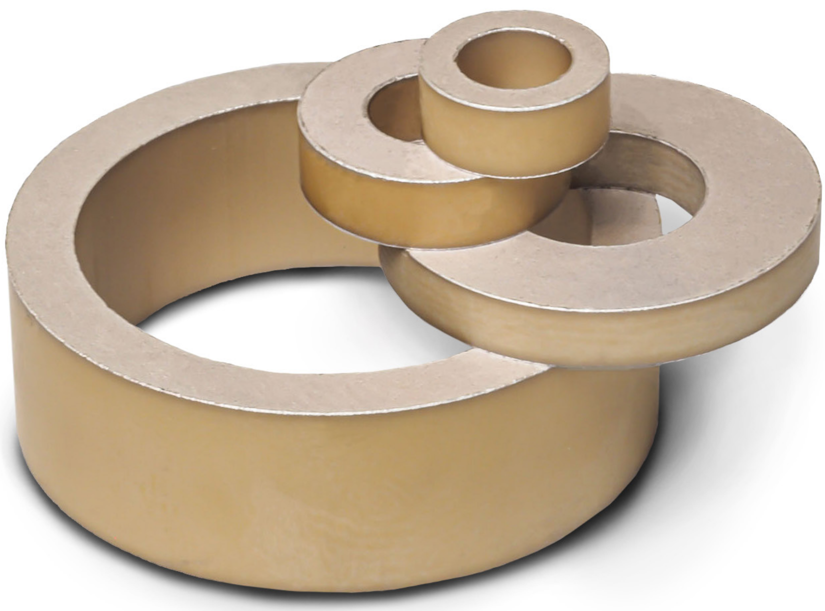
Your Partner in Smart Solutions®

Piezoelectric Components and Devices



Product Catalogue

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CTS Corporation

At CTS Corporation, we develop and manufacture state-of-the-art piezoelectric products, providing you with custom-made components that meet your exact geometrical, dimensional and performance specifications. Our product portfolio encompasses both bulk and multilayer piezoceramics, single crystals, printed thick film and built-to-print sensors and transducers. Our production capabilities in these areas are nearly unmatched, and our components are continuously achieving an industry-low batch-to-batch variation.

A Product for Every Purpose

Our piezoelectric products are widely used across major industries including med-tech, aerospace/defense and the industrial sector. Components from CTS enable complex and high-performance applications such as diagnostic and therapeutic medical equipment, underwater acoustics, flow/vibration measurement and non-destructive testing. For any and every sensing, actuating and transducing purpose, we can provide you with a fitting solution. In addition to manufacturing your components, our piezoelectric expertise allows us to offer various value-add services such as composite manufacture, wire soldering as well as transducer sub-assembly and testing to further optimize your product for its intended use.

Advancing Next-Gen Tech

In addition to our commercial activities, we have built strong and lasting relations with academic insitutions worldwide, collaborating with leading universities in Europe and North America. Working closely together with scientists, scholars and private developers alike, we stay at the forefront of the development, spurring research into the next generation of piezoelectric solutions and helping entrepreneurs and start-ups turn their innovative product ideas into reality.

Pursuing Perfection

In accordance with our company values and long-standing business tradition, we at CTS Corporation remain committed to guiding our customers through the development phase in order to find the optimal balance between specifications, tolerances and pricing.

Contact us and let us together find the piezoelectric solution that is just right for you.

