Piezoelectric Polycrystalline (PZT) Components and Wafers

Sense

Move

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Industry Leading Piezoelectric Polycrystalline (PZT) Component Manufacturing and Engineering

CTS offers high-performance piezoelectric materials for a wide range of applications, including Medical, Defense, Inkjet, Industrial, Oil and Gas and Automotive markets.

Compositions available in High-Density (d_{meas}>99.5%d_{theo}) and Standard-Density (d_{meas}=97%d_{theo}) formulations, these piezoelectric materials can be produced in various shape components and wafer in high volumes to support end-product specifications and volume.

CTS' Piezoelectric Polycrystalline (PZT) Ceramics are used in a variety of applications such as:

- Consumer Electronics
- Emerging Medical Applications
- Energy Harvesting
- Flow Meters
- Haptics
- Hard Disk Drive Actuators
- Hydrophones
- Inkjet Printer Head
- Micro-Actuators
- Non-Destructive Testing
- Precision Valves
- Sonar (Current and Next Generation)
- Transducers
- Ultrasonic Cleaning
- Ultrasonic Imaging

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High Density Material

» CTS manufactures industry leading high density (HD) polycrystalline piezoelectric material Measured Density > 99.5% Theoretical Density

» Fine grain size (<3.5 □m) to enable micro-machining of features

Uniform Electrical Properties

» Wafer-to-wafer and across the wafer

Large Wafer Size

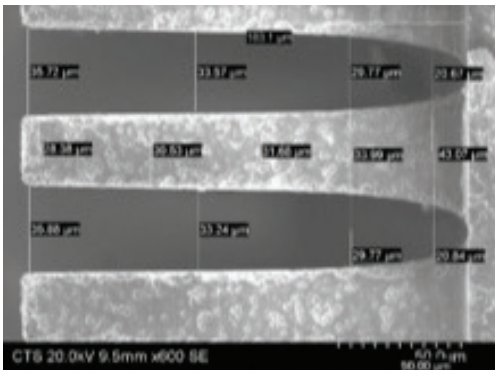
» Length and Width up to 5.8" (147 mm) x 3.25" (82.6 mm) wafers

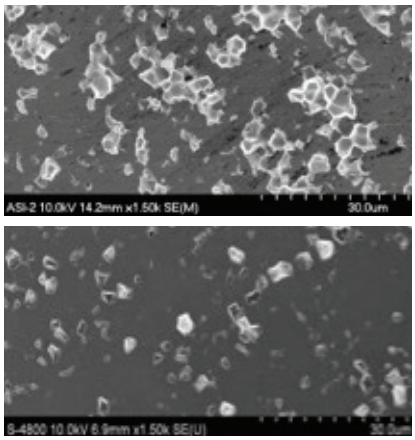
» Diameter - 0.25" (6.4 mm) to 6" (152.4 mm) rounds for MEMS processing

Volume Processing

» Over 100 metric tons of PZT produced annually

Process Capabilities





Dicing

Over 40 dicing saws in production. Strong dicing experience set covering a wide range of customer applications. High precision, high throughput equipment.

Surface Finish

Machining operations can be optimized to obtain a variety of surface finishes. Surface finishes as low as 250 Å Ra are achievable.

Thick and Thin Film Elelctrodes

More than 15 sputtering systems worldwide. Typical thin film electrode materials include sputtered Ni, NiCr, Ti, Sn, Au, Cr and film thickness varies from 1,000 Å to 12,500 Å. Typical thick film electrode material includes Ag and thick film thickness varies from 10 µm to 15 µm.

Photolithographic patterning available with resolution with up to 25 µm lines.

Metal electrode features can be formed by etching using photolithography techniques in clean-rooms.

