

Optimizing piezoelectric and ferroelectric properties in BCZT ceramics via Nd/Mn co-doping and sintering engineering

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Table S1. Cell volume and density of x mol% Nd/Mn BCZT ceramics sintered at different temperatures.

Composition (mol%)	Sintering temperature (°C)	Theoretical volume (Å ³)	Bulk density (g/cm ³)	Theoretical density (g/cm ³)	Relative density (%)
x = 0.05	1490	64.60	5.10	5.73	89.1
	1505	64.60	5.16	5.73	90.1
	1520	64.47	5.19	5.74	90.4
x = 0.1	1490	64.40	5.11	5.75	88.9
	1505	64.40	5.25	5.75	91.3
	1520	64.40	5.27	5.75	91.7
x = 0.5	1490	64.37	5.08	5.74	88.5
	1505	64.37	5.27	5.74	91.7
	1520	64.37	5.20	5.74	90.6
x = 1	1475	64.42	5.01	5.73	87.4
	1490	64.42	5.09	5.73	88.8
	1505	64.41	4.99	5.73	87.1

Table S2. P_r , E_c , d_{33}^* , K_p , Q_m and d_{33} of x mol% Nd/Mn BCZT ceramics prepared at different sintering temperatures.

Composition (mol%)	Sintering temperature (°C)	P_r ($\mu\text{C}/\text{cm}^2$)	E_c (kV/cm)	d_{33}^* (pm/V)	K_p	Q_m	d_{33} (pC/N)
x = 0.05	1490	8.81	3.10	647.2	0.365±0.022	130.3±7.4	175.8±13.1
	1505	9.39	3.83	657.1	0.322±0.025	97.8±2.7	276.0±6.7
	1520	9.42	3.82	683.0	0.357±0.022	131.4±6.4	232.3±8.1
x = 0.1	1490	8.31	3.07	598.4	0.335±0.026	132.6±2.0	217.0±18.2
	1505	8.26	3.02	630.1	0.327±0.028	131.2±4.0	240.0±13.1
	1520	8.91	3.44	128.8	0.343±0.026	165.3±7.8	222.3±7.4
x = 0.5	1490	7.86	3.08	668.7	0.338±0.025	424.5±6.0	278.0±7.3
	1505	8.13	3.28	670.4	0.329±0.026	392.8±6.0	284.2±4.5
	1520	8.19	3.41	685.1	0.310±0.024	259.9±3.9	257.6±6.4
x = 1	1475	7.37	2.84	584.1	0.242±0.022	100.6±4.9	212.2±12.4
	1490	7.54	2.89	627.5	0.291±0.022	203.7±9.5	209.7±8.7
	1505	7.42	2.85	595.2	0.278±0.028	215.6±4.5	197.7±9.7

