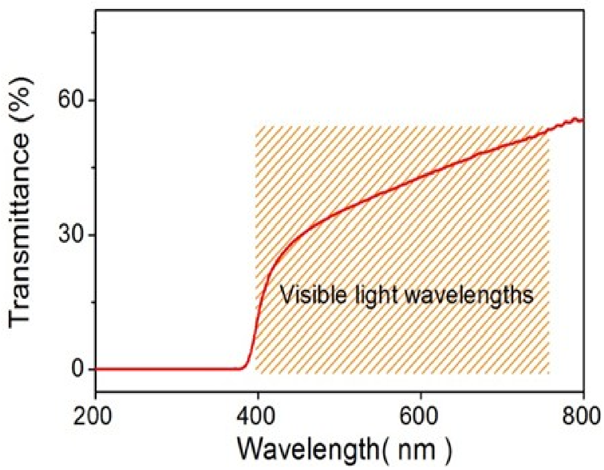

Fig. S3 Optical transmittance spectra of $L_{0.02}$KNN-6.5BZ-1BNT sample of 0.35 mm in thickness. The optical transmittance reaches around 40% at the 633 nm wavelength.

IV. Dielectric property

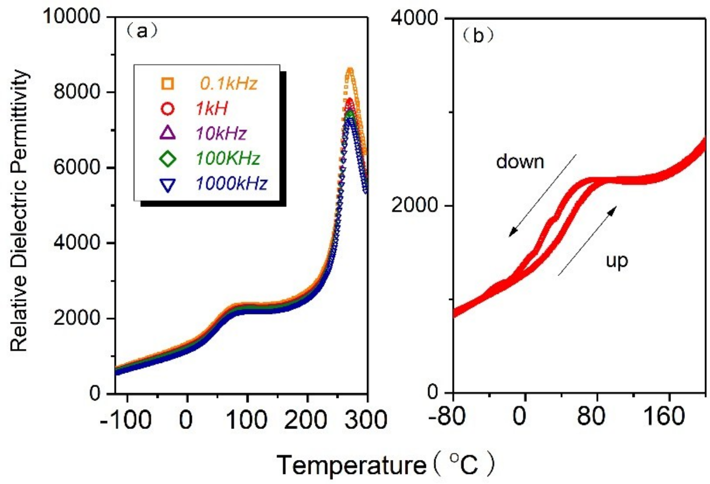

Fig. S4 (a) the temperature-dependent permittivity of the x=0.02 sample at different frequencies.(b) the temperature hysteresis.

V. Piezoelectric property

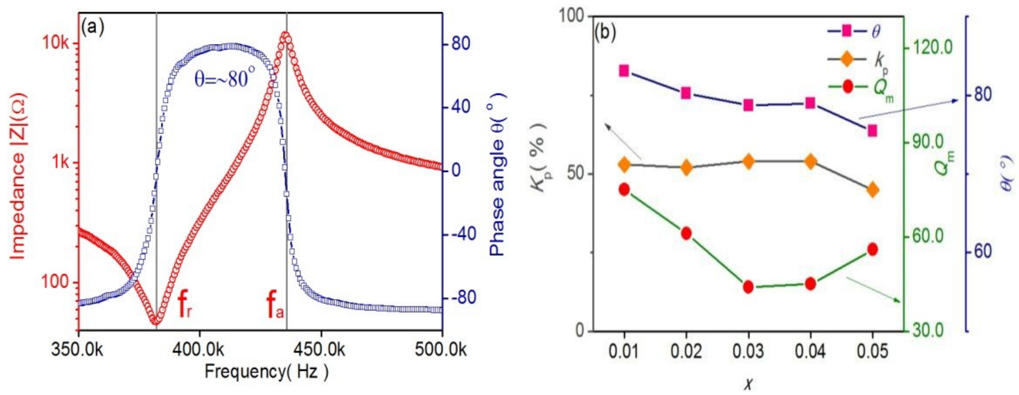

Fig. S5 (a) The frequency dependence of the impedance and phase angle of $L_{0.03}$KNN-6.5BZ-1BNTsamples. (b) Summarized results in θ , k_p and Q_m of L_xKNN-6.5BZ-1BNT ceramics as functions of Li contents.

It can be seen that the sample with x=0.03 displays a square-like resonance peak, featured with both the resonance 381 kHz and anti-resonance frequency 435 kHz. It was calculated that the planar mode electromechanical coupling factor k_p could reach 54% according to the **Equation S2** as follows.

$$k_p = \frac{1}{\sqrt{0.395\frac{f_r}{f_r - f_a} + 0.574}} \qquad (S2)$$

VI. Comparison of temperature dependence of piezoelectricity

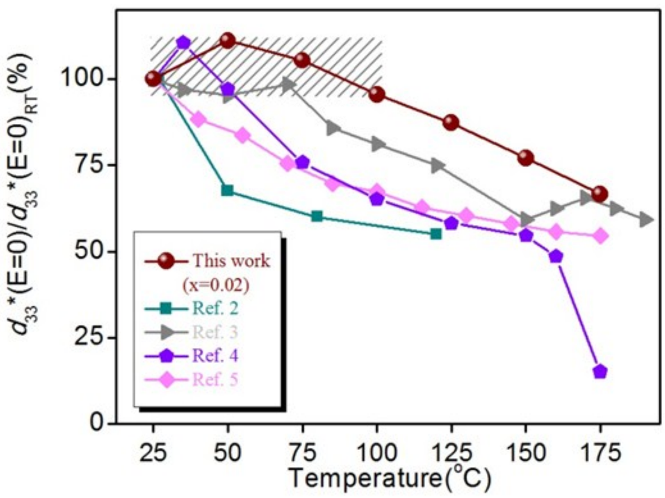

Fig. S6 Comparison of temperature dependence of small signal d_{33}^{*}(E=0)for various ceramics as normalized to its room temperature value $d_{33}^{*}(E=0)_{RT}$.

VII. Temperature dependence of ferroelectric property

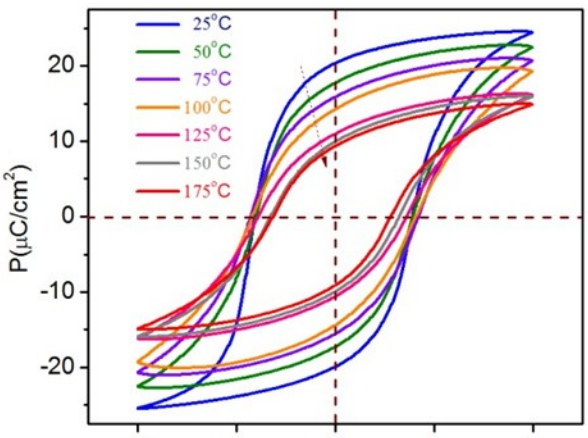

Fig. S7 P-E loops of of $L_{0.02}$KNN-6.5BZ-1BNT ceramics at different temperatures.

Reference

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