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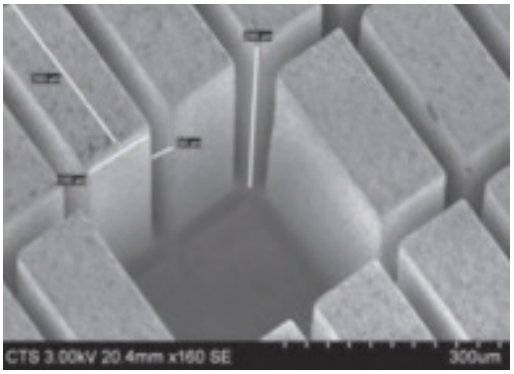
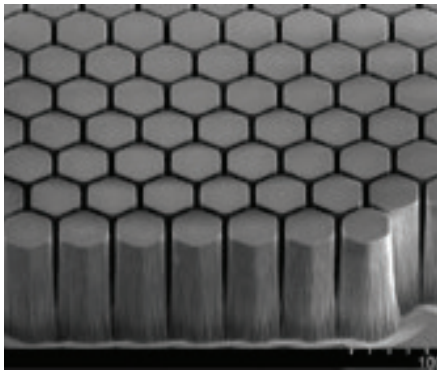
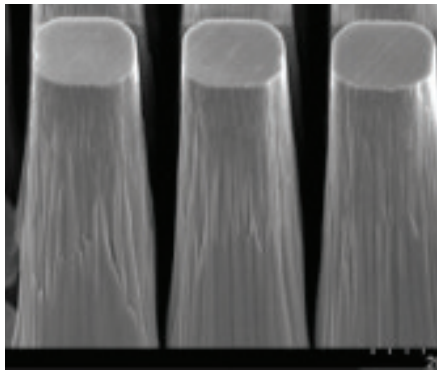




