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Achieving high energy efficiency and energy density in $PbHfO_3$-based antiferroelectric ceramics

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Table. S1-1 The permittivity of PLHS*x* ceramics at room temperature.

Composition (Hf^{4+})	1kHz	10 kHz	100 kHz	1000 kHz
0.41	245	240	237	235
0.43	256	253	250	249
0.45	280	278	277	277
0.47	294	293	292	291

Table. S1-2 The permittivity of PLHS*x* ceramics at the temperature of AFE-MCC.

Composition (Hf^{4+})	1kHz	10 kHz	100 kHz	1000 kHz
0.41	280	278	275	273
0.43	299	296	294	293
0.45	332	330	329	330
0.47	351	350	349	349

Table. S1-3 The permittivity of PLHS*x* ceramics at the temperature of MCC-PE.

Composition (Hf^{4+})	1kHz	10 kHz	100 kHz	1000 kHz
0.41	278	257	248	247
0.43	290	273	267	266
0.45	310	305	302	302
0.47	331	325	322	321

Table. S2-1 The dielectric loss of PLHS*x* ceramics at room temperature.

Composition (Hf^{4+})	1kHz	10 kHz	100 kHz
0.41	0.03	0.0129	0.0089
0.43	0.019	0.01	0.007
0.45	0.01	0.005	0.002
0.47	0.009	0.004	0.002

Table. S2-2 The dielectric loss of PLHS*x* ceramics at the temperature of AFE-MCC.

Composition (Hf^{4+})	1kHz	10 kHz	100 kHz
0.41	0.0182	0.009	0.0076
0.43	0.011	0.006	0.005
0.45	0.008	0.004	0.002
0.47	0.006	0.003	0.002

Table. S2-3 The dielectric loss of PLHS*x* ceramics at the temperature of MCC-PE.

Composition (Hf^{4+})	1kHz	10 kHz	100 kHz
0.41	0.086	0.042	0.013
0.43	0.0624	0.031	0.009
0.45	0.023	0.011	0.005
0.47	0.022	0.011	0.006

Table. S3 The average ionic radii of A-site and B-site cations and tolerance factor of PLHS*x* ceramics.

Composition (Hf^{4+})	$R_{A\text{-site}}$ (Å)	$R_{B\text{-site}}$ (Å)	Tolerance factor
0.41	1.4874	0.6982	0.9795

0.43	1.4874	0.6986	0.9794
0.45	1.4874	0.6990	0.9792
0.47	1.4874	0.6994	0.9790

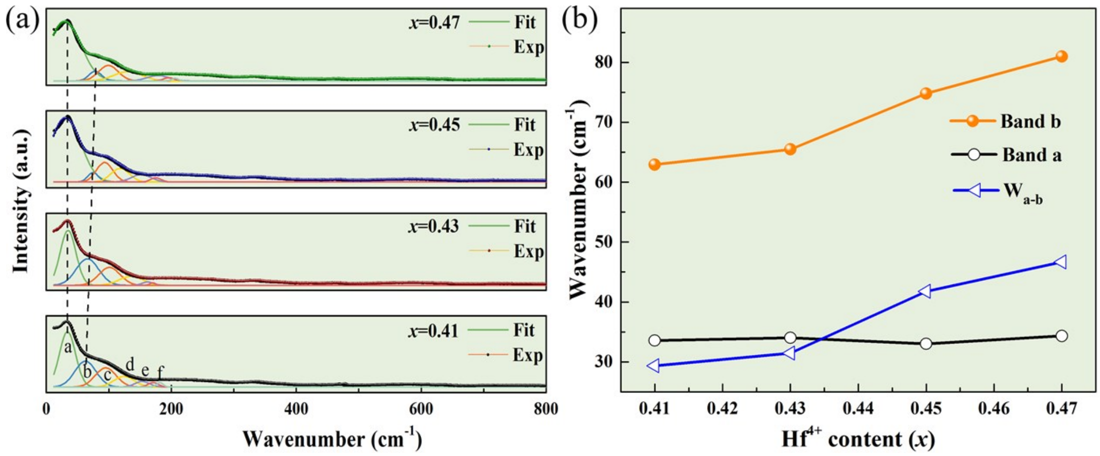

Fig. S1 (a) The Raman spectra and the Lorentzian deconvolutions of PLHSx antiferroelectric ceramics; (b) The evolution of position between band a, b and Wa-b (Wa-b=Wb-Wa) as a function of Hf4+ content.

