ADVANCED MATERIALS

Supporting Information

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Coherent Precipitates with Strong Domain Wall Pinning in Alkaline Niobate Ferroelectrics

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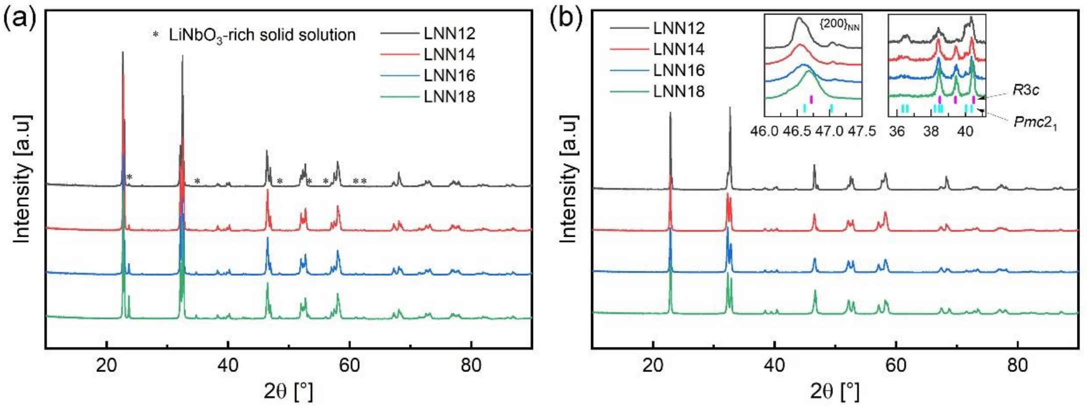

Figure S1. (a) XRD patterns of LNN samples calcined at 850°C for 4 h. The composition range is $0.12 < x < 0.18$. Reflections from the LN_{ss} phase are marked with asterisks. (b) XRD patterns of as-quenched LNN samples ($0.12 < x < 0.18$) from 1300°C. Enlarged region of the {200} reflections and the superlattice reflections are highlighted in the insets. The positions of reflections from the $R3c$ and $Pmc2_1$ phases are labeled with purple and cyan ticks, respectively.

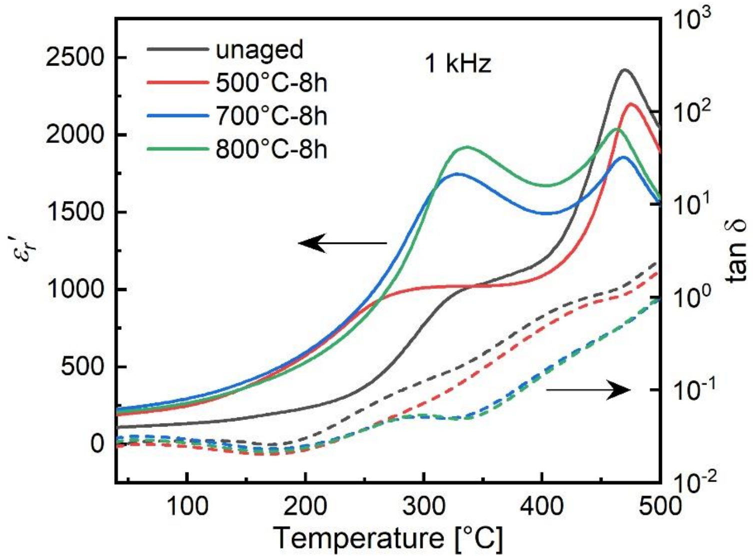

Figure S2. Temperature-dependent permittivity curves of unaged LNN18 and LNN18 aged at 500°C–800°C for 8 h. The permittivity was measured during the heating process and the heating rate was 2 K/min. The measuring frequency was 1 kHz.

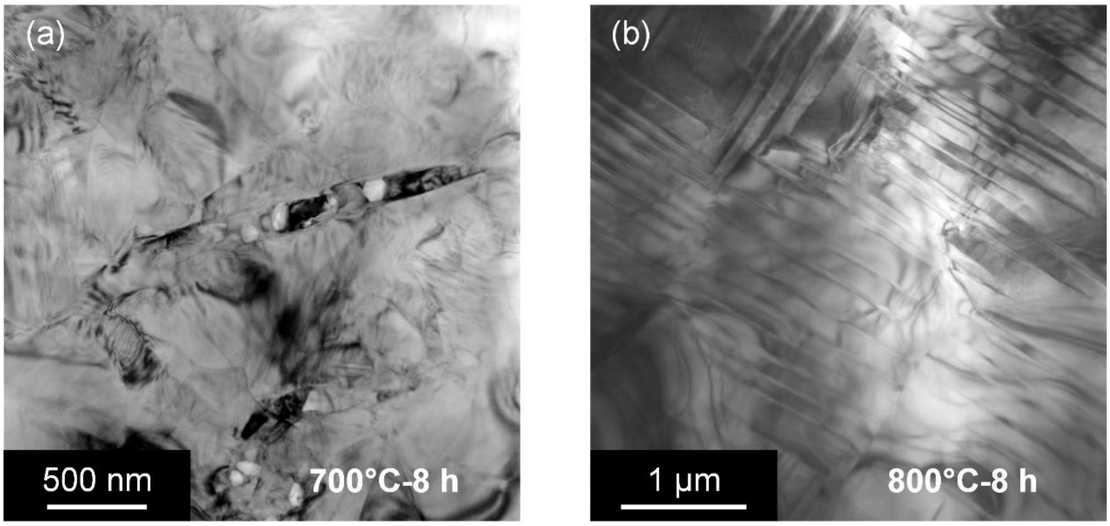

Figure S3. Bright-field TEM images of (a) 700°C-8 h and (b) 800°C-8 h LNN18 samples. The 700°C-8 h sample reveals much larger precipitates as compared to the 600°C-8 h sample, but the number density of the precipitate drops significantly. The 800°C-8 h has no precipitates inside the ferroelectric grains.