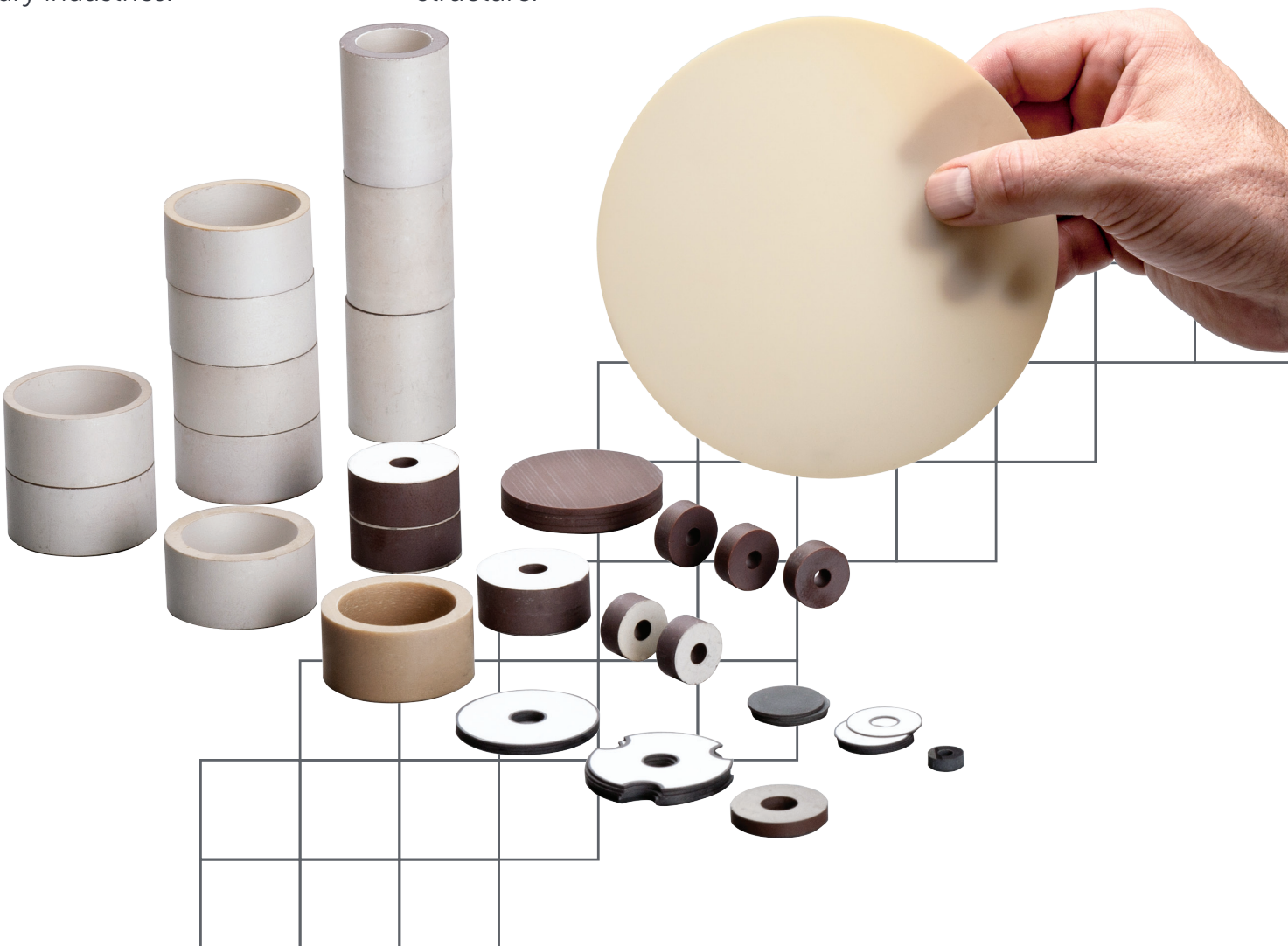


1-3 and 2-2 PZT Composites

Piezoelectric ceramic in an epoxy matrix in 1-3 or 2-2 configurations. Widespread Industrial Use: Ultrasound, Sonar, and Non-Destructive Testing applications in the Medical, Biometric, Electronics, and Military industries.

Reactive Ion Etching Process

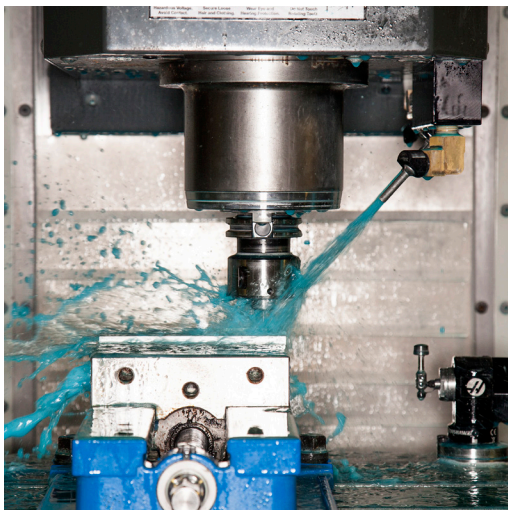
Reactive Ion Etching process is a plasma based process utilized to create high aspect ratio composites that might not necessarily be created utilizing dicing process. Reactive ion etching process provides best results for sophisticated electrode patterns and high frequency composites for Intravascular Ultrasound (IVUS) applications. SEM images above show high frequency 1-3 single crystal composite structure.



Finishing and Value Added Operations

CTS provides a broad range of capabilities to accommodate your design needs, including:

- » High Volume Wire Saws
- » Lap or Grind to Desired Surface Roughness
- » Varying Wafer Geometry from Large Rounds (up to 150mm dia.) & Tubes to Small Squares & Washers
- » Thin Wafer Processing (< 50um)
- » Precision Dicing and Grinding
- » Clean Room Capabilities

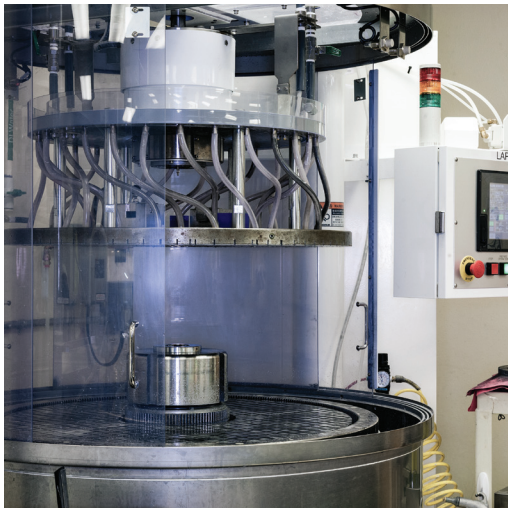


Precision Milling

CTS also provides further processing both domestically and in Asia to include anything from MEMS technology compatible round wafers to turnkey solutions that will meet your design specifications.

