



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	$\rho$	kg/m <sup>3</sup>	7550	7750	7550	7550	7700	7930	7550
Curie Point	$T_c$	°C	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 x 10 <sup>-12</sup> (or)	-110	-98	-120	-125	-133	-130	-130
Displacement Coefficient	$d_{33}$	m/V x 10 <sup>-12</sup>	230	255	250	300	304	310	350
	$d_{15}$					500			
Piezoelectric Voltage Coefficient	$g_{31}$		-14	-10.8	-12.3	-10.9	-12	-10.9	-10.1
Voltage Coefficient	$g_{33}$	V·m/N x 10 <sup>-3</sup>	26	28	25.7	26.1	27.5	25.9	30.4
	$g_{15}$					45.2			
Frequency Constants	$N_p$		2270	2300	2180	2200	2170	2280	2080
	$N_{tr}$		2067	2130	2024	2100	2070	2000	
	$N_{ta}$	Hz·m	2361		2310	2375			
	$N_{33}$		1550		1520	1500			
	$N_{31}$		1630		1620	1570			
	$N_H$		1065		1050	1040			1000
Poisson's Ratio	$\nu$		0.32		0.32	0.34			



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

\* For requests for wafer forms thinner than 0.40 mm, please contact us on [piezosaes@ctscorp.com](mailto:piezosaes@ctscorp.com).

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



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



Property	Symbol	Units	Soft Material Type										
			3195STD	3195HD	NCE51*	3222HD	NCE56*	3203STD	3221HD	3203HD	3241HD	NCE55*	3257HD
Elastic Constants Short Circuit	$Y_{11}^E$	$\times 10^{10} \text{N/m}^2$	6.4	6.6	5.9	6.4	5.6	5.9	6.2	6	6.4	5.9	6.8
	$Y_{33}^E$		5.4	5.4	4.7	5.3	4.2	5.1	5.1	4.8	5.2	4.8	5.5
Elastic Constants Open Circuit	$Y_{11}^D$	$\times 10^{10} \text{N/m}^2$	7.3	7.9	7.0	7.9	6.6	7.2	7.6	7.5	8	6.8	8.1
	$Y_{33}^D$		10.6	11.1	10.4	11.7	9.2	10	12.8	13.2	12.8	9.9	13.2
Thermal Expansion (Perpendicular to poling)	$\alpha$	ppm/°C	3			3.5							
Specific Heat	$C_p$	J/kg·°C	440			420							
		J/mol·°C	145			138							
Thermal Conductivity		W/cm·°C	1.9-2.3			1.9-2.3							
		W/m·°K	1.2			1.2							
Thermal Conductivity with Au Electrodes	$K_d$	W/m·°K	1.45			1.45							

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# Single Crystal Piezoelectric Materials

Property	Symbol	Units	Material Type				
			PMN-28% PT Type A	PMN-32% PT Type B	PIN24%-PMN-PT	PIN33%-PMN-PT	
Density	$r$	kg/m <sup>3</sup>	8100	8100	8122	8141	
Phase Transition	$T_{rt}$	°C	90-100	80-90	100-115	115-135	
Curie Temperature	$T_c$	°C	120-130	130-140	140-170	160-200	
Coercive Field	$E_c$	kV/cm	2.5	2.5	4.5-6	5.5-7	
Piezoelectric Constants	$d_{15}$	pC/N	135	192	122	147	
	$d_{31}$		-568	-760	-646	-651	
	$d_{33}$		1190	1620	1285	1338	
	$e_{15}$	C/m <sup>2</sup>	8.69	8.69	8.52	9.48	
	$e_{31}$		-13.12	-15.99	-9.11	-4.81	
	$e_{33}$		21.72	19.42	17.60	19.31	
	$g_{15}$	x10 <sup>-3</sup> Vm/N	9.53	13.39	7.98	9.97	
	$g_{31}$		-11.67	-12.29	-15.36	-16.23	
	$g_{33}$		24.45	26.15	30.55	33.36	
	$h_{15}$	x10 <sup>8</sup> V/m	6.69	9.59	5.97	7.10	
	$h_{31}$		-16.55	-25.81	-11.86	-6.00	
	$h_{33}$		27.41	31.34	22.92	24.10	
	Dielectric Constants	$\epsilon_{11}^S$	$(\epsilon_0)$	1467	1368	1611	1509
		$\epsilon_{33}^S$		895	700	868	905
		$\epsilon_{11}^T$		1600	1620	1728	1666
$\epsilon_{33}^T$		5500		7000	4753	4532	
$\beta_{11}^S$		x10 <sup>-4</sup> /( $\epsilon_0$ )	6.82	7.31	6.21	6.63	
$\beta_{33}^S$			11.17	14.29	11.52	11.05	
$\beta_{11}^T$			6.25	6.17	5.79	6.00	
$\beta_{33}^T$			1.82	1.43	2.10	2.21	
Electromechanical Coupling Constants	$k_{15}$		28%	39%	26%	31%	
	$k_{31}$		43%	44%	46%	47%	
	$k_{33}$		90%	93%	89%	89%	
	$k_t$		60%	62%	50%	54%	
Elastic Stiffness Constants	$C_{11}^E$	10 <sup>10</sup> N/m <sup>2</sup>	11.58	11.21	12.43	11.57	
	$C_{12}^E$		10.23	10.16	10.90	10.03	
	$C_{13}^E$		9.31	9.04	11.02	10.15	
	$C_{33}^E$		10.71	9.68	12.45	11.32	
	$C_{44}^E$		6.44	6.05	6.98	6.45	
	$C_{66}^E$		6.01	5.51	6.21	5.44	
	$C_{11}^D$		13.75	15.34	13.51	11.86	
	$C_{12}^D$		12.40	14.29	11.98	10.32	
	$C_{13}^D$		5.71	4.03	8.93	8.99	
	$C_{33}^D$		16.66	15.77	16.49	15.97	
	$C_{44}^D$		7.02	7.16	7.49	7.12	
	$C_{66}^D$		6.01	5.51	6.21	5.44	
Elastic Compliance Constants	$S_{11}^E$	10 <sup>-12</sup> m <sup>2</sup> /N	45.86	58.85	45.76	47.18	
	$S_{12}^E$		-28.11	-36.58	-19.60	-17.75	
	$S_{13}^E$		-15.43	-20.80	-23.16	-26.39	
	$S_{33}^E$		36.15	49.18	49.04	56.15	
	$S_{44}^E$		15.53	16.53	14.33	15.50	
	$S_{66}^E$		16.64	18.15	16.10	18.38	
	$S_{11}^D$		39.23	49.53	35.84	36.62	
	$S_{12}^D$		-34.73	-45.90	-29.52	-28.32	
	$S_{13}^D$		-1.54	-0.93	-3.43	-4.67	
	$S_{33}^D$		7.06	6.82	9.78	11.52	
	$S_{44}^D$		14.24	13.96	13.35	14.04	
	$S_{66}^D$		16.64	18.15	16.10	18.38	