Ultrasound scanning and imaging enabled by a piezoelectric transducer

Bulk Piezoceramic Components

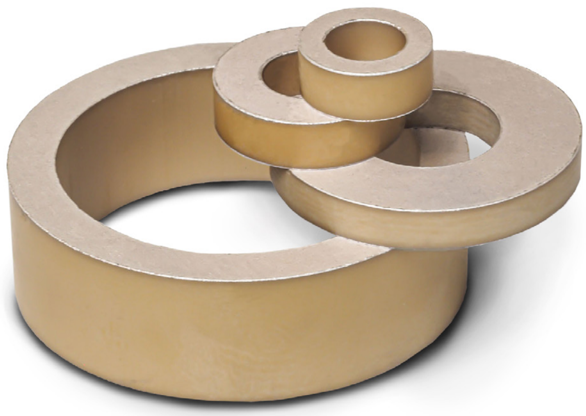
Our polycrystalline piezoceramic components find use in many high-demanding industrial and medical applications and are vital to the functionality of ultrasound transducers, vibration sensors and sonar devices – just to name a few. Our components are among the most durable and reliable products on the market, continuously achieving the highest possible electromechanical performance and reproducibility while displaying some of the lowest aging rates in the industry.

Versatile piezoceramic plates in different sizes

The majority of our components can and will be manufactured according to your exact dimensional and performance requirements. They are available in every standard geometry, including:

Discs, Rings and Rods

The radial symmetry of these circular components enables efficient energy conversion and uniform stress distribution. They are often used to generate high-power ultrasound or are utilized in flowmeter and ultrasonic inspection applications.

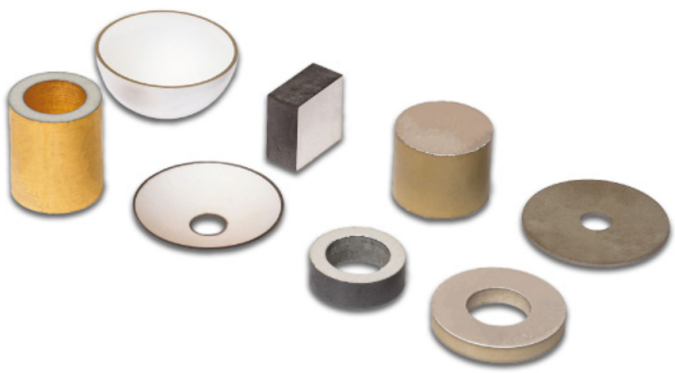


Piezoceramic rings for axial or radial vibration

Plates, Wafers, Bars and Wedges

Rectangular components ideal for unidirectional force/displacement and uniform deformation. The simple shape allows for easy manufacture and wide applicability, including medical imaging and drop-on-demand inkjet printing.

Advanced Piezoceramic Components



Tubes and Cylinders

Utilized for either radial, wall-thickness or shear vibration, tubes and cylinders offer good resonance control, reliable operation and high durability. Often used in underwater applications, medical therapeutics and accelerometers.

Bowls and Hemispheres

Concave components used to focus ultrasonic energy on a pin-pointed target. Bowls are typically employed in medical therapeutics e.g., non-invasive surgery. Hemispheres are often utilized in hydrophones and acoustic communication.

Focusing bowl used in High-Intensity Focused Ultrasound (HIFU) to focus ultrasonic energy on target

Shear Plates and Shear Stacks

These components make use of the shear vibration mode to achieve high piezoelectric coefficients while offering increased resistance to temperature variations. A popular choice for accelerometers and single/multiaxial actuation.

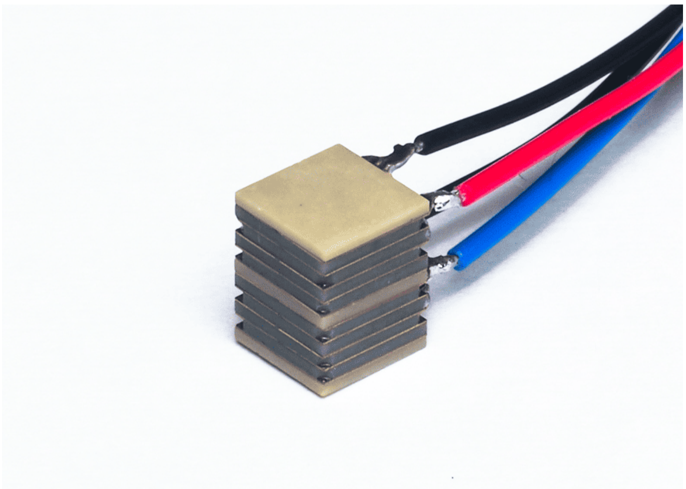


Plate stack designed for biaxial shear actuation

Piezoceramic Composites

The combination of a piezoceramic material and a polymer resin, composites exhibit strong piezoelectric activity, high coupling and great flexibility.