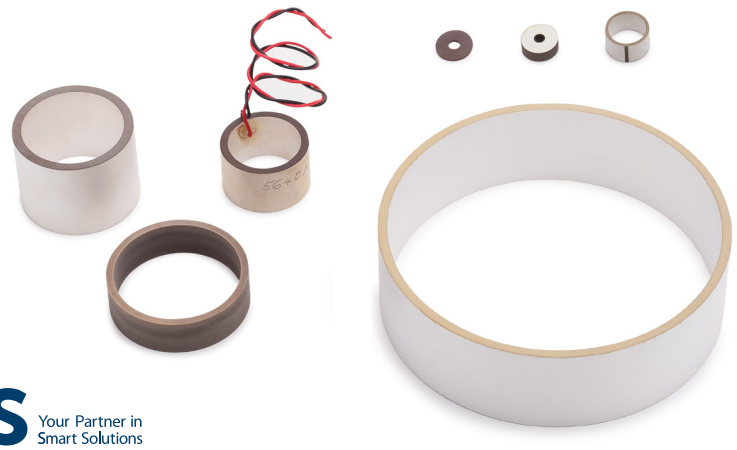
Our advanced processing capabilities include:

- » Composite Manufacturing. Both 2-2 and 1-3 Composites
- » Sputtered Thin Films
- » Thick Film Applications
- » Shadow Mask Sputtered Features
- » Precision Photolithographic Thin Film
- » Testing Piezoelectric Properties
- » Assembly, Lead Attachment
- » Wafer Bonding Using State of the Art Epoxy Systems
- » Custom Packaging to Match Your Processing Needs
- » Tape & Frame Packaging
- » Tape Cast Ceramic Process Capability
- » Co-fired Multilayer Actuators



High Volume Lapping

Photolithography



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Manufacturing Locations

USA
Albuquerque

» Total Space: 97,160 Sq. Ft.
» Employees: 220
» Engineering, Foundry, and Manufacturing Process Design Center
» Worldwide Ceramic Production Facility
» Cost of Quality Initiative-6 Sigma
» ISO 9001:2008 Certified

China
Tianjin

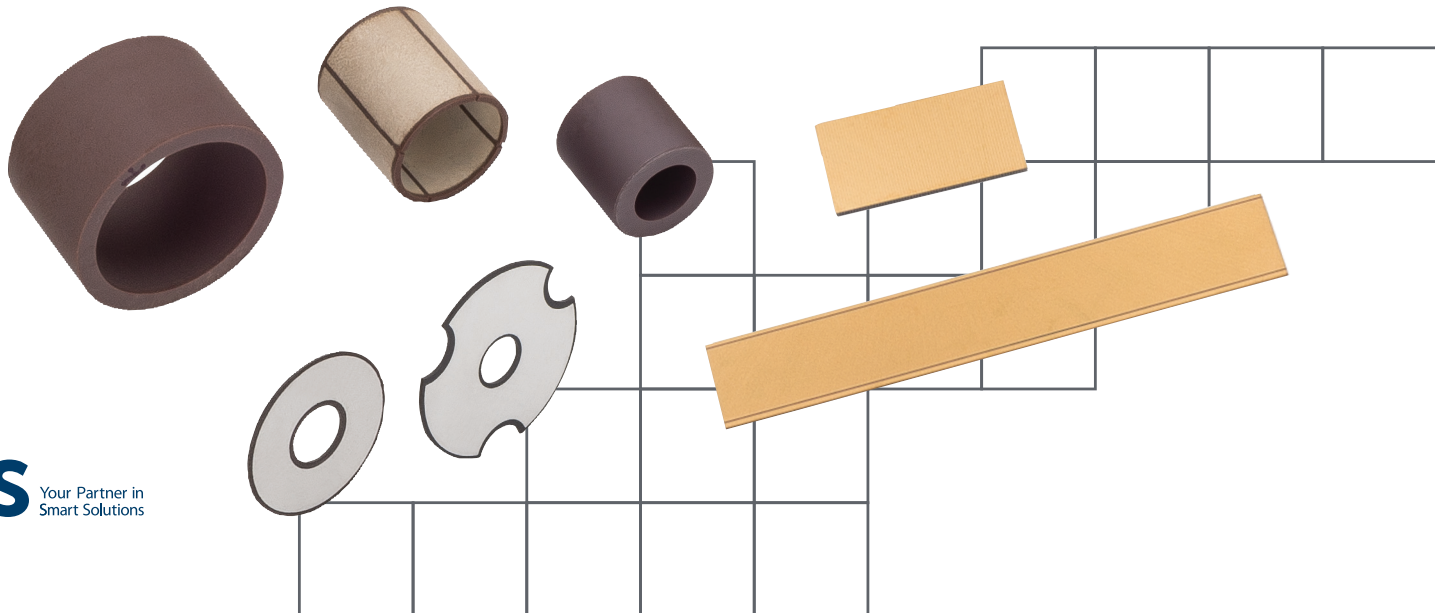
» Total Space: 221,737 Sq. Ft.
» Employees: 419
» High Volume Manufacturing Facility for PZT and RF Ceramic Products HDD PZT Finishing
» Cost of Quality Initiative-6 Sigma
» ISO 9001/TL9000, ISO 14001, & OHSAS 180001 Certified

