

Lead-Free Piezoelectric Material Data

Parameters of Lead-Free Materials

		BNT materials					KNN materials	
			Unit	PIC700 ¹⁾	PIC701 ¹⁾		PIC753 ¹⁾	PIC758 ²⁾
Physical and dielectric properties								
Density		ρ	g/cm³	5.7	5.7		4.8	4.8
Curie temperature		T _C	°C	190 ³⁾	230 ³⁾		300	290
Coercive field strength		E _c	kV/mm	2.8	3.9		1.1	1.2
Relative permittivity	in polarization direction ⊥ to polarity	ε ^T ₃₃ / ε ₀		680	542		1341	850
		ε ^T ₁₁ / ε ₀		655	629		1222	950
Dielectric loss factor		tan δ	10 ⁻³	30	20		13	20
Electro-mechanical properties								
Coupling factor		k _p		0.14	0.13		0.53	0.43
		k _t		0.41	0.39		0.45	0.42
		k ₃₁		0.09	0.08		0.30	0.27
		k ₃₃		0.43	0.37		0.59	0.57
		k ₁₅		0.25	0.31		0.58	0.55
Piezoelectric charge coefficient		d ₃₁	10 ⁻¹² C/N	-20	-17		-118	-75
		d ₃₃		100	71		241	170
		d ₁₅		90	108		316	287
Piezoelectric voltage coefficient		g ₃₁	10 ⁻³ Vm/N	-3.3	-3.5		-9.9	-9.9
		g ₃₃		16	14.8		20.0	22.5
		g ₁₅		14.5	19.4		29.2	34.1
Acousto-mechanical properties								
Frequency coefficient (serial resonance fs)		N _p	Hz · m	2984	3071		2869	
		N _i		2228	2302		2065	2296
		N _s		2420	2403		2445	2582
		N _t		2576	2503		2739	3048
		N _s		1516	1535		1555	1315
Elastic compliance coefficient		S ₁₁ ^E	10 ⁻¹² m²/N	8.8	8.2		12.2	9.8
		S ₃₃ ^E		9.1	7.5		13.6	11.6
Elastic stiffness coefficient		C ₃₃ ^D	10 ¹⁰ N/m²	15.1	13.5		17.2	17.8
Mechanical quality factor		Q _m		100	100		200	585
Temperature stability								
Temperature coefficient of ε ^T ₃₃ (in the range of -20 to +125 °C)		TK ε ₃₃	10 ⁻³ /K					
Time stability (relative change of the parameters per decade of time in %)								
Relative permittivity		C _ε						
Coupling factor		C _k	%					

Modified materials on request. The materials are not yet approved for production.
The reliability of lead-free materials must be re-evaluated in each application case. It may differ from the reliability of materials containing lead.

- 1) Preliminary data, subject to change
- 2) Material under development, no specifications
- 3) Depolarization temperature

The following values apply approximately for lead-free materials from PI Ceramic:
Specific heat capacity:
WK KNN = approx. 420 J kg⁻¹ K⁻¹
WK BNT = approx. 101 J kg⁻¹ K⁻¹
Specific thermal conductivity: WL
KNN = approx. 2.5 W m⁻¹ K⁻¹
WL BNT = approx. 1.4 W m⁻¹ K⁻¹

The data is determined using test pieces with the geometric dimensions laid down in EN 50324-2 standard and are typical values.
All data provided is determined 24 h to 48 h after the time of polarization at an ambient temperature of 23 ±2 °C. A complete coefficient matrix of the individual materials is available on request. If you have any questions about the interpretation of the material characteristics, please contact PI Ceramic.

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Standard Piezoelectric Material Data