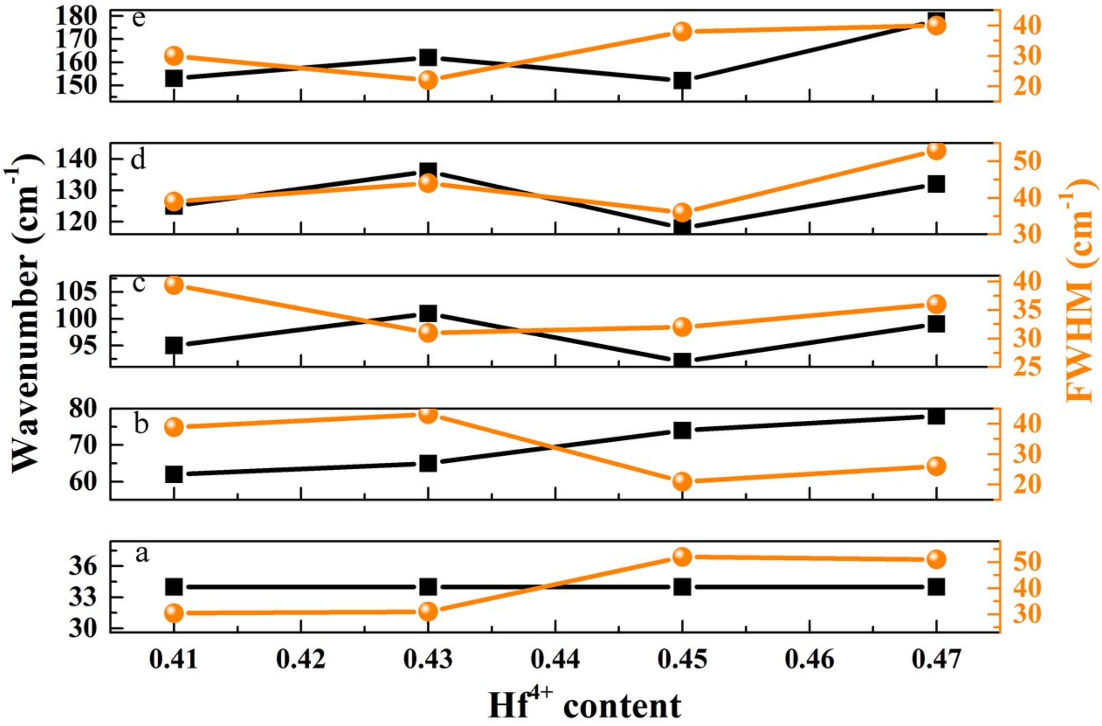

Fig. S2 The temperature dependence of wavenumber and FWHM of modes (a, b, c, d, and e) for PLHSx ceramics.

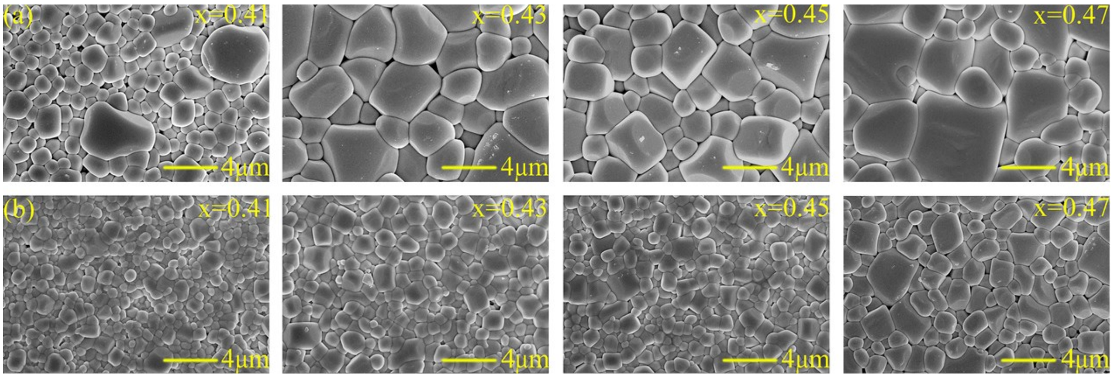

Fig. S3-1 SEM of PLHSx ceramics sintered at different temperatures prepared by (a) traditional method (b) rolling process.