Mexico
Nogales

» Total Space: 67,000 Sq. Ft.
» Employees: 323
» Ceramic Manufacturing for Piezo and RF Ceramic Components, EMI/RFI Filters, Thermal Products, Dielectric/Coaxial Resonators
» MLA in place for piezoelectric products
» Cost of Quality Initiative-6 Sigma
» ISO 9001:2008 Certified

PZT4 & 8 Materials (Hard PZT) – Technical Data Table (Typical Values)

Property	Symbol	Units	Material Type			
			K1000	K1100	K1300	K1450
Dielectric Constant (1kHz)	K^T_3		1000	1100	1300	1450
Dielectric Loss Factor (1kHz)	$\tan\delta_e$		0.004	0.004	0.005	0.012
Density	ρ	g/cm^3	7.55	7.55	7.55	7.55
Curie Point	T_c	ºC	325	325	325	320
Mechanical Quality Factor	Q_m		1000	600	500	350
Coupling Coefficients	k_p		0.51	0.51	0.55	0.57
	k_{33}		0.62	0.62	0.69	
	k_{31}		0.29	0.30	0.32	0.32
	k_t		0.58		0.67	
Piezoelectric Charge (Displacement Coefficient)	d_{31}	Coul/N x 10^{-12} (or) m/V x 10^{-12}	-95	-100	-120	-130
	d_{33}		230	230	280	350
	d_{15}		325	325	350	
Piezoelectric Voltage Coefficient (Voltage Coefficient)	g_{31}	V·m/N x 10^{-3}	-10.7	-10.3	-10.4	-10.1
	g_{33}		26.0	23.6	24.3	30.4
	g_{15}		36.7	33.4	30.4	
Frequency Constants	N_r	Hz·m	2290	2280	2230	2080
	N_{tr}		1980	1970	1960	
	N_H		1065	1050	1040	1000
Elastic Constants Short Circuit	S^E_{11}	$10^{-12}m^2/N$	11.5	11.5	12.5	12.5
	S^E_{33}		13.5	13.5	16.7	
Elastic Constants Open Circuit	S^D_{11}	$10^{-12}m^2/N$	10.5	10.5	11.2	11.2
	S^D_{33}		8.3	8.3	8.7	
Elastic Constants Short Circuit	Y^E_{11}	x $10^{10}N/m^2$	8.7	8.7	8.0	8.0
	Y^E_{33}		7.4	7.4	6.0	
Elastic Constants Open Circuit	Y^D_{11}	x 10^{10} N/m^2	9.5	9.5	8.9	8.9
	Y^D_{33}		8.1	7.4	11.5	



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PZT5A & 5J Materials (Soft PZT) – Technical Data Table (Typical Values)

