PZT Materials
Complete Properties

Property	Symbol	Units	Hard Material Type						
			K1000	**NCE81***	**K1100**	**K1300**	**NCE40***	**NCE41***	**K1450**
Dielectric Constant (1 kHz)	K^T_3		1000	1030	1100	1300	1250	1350	1450
Dielectric Loss Factor (1 kHz)	$\tan\delta_e$		<0.004	0.0017	<0.004	<0.005	0.0025	0.004	<0.012
Dielectric Loss Factor (at 0.4kV/mm)	$\tan\delta_e$			0.006			0.011		0.02
Dielectric Constant (1 kHz)	K^T_1					1250			
Clamped Dielectric Constant	K^S_3		445		550	600			
Density	ρ	kg/m^3	7550	7750	7550	7550	7700	7930	7550
Curie Point	T_c	ºC	325	300	325	325	318	318	320
Mechanical Quality Factor	Q_m		1000	1300	550	500	700	1400	350
Coupling Coefficients	k_p		0.56	0.56	0.57	0.58	0.58	0.57	0.57
	k_{33}		0.64	0.69	0.66	0.7	0.68	0.68	
	k_{31}		0.33	0.31	0.33	0.32	0.35	0.33	0.32
	k_t		0.52	0.47	0.52	0.51	0.48	0.5	
	k_{15}		0.58			0.65			
Piezoelectric Charge	d_{31}	$Coul/N \times 10^{-12}$ (or)	-110	-98	-120	-125	-133	-130	-130
Displacement Coefficient	d_{33}	$m/V \times 10^{-12}$	230	255	250	300	304	310	350
	d_{15}					500			
Piezoelectric Voltage Coefficient	g_{31}	$V \cdot m/N \times 10^{-3}$	-14	-10.8	-12.3	-10.9	-12	-10.9	-10.1
Voltage Coefficient	g_{33}		26	28	25.7	26.1	27.5	25.9	30.4
	g_{15}					45.2			
Frequency Constants	N_p	Hz·m	2270	2300	2180	2200	2170	2280	2080
	N_{tr}		2067	2130	2024	2100	2070	2000	
	N_{ta}		2361		2310	2375			
	N_{33}		1550		1520	1500			
	N_{31}		1630		1620	1570			
	N_H		1065		1050	1040			1000
Poisson's Ratio	Y		0.32		0.32	0.34			

Property	Symbol	Units	Hard Material Type						
			K1000	**NCE81***	**K1100**	**K1300**	**NCE40***	**NCE41***	**K1450**
Elastic Constants Short Circuit	S^E_{11}	$x\ 10^{-12} m^2/N$	12	11.1	12.1	11.1	12.4	12.5	12.5
	S^E_{33}		14.6	15	14.7	16	14.6	16	
	S^E_{12}		-3.9	-4.3	-3	-3.8	-3.4	-4.1	
	S^E_{13}		-5.2	-5.4	-5.3	-4.5	-5.4	-5.7	
	S^E_{55}			34.5		50.4	34.5	39.5	
	S^E_{66}		31.8	30.8	30.2	29.8	31.5	33.2	
Elastic Constants Open Circuit	S^D_{11}	$x\ 10^{-12} m^2/N$	10.5	10	10.7	10	10.9	11.1	11.2
	S^D_{33}		9.5	7.9	8.2	8.2	7.8	8.6	
	S^D_{55}			23.1		29.1	23.1	20.8	
Elastic Constants Short Circuit	Y^E_{11}	$x\ 10^{10} N/m^2$	8.3	9.0	8.3	9	8.1	8.0	8
	Y^E_{33}		6.8	6.7	6.8	6.3	6.8	6.3	
Elastic Constants Open Circuit	Y^D_{11}	$x\ 10^{10} N/m^2$	9.5	10	9.3	10	9.2	9.0	8.9
	Y^D_{33}		10.5	12.7	12.3	12.2	12.7	11.6	

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Data represent typical material values. Actual production values may vary ±10% for dielectric properties and ±5% for electromechanical and physical properties.