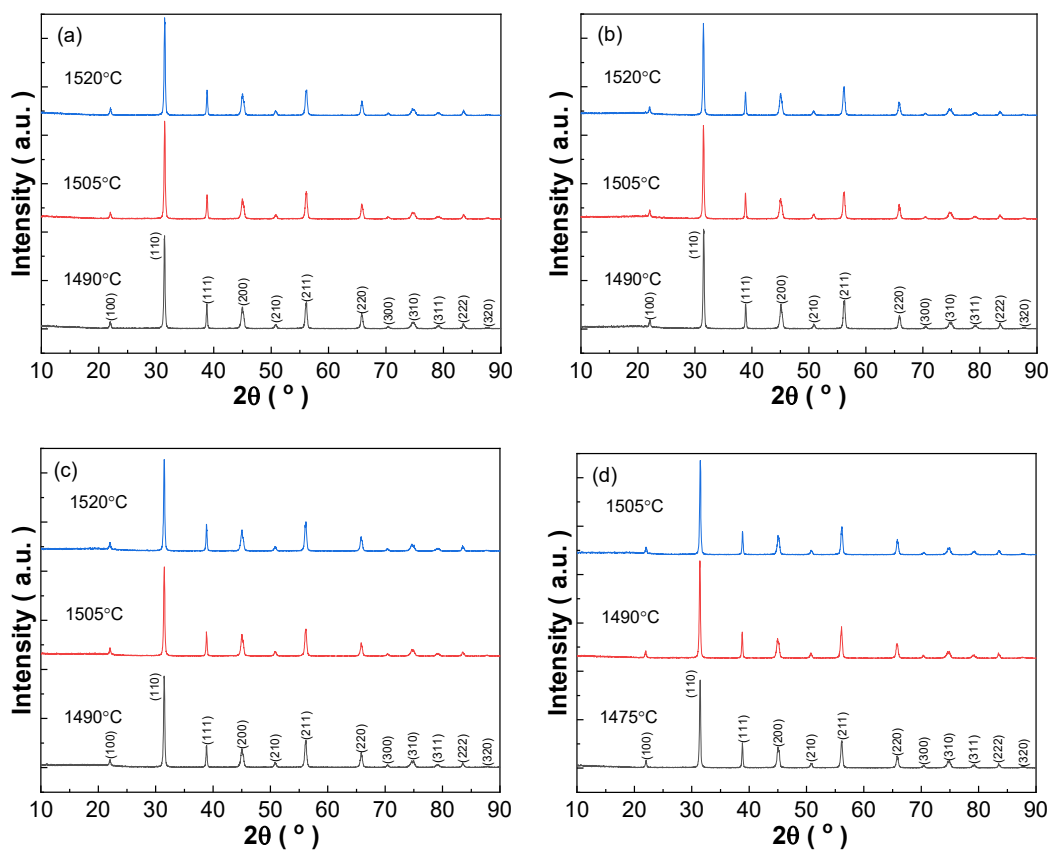


Figure S1. XRD patterns of x mol% Nd/Mn BCZT ceramics prepared at different sintering temperatures.

(a) $x=0.05$; (b) $x=0.1$; (c) $x=0.5$; (d) $x=1$.

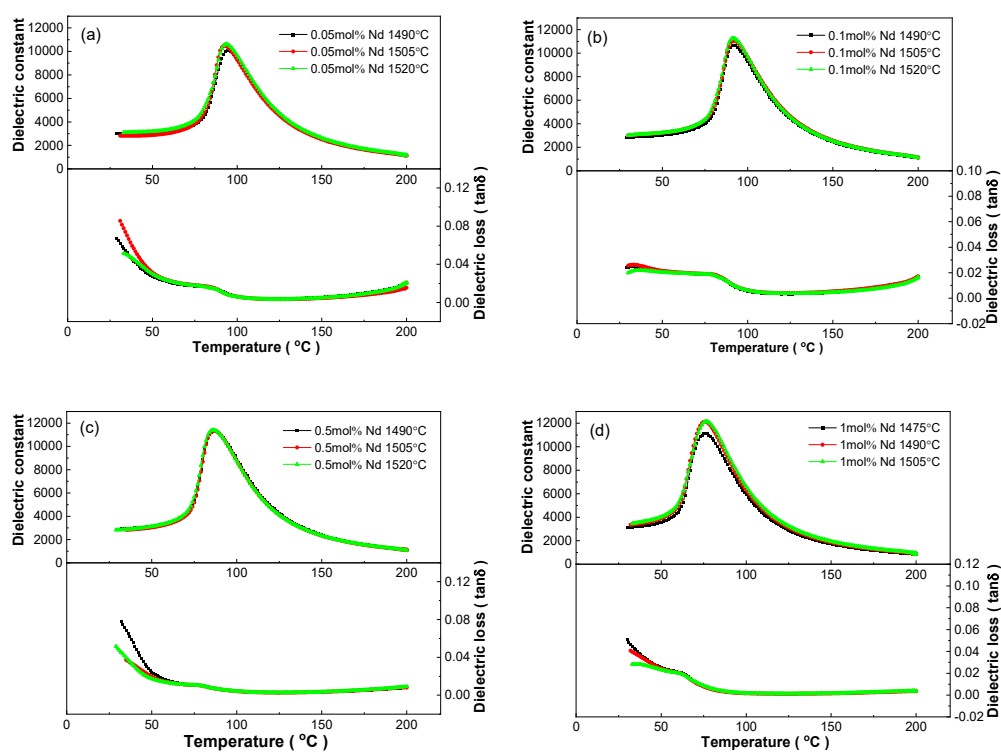


Figure S2. Dielectric performance-temperature relationship of x mol% Nd/Mn BCZT

ceramics prepared at different sintering temperatures at 1 kHz.

(a) $x=0.05$; (b) $x=0.1$; (c) $x=0.5$; (d) $x=1$.