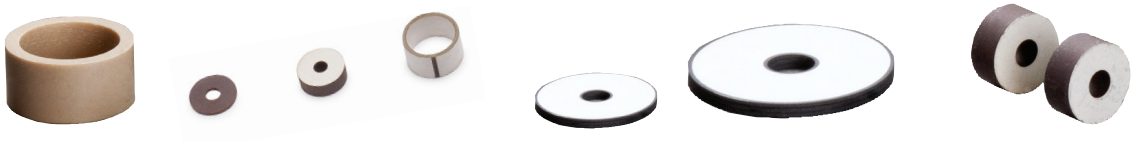
Property	Symbol	Units	Material Type		
			3195STD	3195HD	3222HD
Dielectric Constant (1kHz)	K^T_3		1800	1900	2650
Dielectric Loss Factor (1kHz)	$\tan\delta_e$		0.02	0.02	0.02
Dielectric Constant (1kHz)	K^T_1		1500	1600	2948
Clamped Dielectric Constant	K^S_3		875	900	800
Density	ρ	g/cm^3	7.7	7.95	7.90
Curie Point	T_c	ºC	350	350	270
Mechanical Quality Factor	Q_m		80	80	80
Coercive Field (Measured < 1 Hz)	E_c	kV/cm	14.9	12.0	
Remanent Polarization	P_r	$\mu Coul/cm^2$	39.2	39.0	
Coupling Coefficients	k_p		0.63	0.68	0.72
	k_{33}		0.70	0.72	0.74
	k_{31}		0.35	0.40	0.45
	k_t		0.49	0.49	0.53
	k_{15}		0.56	0.61	0.77
Piezoelectric Charge (Displacement Coefficient)	d_{31}	$Coul/N \times 10^{-12}$ (or) $m/V \times 10^{-12}$	-175	-190	-270
	d_{33}		350	390	485
	d_{15}		360	460	850
Piezoelectric Voltage Coefficient (Voltage Coefficient)	g_{31}	$V\cdot m/N \times 10^{-3}$	-11.0	-11.3	-11.15
	g_{33}		24.2	23.2	21.3
	g_{15}		27.1	32.4	32.6
Frequency Constants Radial	N_r	Hz·m	2020		1910
Resonant Thickness	N_{tr}	Hz·m	2025	2110	2050
Anti-Resonant Thickness	N_{ta}	Hz·m	2250	2360	2350
	N_{31}	Hz·m	1420	1440	1420
Thermal Expansion (Perpendicular to poling)	α	ppm/ºC		3.0	
Specific Heat	C_p	J/kg·ºC		440	
		J/mol·ºC		145	
Thermal Conductivity	K_d	W/cm·ºC		1.9-2.3	
		W/m·ºK		1.2	
with Au Electrodes		W/m·ºK		1.45	
Poisson's Ratio	υ		0.32	0.34	0.31
Elastic Constants Short Circuit	S^E_{11}	$\times 10^{-12} m^2/N$	15.6	15.1	15.8
	S^E_{33}		18.6	18.6	18.8
	S^E_{12}		-5.3	-4.8	-5.0
	S^E_{13}		-6.8	-7.6	-7.7
	S^E_{55}		37.0	40.0	47.0
Elastic Constants Open Circuit	S^D_{11}	$10^{-12} m^2/N$	13.7	12.7	12.6
	S^D_{33}		9.4	9.0	8.5
	S^D_{55}		25.4	25.1	19.1
Elastic Constants Short Circuit	Y^E_{11}	$\times 10^{10} N/m^2$	6.4	6.6	6.4
	Y^E_{33}		5.4	5.4	5.3
Elastic Constants Open Circuit	Y^D_{11}	$\times 10^{10}$ N/m²	7.3	7.9	7.9
	Y^D_{33}		10.6	11.1	11.7

PZT5H Materials (Soft PZT) – Technical Data Table (Typical Values)