Stacks and Assemblies

Customized stacks and assemblies, providing greater displacements, force outputs and currents.

Explore our bulk piezo components!

Scan the code, or click HERE

Single Crystals

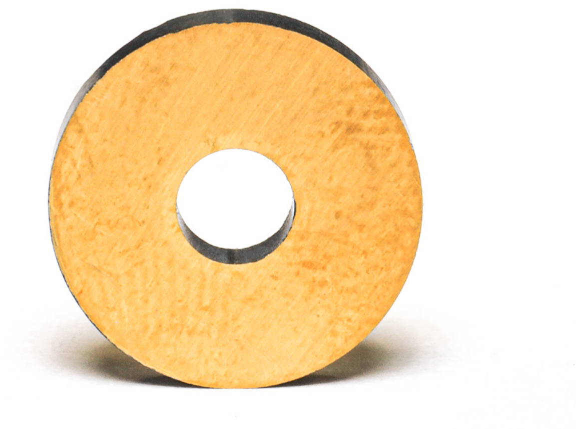
CTS is the world's largest, fully integrated developer and manufacturer of piezoelectric single crystals, specializing in lead magnesium niobate-lead titanate (PMN-PT) materials.

Single crystals are the pinnacle of piezoelectric technology, achieving unmatched levels of sensitivity and energy coupling. Their high piezoelectric charge coefficients and coupling factors make them ideal for transducer applications, especially in medical imaging where they offer notably increased bandwidth. Their superior energy conversion allows for compact designs with fewer and smaller components, lowering the overall power consumption. These features are particularly beneficial to underwater applications and handheld devices such as portable ultrasound scanners.

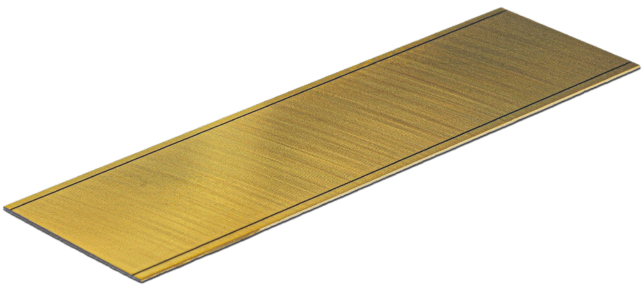
CTS designs and manufactures single crystal components to our customers' exact dimensional requirements in all standard geometries.

Plates, Wafers and Bars

Versatile components offering consistent surface performance, improved durability and precise frequency control. The component of choice for high-performance medical ultrasound imaging, granting improved image quality and unlocking 3D and 4D imaging.

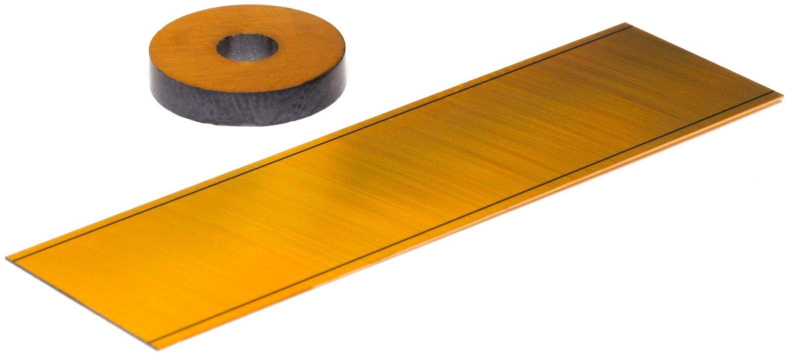


Single crystal ring component for underwater acoustics



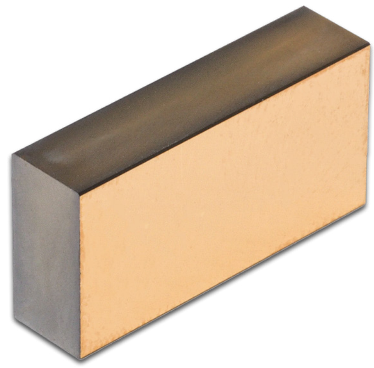
Single crystal plates are often employed in medical imaging applications