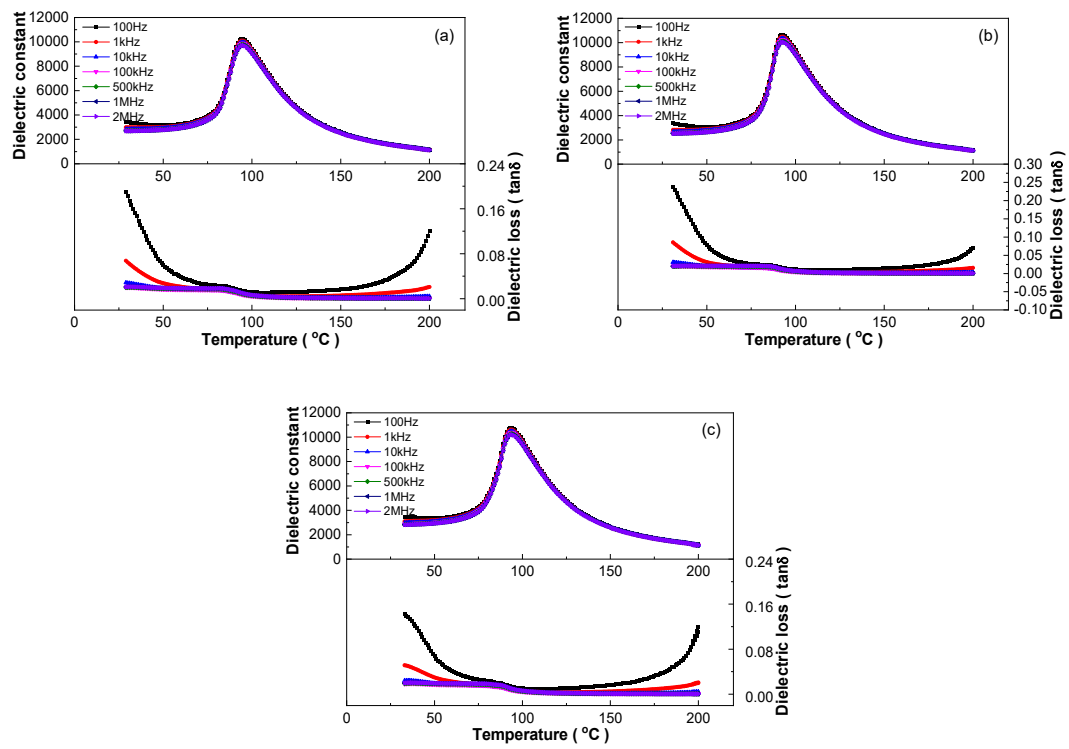


Figure S3. Effects of frequency on dielectric properties of 0.05 mol% Nd/Mn BCZT ceramics prepared at different sintering temperatures.

(a) 1490 °C; (b) 1505 °C; (c) 1520 °C.