Property	Symbol	Units	Material Type			
			3221HD	3203STD	3203HD	3241HD
Dielectric Constant (1kHz)	K^T_3		3450	3250	3800	4100
Dielectric Loss Factor (1kHz)	$\tan\delta_e$		0.02	0.02	0.02	0.02
Dielectric Constant (1kHz)	K^T_1		3550	2800	3200	3420
Clamped Dielectric Constant	K^S_3		1000	775	1200	1300
Density	ρ	g/cm^3	7.87	7.7	7.87	7.88
Curie Point	T_c	ºC	242	225	225	223
Mechanical Quality Factor	Q_m		50	50	50	50
Coercive Field (Measured < 1 Hz)	E_c	kV/cm	8.8	10.6	8.0	9.0
Remanent Polarization	P_r	$\mu Coul/cm^2$	38.5	37.2	39.0	38.5
Coupling Coefficients	k_p		0.74	0.69	0.75	
	k_{33}		0.78	0.70	0.78	0.77
	k_{31}		0.46	0.41	0.43	0.44
	k_t		0.54	0.56	0.55	0.55
	k_{15}		0.78	0.72	0.78	0.75
Piezoelectric Charge (Displacement Coefficient)	d_{31}	Coul/N x 10^{-12} (or) m/V x 10^{-12}	-300	-270	-320	-325
	d_{33}		600	530	650	640
	d_{15}		1000	790	1000	880
Piezoelectric Voltage Coefficient (Voltage Coefficient)	g_{31}	V·m/N x 10^{-3}	-9.8	-9.4	-9.5	-8.9
	g_{33}		19.7	18.4	19.0	17.6
	g_{15}		31.8	31.9	35.3	29.1
Frequency Constants Radial	N_r	Hz·m	1830	1920		
Resonant Thickness	N_{tr}	Hz·m	2020	1870	2000	2000
Anti-Resonant Thickness	N_{ta}	Hz·m	2340	2220	2350	2340
	N_{31}	Hz·m		1400		
Thermal Expansion (Perpendicular to poling)	α	ppm/ºC			3.5	
Specific Heat	C_P	J/kg·ºC			420	
		J/mol·ºC			138	
Thermal Conductivity	K_d	W/cm·ºC			1.9-2.3	
		W/m·ºK			1.45	
with Au Electrodes		W/m·ºK			1.45	
Poisson's Ratio	υ				0.31	0.31
Elastic Constants Short Circuit	S^E_{11}	x $10^{-12}m^2/N$	16.0	16.7	16.6	15.6
	S^E_{33}		19.8	19.7	21.0	19.2
	S^E_{12}		-4.2	-5.6	-4.2	-4.7
	S^E_{13}		-7.2	-7.6	-8.2	-7.7
	S^E_{55}		54.0	48.5	52.4	45.9
Elastic Constants Open Circuit	S^D_{11}	$10^{-12}m^2/N$	12.6	13.9	13.5	12.5
	S^D_{33}		7.8	10.0	8.2	7.8
	S^D_{55}		21.1	23.4	20.5	20.1
Elastic Constants Short Circuit	Y^E_{11}	x $10^{10}N/m^2$	6.2	5.9	6.0	6.4
	Y^E_{33}		5.1	5.1	4.8	5.2
Elastic Constants Open Circuit	Y^D_{11}	x 10^{10} N/m^2	7.6	7.2	7.5	8.0
	Y^D_{33}		12.8	10.0	13.2	12.8

High Dielectric Piezo-Materials – Technical Data Table (Typical Values)

Property	Symbol	Units	Material Type	
			3257HD	3265HD
Dielectric Constant (1kHz)	K^T_3		5700	6500
Dielectric Loss Factor (1kHz)	$\tan\delta_e$		0.03	0.03
Clamped Dielectric Constant	KS3		2050	2100
Density	ρ	g/cm^3	8.22	8.22
Curie Point	T_c	ºC	155	>135
Mechanical Quality Factor	Q_m		75	75
Coupling Coefficients	k_p		0.70	0.66
	k_{33}		0.76	0.73
	k_{31}		0.41	0.40
	k_t		0.50	0.49
	k_{15}		0.65	0.68
Piezoelectric Charge (Displacement Coefficient)	d_{31}	Coul/N x 10^{-12} (or) m/V x 10^{-12}	-360	-370
	d_{33}		730	750
	k_{15}		850	900
Piezoelectric Voltage Coefficient (Voltage Coefficient)	g_{31}	V·m/N x 10^{-3}	-7.1	-6.4
	g_{33}		14.5	13.0
	z		16.3	18.8
Frequency Constants	N_r	kHz·m	1940	2020
	N_{tr}		2090	2095
	N_{ta}		2350	2340
	N_{33}		1590	1550
	N_{31}		1430	1440
Poisson's Ratio	υ		0.32	0.32
Elastic Constants Short Circuit	S^E_{11}	$10^{-12}m^2/N$	14.7	14.5
	S^E_{33}		18.1	18.0
	S^E_{12}		-4.7	-4.7
	S^E_{13}		-7.3	-7.2
	S^E_{35}		38.1	41.4
Elastic Constants Open Circuit	S^D_{11}	$10^{-12}m^2/N$	12.2	12.2
	S^D_{33}		7.6	8.4
	S^D_{35}		22.0	22.3
Elastic Constants Short Circuit	Y^E_{11}	x $10^{10}N/m^2$	6.8	6.9
	Y^E_{33}		5.5	5.6
Elastic Constants Open Circuit	Y^D_{11}	x 10^{10} N/m^2	8.1	8.2
	Y^D_{33}		13.2	11.9