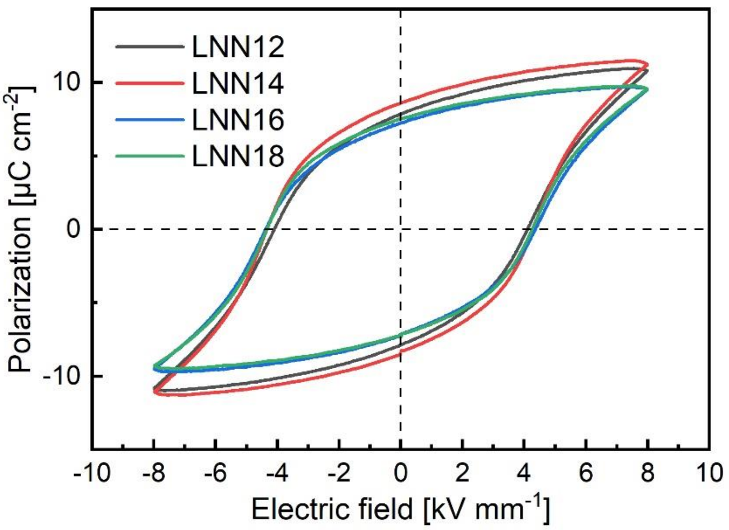

Figure S4. Polarization hysteresis loops of unaged LNN samples with composition of $0.12 < x < 0.18$. An electric field with a frequency of 1 Hz of a bipolar triangular waveform was applied.

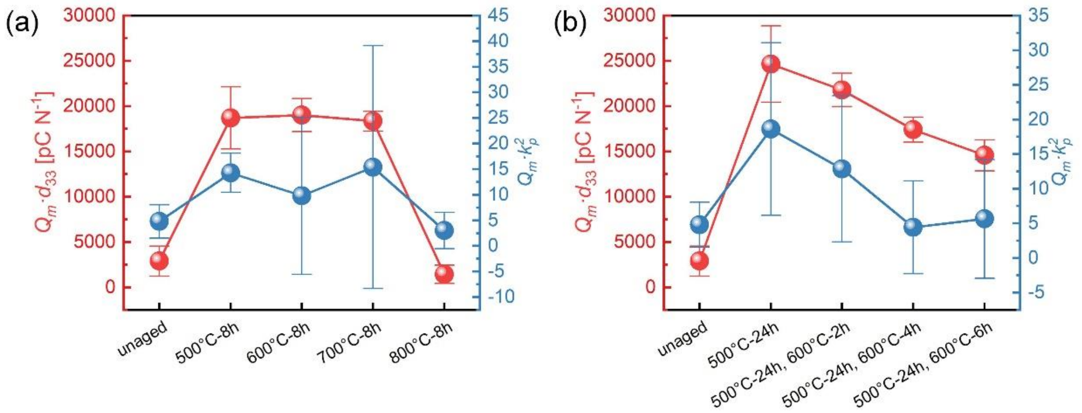

Figure S5. Complete form of figures of merit of the (a) one-stage and (b) two-stage aged LNN18 ceramics, where $Q_m \cdot d$ is for resonance actuator applications (*e.g.*, ultrasonic motors) and $Q_m \cdot k^2$ is for resonance transducer applications (*e.g.*, piezoelectric transformers, sonars).[1]

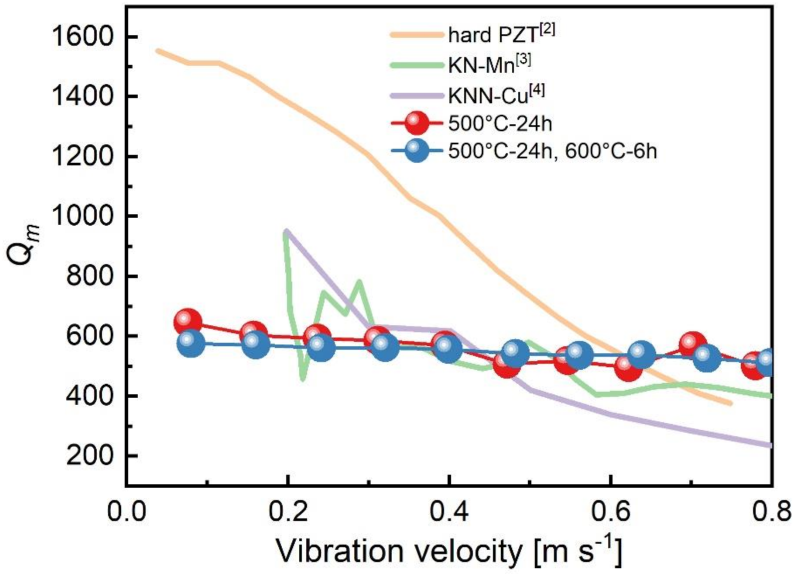

Figure S6. High-vibration-velocity Q_m of aged LNN18, hard-doped PZT[2], Mn-doped $KNbO_3$,[3] and Cu-doped KNN.[4] The precipitation-hardened LNN samples exhibit larger Q_m than the reference above the vibration velocity of ~0.6 m/s.

References:

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[4] E. A. Gurdal, S. O. Ural, H. Y. Park, S. Nahm, K. Uchino, *Sensors and Actuators A: Physical* **2013**, *200*, 44.