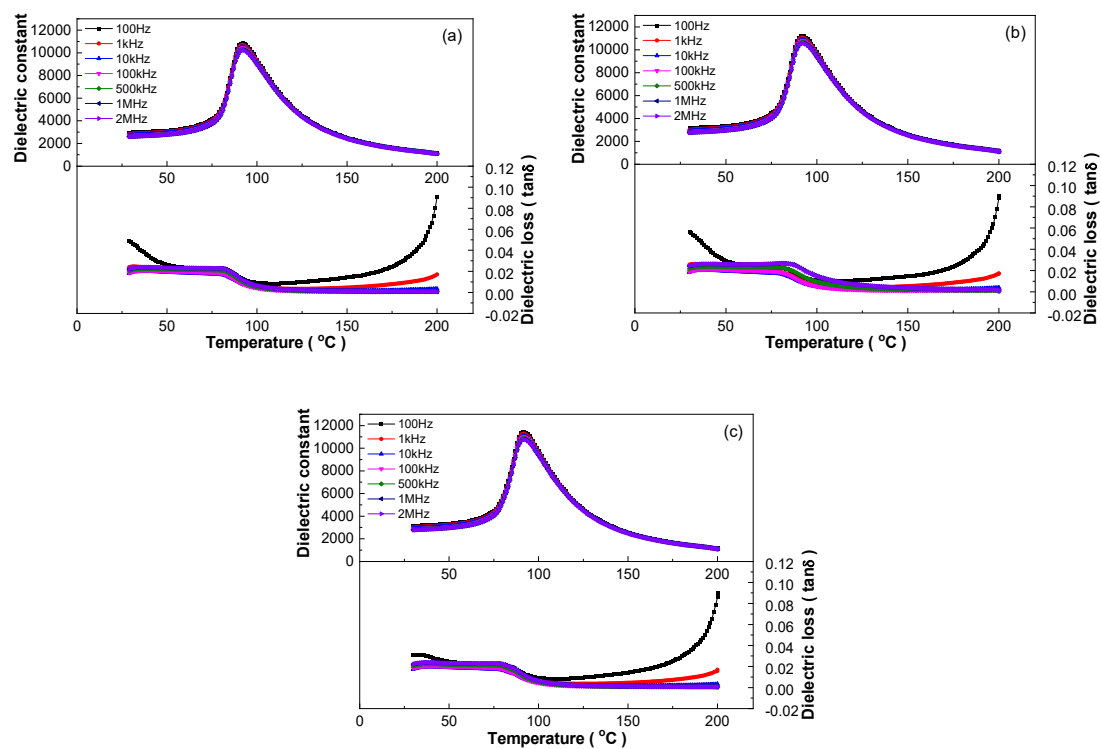


Figure S4. Effects of frequency on dielectric properties of 0.1 mol% Nd/Mn BCZT

ceramics prepared at different sintering temperatures.

(a) 1490 °C; (b) 1505 °C; (c) 1520 °C.

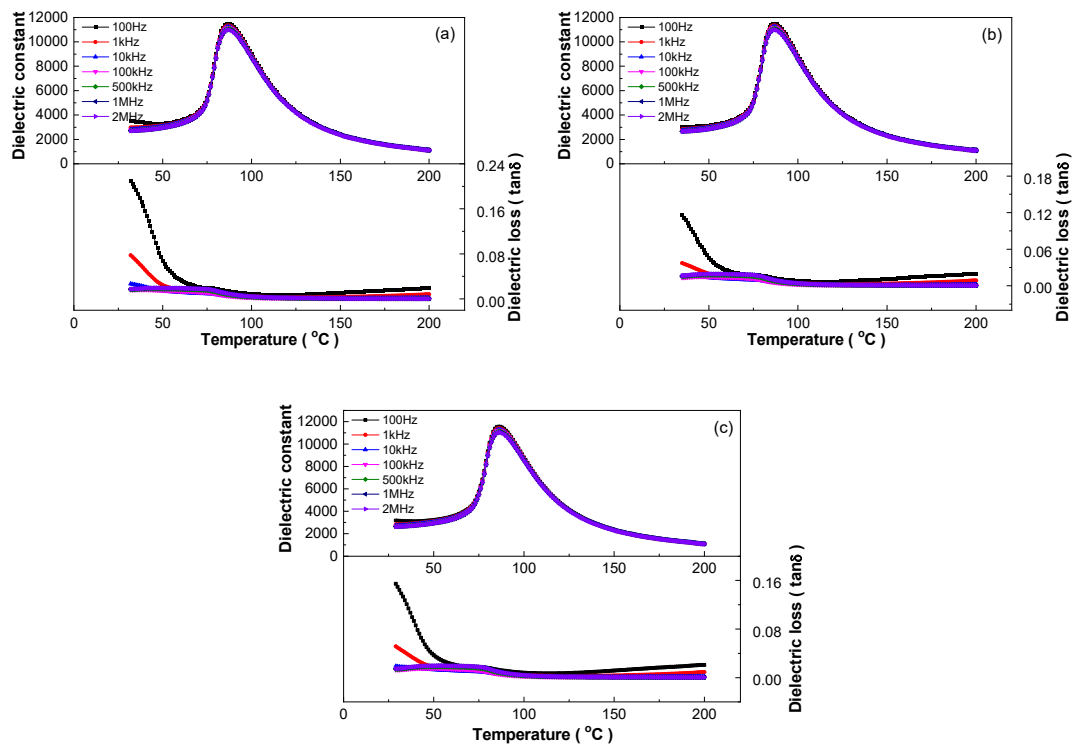


Figure S5. Effects of frequency on dielectric properties of 0.5 mol% Nd/Mn BCZT ceramics prepared at different sintering temperatures.