Specific Parameters of Standard Materials

			Ferroelectric soft PZT materials							Ferroelectric hard PZT materials				
			Unit	PIC151	PIC255/ PIC252	PIC155	PIC153	PIC152		PIC181	PIC184	PIC144	PIC241	PIC300
Physical and dielectric properties														
Density		ρ	g/cm³	7.8	7.8	7.75	7.6	7.75		7.85	7.75	7.9	7.8	7.75
Curie temperature		T _C	°C	250	350	340	160	340		330	320	320	270	370
Coercive field strength (at 25 °C)		E _c	kV/mm	1.0	1.5	1.0	0.6	0.8						
Relative permittivity	in polarization direction	ε ^T ₃₃ / ε ₀		2500	1800	1600	4500	1350		1200	1200	1300	1750	1030
	⊥ to polarity	ε ^T ₁₁ / ε ₀		1980	1750	1850	3500	1100		1250	1250	1500	1500	960
Dielectric loss factor		tan δ	10 ⁻³	20	20	25	30	15		3	3	3	5	3
Electro-mechanical properties														
Coupling factor		k _p		0.62	0.62	0.62	0.62	0.48		0.56	0.55	0.60	0.55	0.47
		k _t		0.53	0.47	0.48	0.49	0.41		0.46	0.44	0.48	0.45	0.41
		k ₃₁		0.38	0.35	0.35	0.33	0.25		0.32	0.30	0.30	0.32	0.27
		k ₃₃		0.69	0.69	0.69	0.72	0.58		0.66	0.63	0.66	0.65	0.57
		k ₁₅		0.65	0.66	0.65	0.66	0.46		0.63	0.65	0.65	0.63	0.48
Piezoelectric charge coefficient		d ₃₁	10 ⁻¹² C/N	-210	-180	-165	-295	-90		-120	-99	-105	-140	-85
		d ₃₃		500	400	360	600	240		265	220	225	300	190
		d ₁₅		610	550	540	780	235		475	421	419	431	248
Piezoelectric voltage coefficient		g ₃₁	10 ⁻³ Vm/N	-10.1	-11.8	-12.8	-7.9	-8.7		-10.6	-10.7	-10.4	-9.2	-9.3
		g ₃₃		21.5	25	27.9	16.4	23.4		23	22.4	23.3	19.9	20.8
		g ₁₅		33.9	38.4	46	23.3	23.7		37.2	35.8	33.9	33.3	29.3
Acousto-mechanical properties														
Frequency coefficient (serial resonance fs)		N _p	Hz · m	1940	2000	1930	1940	2280		2270	2175	2170	2200	2400
		N ₁		1500	1420	1500	1380	1570		1640	1590	1620	1590	1700
		N ₃		1360	1370	1340	1345	1530		1560	1560	1540	1550	1700
		N _t		1950	2000	1990	2020	2100		2110	2035	2035	2020	2100
		N ₅		830	870	820	890	1130		1000	960	960	980	1050
Speed of sound		v ₁ ^E	m/s	3000	2840	3000	2760	3140		3280	3180	3240	3180	3400
		v ₃ ^D		3820	3690	3750	3650	3750		4060	3990	4090	3890	3990
		v ₅ ^D		2290	2340	2340	2260	2500		2400	2090	2450	2440	2330
		v _t ^D		3900	4000	3980	4040	4200		4220	4070	4070	4040	4200
Elastic compliance coefficient		S ₁₁ ^E	10 ⁻¹² m²/N	16.4	16	16.1	17.2	13.1		11.8	12.2	12.4	12.6	11.2
		S ₃₃ ^E		19.4	19	19.3	20	14.8		13.3	13.7	14.3	14.4	12
Elastic stiffness coefficient		C ₃₃ ^D	10 ¹⁰ N/m²	15.7	15.4	15.8	15.5	16.6		17	15.8	16.6	15.5	16.3
Acoustic impedance (pressure wave in polarization direction)		Z ³³	MRayl (=10 ⁶ kg/m²/s)	35.0	34.7	35.0	34.4	35.9		36.6	35.1	36.2	34.9	35.7
Mechanical quality factor		Q _m		100	80	80	50	100		2000	400	1000	500	1400
Temperature stability														
Temperature coefficient of ε ^T ₃₃ (in the range of -20 to +125 °C)		TK ε ₃₃	10 ⁻³ /K	4	3	4	15	2		3	4		3	2
Time stability (relative change of the parameters per decade of time in %)														
Relative permittivity		C _ε			-1.0	-2.0					-4.0			
Coupling factor		C _k	%		-1.0	-2.0					-2.0			

Modified materials on request.

Recommended operating temperature: up to 50 % of Curie temperature.

The following values are valid approximations for all PZT materials from PI Ceramic:

Specific heat capacity:
WK = approx. 350 J kg⁻¹ K⁻¹

Specific thermal conductivity:

WL = approx. 1.1 W m⁻¹ K⁻¹

Poisson's ratio (lateral contraction):
 σ = approx. 0.34

Coefficient of thermal expansion:

α_3 = approx. -4 to -6 × 10⁻⁶ K⁻¹
(in the polarization direction, shorted)
 α_1 = approx. 4 bis 8 × 10⁻⁶ K⁻¹ (perpendicular to the polarization direction, shorted)

Static compressive strength:
>600 MPa

The data is determined using test pieces with the geometric dimensions laid down in EN 50324-2 standard and are typical values.

All data provided is determined 24 h to 48 h after the time of polarization at an ambient temperature of 23 ±2 °C.

A complete coefficient matrix of the individual materials is available on request. If you have any questions about the interpretation of the material characteristics, please contact PI Ceramic.

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