PMN-PT & PIN-PMN-PT Single Crystals



Discs, Rings and Rods

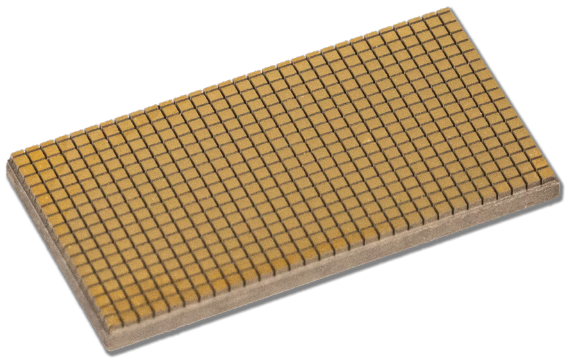
The radial symmetry enables even stress distribution, allowing these components to efficiently facilitate the transduction of acoustic waves. With their central aperture, they can favorably be employed in optical technology or as stacks in compact active sonar transducers.



Single crystal shear plates enable high strain and efficient power conversion

Shear Plates

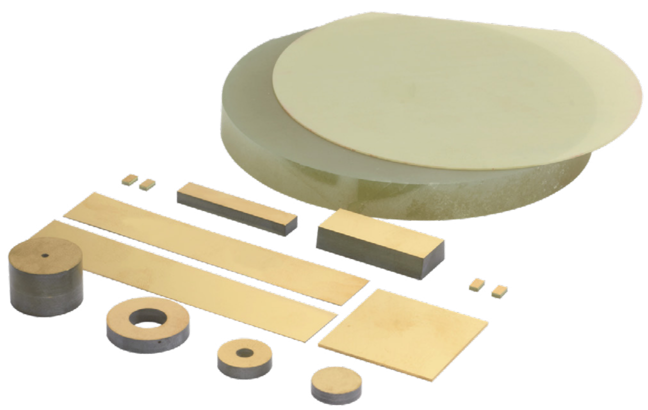
The shear deformation enabled by these components allows for fine control and accurate lateral movement of precision position applications. As shear waves propagate more slowly than longitudinal waves, shear plates are also highly effective for surface inspection in non-destructive testing.



Array of high-frequency single crystal composites for intravascular ultrasound

Composites and High-Frequency Composites

Single crystal composites combine the high piezoelectric performance of PMN-PT and PIN-PMN-PT crystals with more pliable materials such as polymer resins, inheriting both strong piezoelectric properties and mechanical flexibility. Composite processing allows for suppression of lateral modes and offers improved acoustic and electrical impedance matching. High-frequency composites will often be used in intravascular ultrasound applications (IVUS).



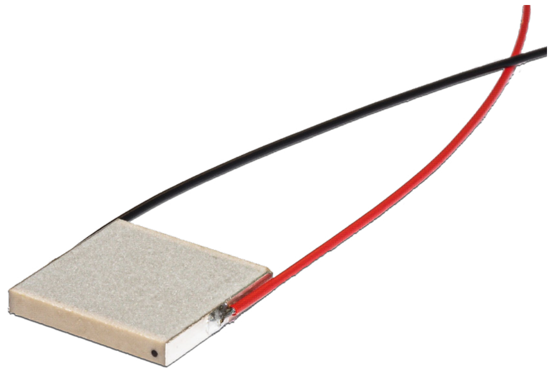
Explore our single crystal components!