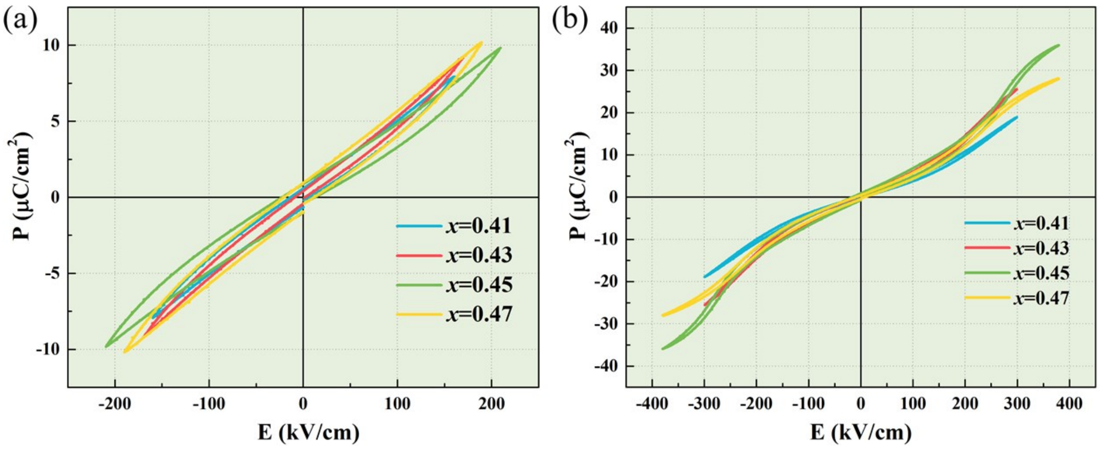

Fig. S3-2 The P-E loops of Pb0.98La0.02(HfxSn1-x)0.995O3 ceramics made via (a) traditional method and (b) rolling process.

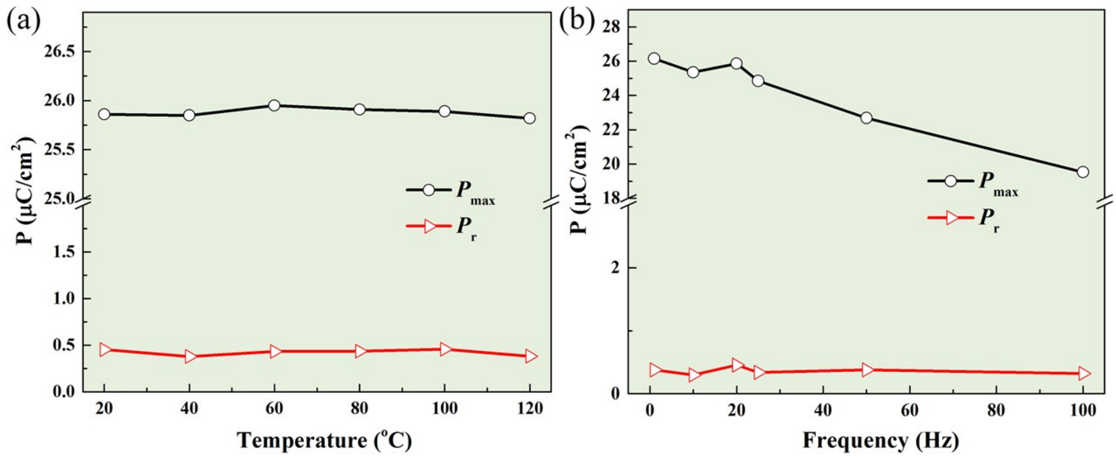

Fig. S4 The Pmax and Pr as a function of (a) temperature and (b) frequency.