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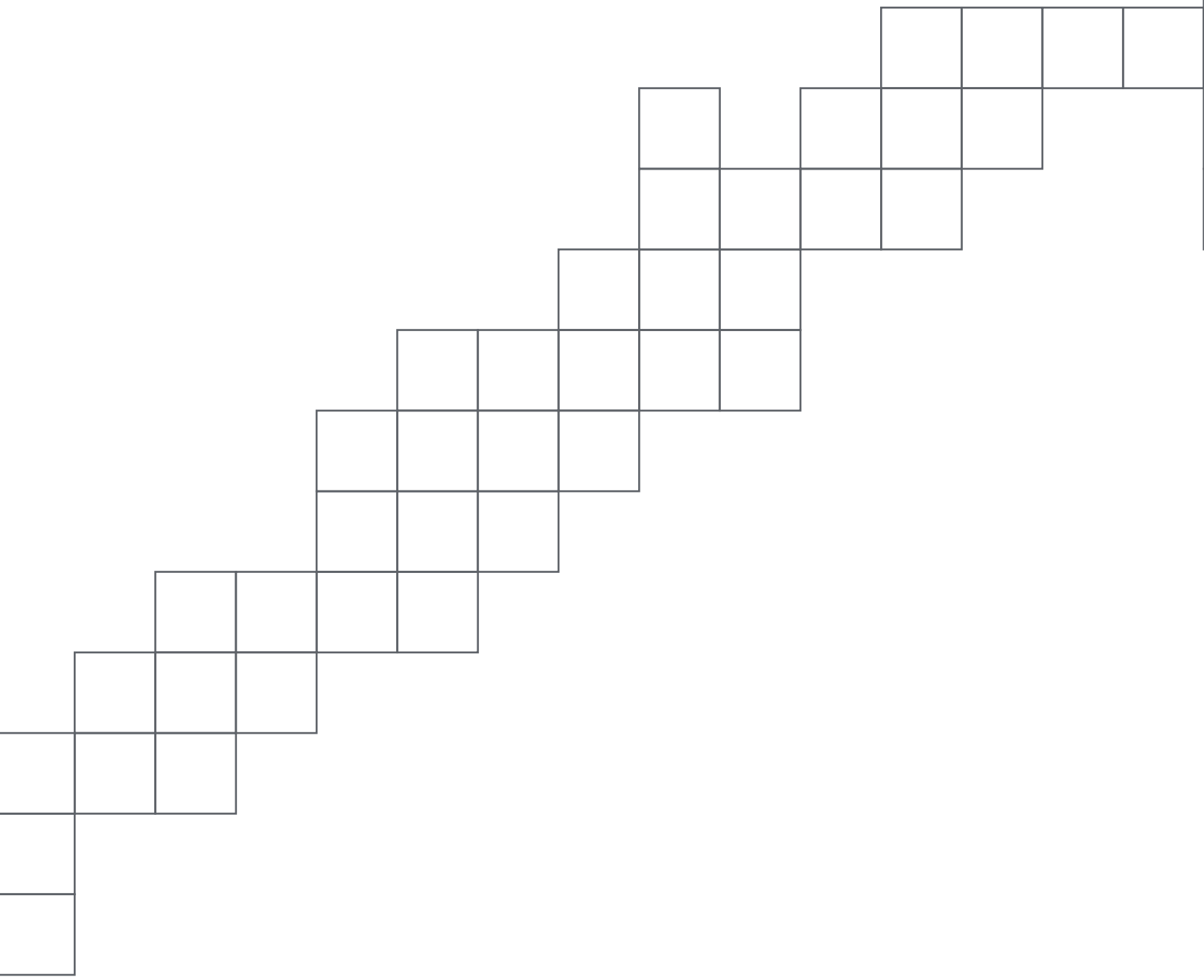

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