Scan the code, or click HERE

Multilayer

CTS multilayer products are comprised of extremely thin piezoceramic layers, made by tape casting and subsequently deposited upon each other with alternating positive and negative electrodes in between. This design enables the components to run in actuating applications at much lower driving voltages and allows for higher electrical fields to be applied for greater strain levels.

Our multilayer products excel in applications that require the smallest possible component size such as miniaturized actuators and sensors used in micropositioning, laser tuning and semiconductor applications as well as medical equipment and pacemaker units.



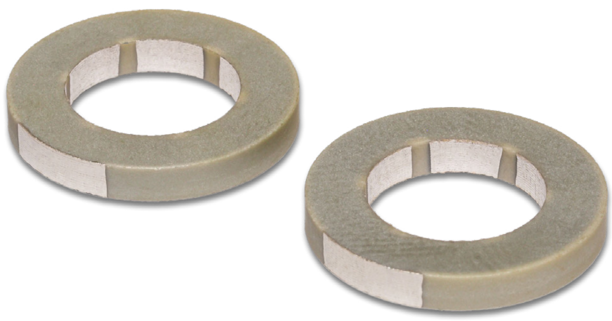
Multilayer plate actuator, capable of ultra fine movements and high-resolution positioning

Plate and Ring Actuators and Stacks

Multilayer actuators combine high force generation with low operating voltages and are often used in optical technology and micro- and nanopositioning. Plate and ring actuators can be stacked to reach desired heights and strokes.

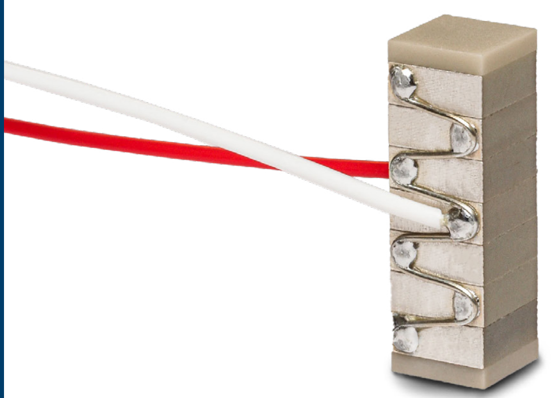
Plate and Ring Benders

Capable of the unique bending deformation mode, allowing for higher displacement output relative to the component's size. A popular choice for valves, haptics, audio and optical positioning applications.



Due to their axial symmetry and central aperture, ring actuators are often used in optical applications

Tape-Casted Multilayer Structures



High-Temperature Stacks

Designed to operate at up to 200°C, these stacks offer stable performances over temperature and excel at high-frequency operation thanks to their lower dissipation.

Preloaded Stacks

Encased in mechanical springs, preloaded stacks can operate under greater tensile stress and strain, such as the inertial forces generated under fast actuation or impact generation.

Damage-Tolerant Stacks

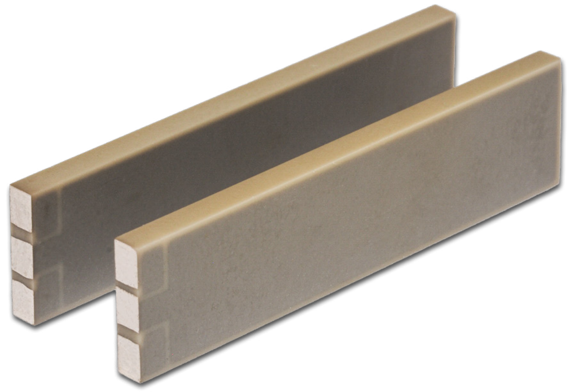
These stacks employ fuses to prevent short circuit conditions in case a single element becomes inoperable, ensuring high reliability and removing the need for urgent maintenance.