(a) 1490 °C; (b) 1505 °C; (c) 1520 °C.

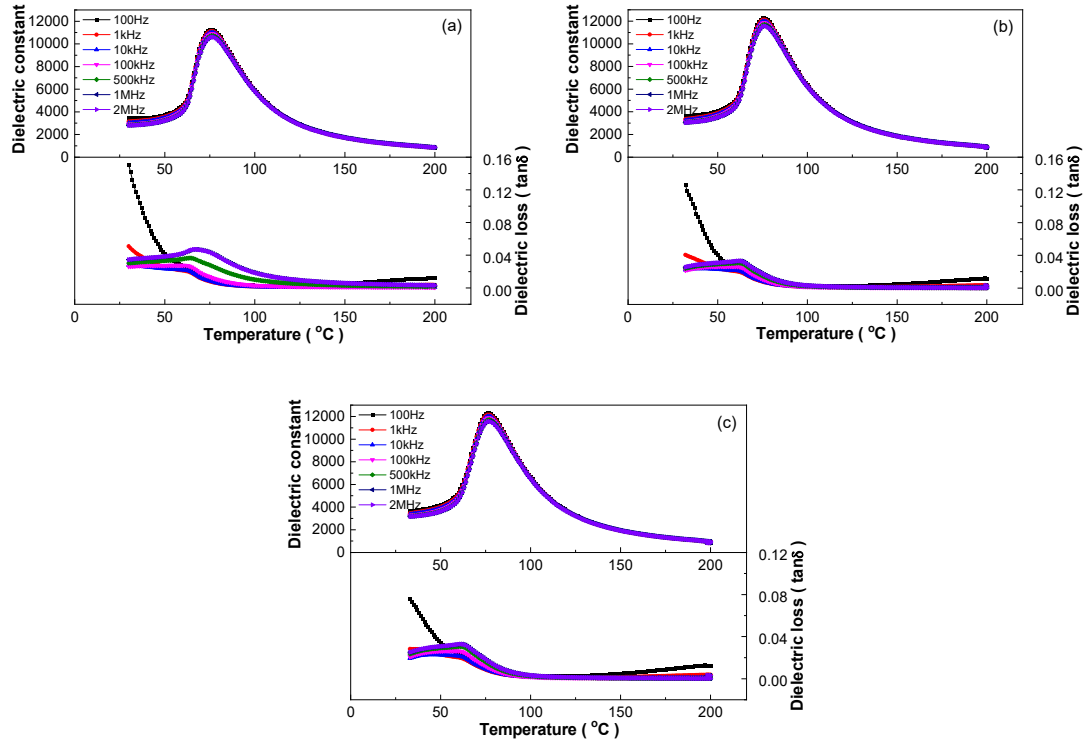


Figure S6. Effects of frequency on dielectric properties of 1 mol% Nd/Mn BCZT ceramics prepared at different sintering temperatures.

(a) 1475 °C; (b) 1490 °C; (c) 1505 °C.