Property	Symbol	Units	Soft Material Type											
			3195STD	3195HD	NCE51*	3222HD	NCE56*	3203STD	3221HD	3203HD	3241HD	NCE55*	3257HD	3265HD
Dielectric Constant (1 kHz)	K^T_3		1800	1900	1900	2650	2900	3250	3450	3800	4100	5000	5700	6500
Dielectric Loss Factor (1 kHz)	$\tan\delta_e$		<0.02	<0.02	0.015	<0.02	0.014	<0.02	<0.02	<0.02	<0.02	0.022	<0.03	<0.03
Dielectric Constant (1 kHz)	K^T_1		1500	1600		2948		2800	3550	3200	3420		5900	5400
Clamped Dielectric Constant	K^S_3		875	900		800		775	1000	1200	1300		2050	2100
Density	ρ	kg/m^3	7700	7950	7850	7900	7650	7700	7870	7870	7880	7920	8220	8220
Curie Point	T_c	ºC	350	350	360	270	242	225	242	225	223	160	155	>135
Mechanical Quality Factor	Q_m		80	80	80	80	75	50	50	50	50	70	75	75
Coercive Field (Measured < 1 Hz)	Ec	kV/cm	14.9	12				10.6	8.8	8	9			
Remanent Polarization	P_r	$\mu Coul/cm^2$	39.2	39				37.2	38.5	39	38.5			
Coupling Coefficients	k_p		0.63	0.68	0.65	0.72	0.64	0.69	0.74	0.75		0.65	0.7	0.66
	k_{33}		0.7	0.72	0.74	0.74	0.74	0.7	0.78	0.78	0.77	0.72	0.76	0.73
	k_{31}		0.35	0.4	0.39	0.45	0.38	0.41	0.46	0.43	0.44	0.37	0.41	0.4
	k_t		0.49	0.49	0.5	0.53	0.5	0.56	0.54	0.55	0.55	0.5	0.5	0.49
	k_{15}		0.56	0.61		0.77		0.72	0.78	0.78	0.75		0.65	0.68
Piezoelectric Charge	d_{31}	Coul/N x 10^{-12} (or)	-175	-190	-208	-270	-250	-270	-300	-320	-325	-320	-360	-370
Displacement Coefficient	d_{33}	m/V x 10^{-12}	350	390	443	485	580	530	600	650	640	694	730	750
	d_{15}		360	460		850		790	1000	1000	880		850	900
Piezoelectric Voltage Coefficient	g_{31}	V·m/N x 10^{-3}	-11	-11.3	-12.4	-11.5	-9.7	-9.4	-9.8	-9.5	-8.9	-7.2	-7.1	-6.4
Voltage Coefficient	g_{33}		24.2	23.2	26.3	21.3	22.6	18.4	19.7	19	17.6	15.7	14.5	13
	g_{15}		27.1	32.4		32.6		31.9	31.8	35.3	29.1		16.3	18.8
Frequency Constants	N_p	Hz·m	2020		1925	1910	1950	1920	1830			1970	1940	2020
	N_{tr}		2025	2110	2000	2050	2020	1870	2020	2000	2000	1990	2090	2095
	N_{ta}		2250	2360		2350		2220	2340	2350	2340		2350	2340
	N_{33}												1590	1550
	N_{31}		1420	1440		1420		1400					1430	1440
Poisson's Ratio	υ		0.32	0.34		0.31				0.31	0.31		0.32	0.32
Elastic Constants Short Circuit	S^E_{11}	x $10^{12} m^2/N$	15.6	15.1	17	15.8	17.8	16.7	16	16.6	15.6	17	14.7	14.5
	S^E_{33}		18.6	18.6	21.3	18.8	23.9	19.7	19.8	21	19.2	21	18.1	18
	S^E_{12}		-5.3	-4.8	-4.8	-5	-5.2	-5.6	-4.2	-4.2	-4.7	-6	-4.7	-4.7
	S^E_{13}		-6.8	-7.6	-8.9	-7.7	-9.9	-7.6	-7.2	-8.2	-7.7	-7.5	-7.3	-7.2
	S^E_{55}		37	40	49.0	47	48.9	48.5	54	52.4	45.9	36.2	38.1	41.4
	S^E_{66}		41.6	39.8	43.4		46.1					46		
Elastic Constants Open Circuit	S^D_{11}	x $10^{12} m^2/N$	13.7	12.7	14.4	12.6	15.2	13.9	12.6	13.5	12.5	14.7	12.2	12.2
	S^D_{33}		9.4	9	9.6	8.5	10.8	10	7.8	8.2	7.8	10.1	7.6	8.4
	S^D_{55}		25.4	25.1	22.9	19.1	22.9	23.4	21.1	20.5	20.1	16.4	22	22.3

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			3195STD	3195HD	NCE51*	3222HD	NCE56*	3203STD	3221HD	3203HD	3241HD	NCE55*	3257HD	3265HD
Elastic Constants Short Circuit	Y^E_{11}	x 10^{10}N/m^2	6.4	6.6	5.9	6.4	5.6	5.9	6.2	6	6.4	5.9	6.8	6.9
	Y^E_{33}	x 10^{10}N/m^2	5.4	5.4	4.7	5.3	4.2	5.1	5.1	4.8	5.2	4.8	5.5	5.6
Elastic Constants Open Circuit	Y^D_{11}	x 10^{10}N/m^2	7.3	7.9	7.0	7.9	6.6	7.2	7.6	7.5	8	6.8	8.1	8.2
	Y^D_{33}	x 10^{10}N/m^2	10.6	11.1	10.4	11.7	9.2	10	12.8	13.2	12.8	9.9	13.2	11.9
Thermal Expansion (Perpendicular to poling)	α	ppm/ºC		3						3.5				
Specific Heat	C_p	J/kg·ºC		440						420				
		J/mol·ºC		145						138				
Thermal Conductivity	K_d	W/cm·ºC		1.9-2.3						1.9-2.3				
		W/m·ºK		1.2						1.2				
Thermal Conductivity with Au Electrodes		W/m·ºK		1.45						1.45				

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