Bimorphs and Assemblies

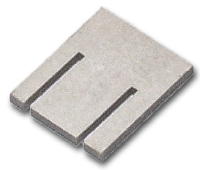
Consisting of two cofired piezo elements with opposite polarity, bimorphs utilize the bending/ flexing mode, either as actuators in e.g., audio applications, or as sensors in accelerometers or vortex flow meters.

Custom Geometries

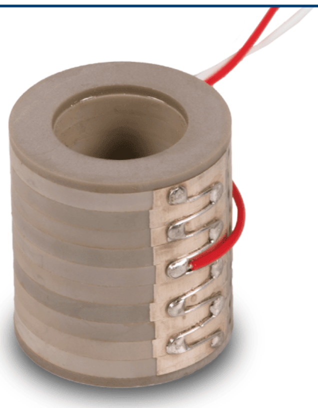
CTS can accommodate customer-specified multilayer designs and unique geometries such as x-y benders, x-y-z bending accelerometers and segmented actuators for adaptive optics.



Bending plates use the bending deformation to produce higher displacements than many other components



Multilayer bimorphs are a monolithic solution with more active material compared to their bulk counterparts



Explore our multilayer products!

Scan the code, or click HERE

Printed Piezo

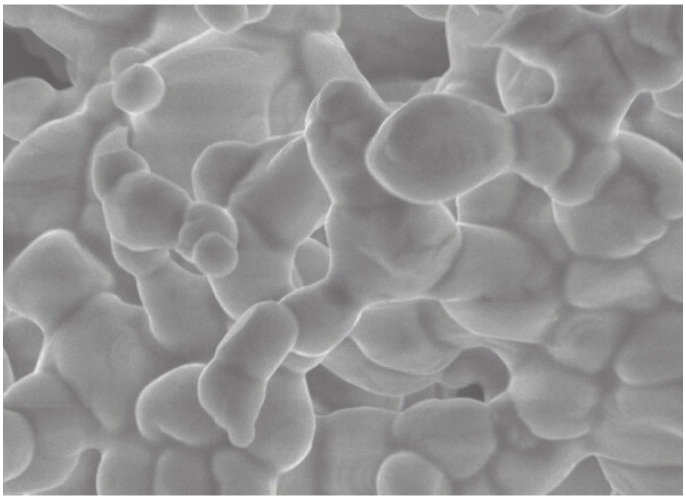
Printed piezoelectric thick film is the ideal material choice for miniaturized sensors and transducers, seeing use in phased/annular arrays, energy harvesting, micro electro-mechanical system (MEMS) accelerometers and 10-30 MHz transducers.

Single element transducer employing InSensor™ thick film on a porous ceramic substrate

InSensor™ Rigid Thick Films

Our dedicated InSensor™ division specializes in the production of advanced PZT thick film which can be deposited onto various industry-common substrates, including alumina, silicon (often used in MEMS-applications) and porous ceramic materials.

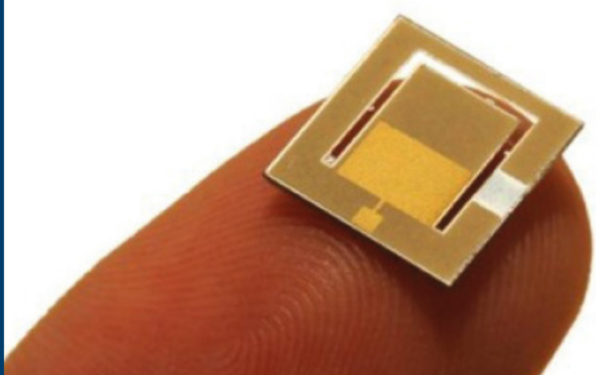
The deposition of thick film onto flat surfaces can be performed by standard screen printing. For more complex surface structures, we have developed a unique printing method comparable to pad printing. By applying this method, we can deposit active thick film layers onto curved and uneven substrate surfaces with a radius of curvature down to 10 mm.