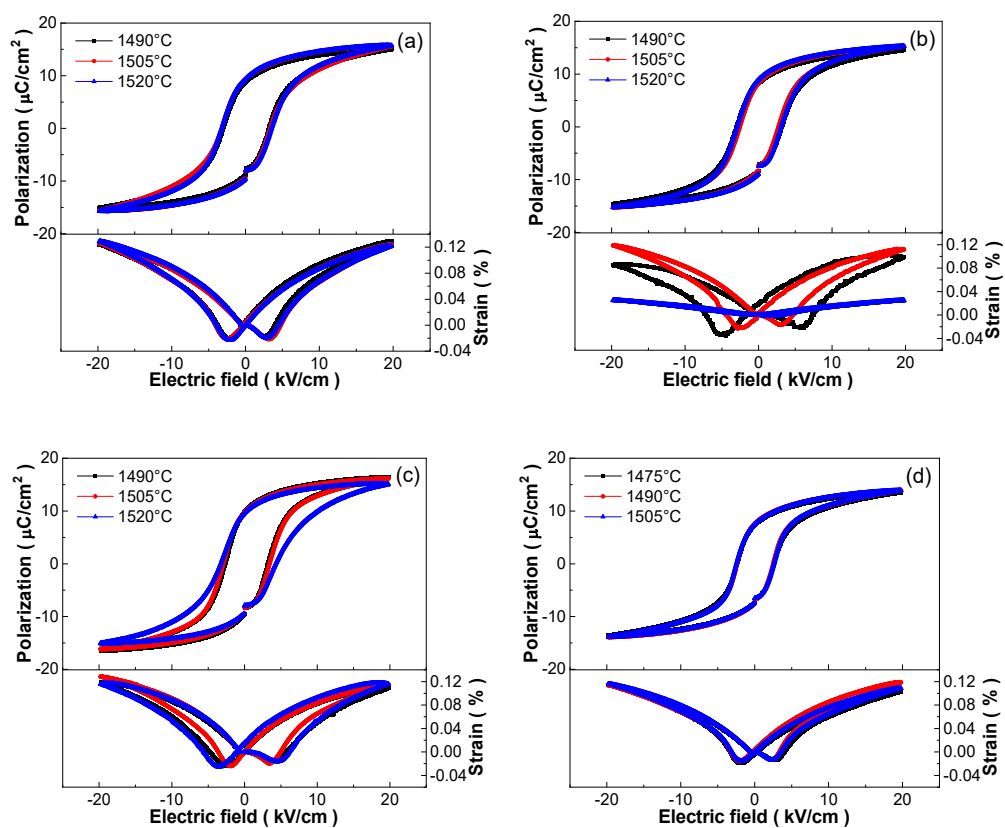


Figure S7. P-E hysteresis loops and S-E curves of x mol% Nd/Mn BCZT ceramics prepared at different sintering temperatures.

(a) $x=0.05$; (b) $x=0.1$; (c) $x=0.5$; (d) $x=1$.

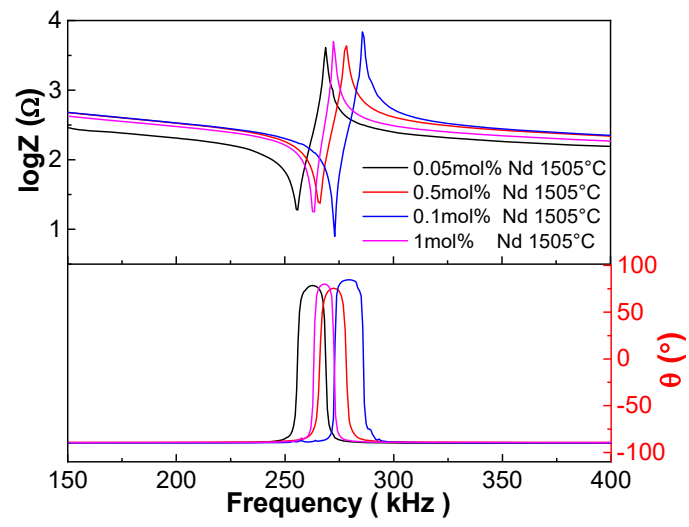


Figure S8. Impedance and phase angle of x mol% Nd/Mn BCZT ceramics prepared at respective selected sintering temperatures (x = 0.05 mol%, 0.1 mol%, 0.5 mol%, 1 mol%).

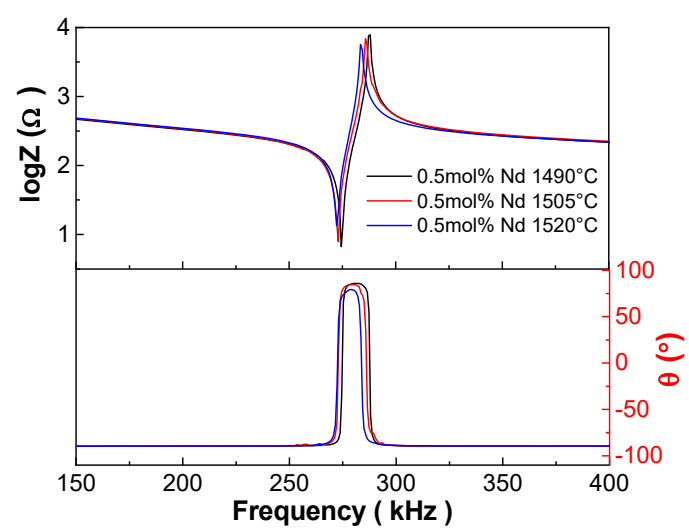


Figure S9. Impedance and phase angle of the 0.5 mol% Nd/Mn BCZT ceramics sintered at different temperatures.