Microstructure of TF2100 thick film PZT

Our piezoelectric thick film material TF2100 is based on our popular hard-doped PZT ceramic formulation, Pz26, which can be used as a direct substitute for all Navy I type materials. The electrical, mechanical and piezoelectric properties of TF2100 are listed in the table on the following page.

Rigid/Flexible Thick Film



PiezoPaint™ Flexible Patches

A new, promising piezoelectric solution from CTS, PiezoPaint™ flexible patches are developed with soft substrate compatibility in mind.

Easily applicable to flexible materials such as textiles, PCBs, plastics and paper, PiezoPaint™ serves as a highly sensitive alternative to PVDF materials and shows great promise in garment applications for sensing, actuating and energy harvesting.

Another potential application is medical treatment, where PiezoPaint™ can administer ultrasonic energy to stimulate cell growth and recovery for active wound healing.

Sample of a PiezoPaint™ flexible patch

Property	Symbol	Unit	InSensor™ TF2100	PiezoPaint™
Relative Free Dielectric Constants (1kHz)	K_{33}^{σ}	-	520	80
Dielectric Dissipation Factor (1kHz)	$\tan\delta$	-	0.008	0.035
Mechanical Quality Factor	Q_m	-	100	
Coupling Coefficients	k_p	-	0.29	
	k_t	-	0.49	0.082
Piezoelectric Charge Coefficients (Displacement Coefficients)	d_{31}	pC/N	-50	-15
	d_{33}		200	40
Piezoelectric Voltage Coefficient	g_{31}	V·m/N x 10^{-3}	-10	
	g_{33}		50	
Acoustic Impedance	Z_a	MRayl	15	13.9

Explore our printed piezo solutions!

Scan the code, or click HERE

Sensors & Transducers

High-performance piezoelectric transducers from CTS enable numerous advanced technologies across the medical, aerospace/defense and industrial sectors such as diagnostic and therapeutic ultrasound equipment, sonar devices, flow meters and vibration sensors. We offer both build-to-print and custom-designed solutions.

Once a reference design has been chosen, we will conduct feasibility studies and simulations to produce a prototype batch. Based on prototype performance, the design can be optimized to meet the requirements before entering production.

Aerial Transducers

These transducers are designed for operation in low acoustic impedance media. Typical applications include gas flow measurement, where acoustic waves are transmitted between two transducers, distance measurement, often used in industrial automation, and gas leak detection.

Contact Transducers

Typically used in non-destructive testing and inspection, offering finer spatial resolution for solids measurements. Applications range from corrosion monitoring of industry pipes to high-frequency microscopy scanning within semiconductor manufacturing.

Aerial transducers for measurements in low acoustic impedance media

Contact transducers offer high-frequency operation up to 200MHz

Ultrasonic Transducers

Immersion Transducers

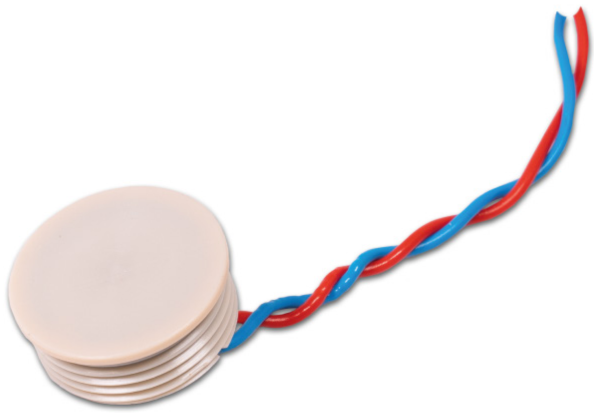
Optimized for materials with acoustic impedance of about 1 MRayl such as water or human tissue. Applications span wide across the industrial, medical and underwater markets with technologies such as flow meters, long-distance sonars, medical doppler transducers and underwater speed logs.

Power Ultrasound Transducers

Taking advantage of our high-power piezoelectric materials, these transducers are fine-tuned to generate high ultrasonic energy. As such, they see frequent use in medical therapeutics, enabling ultrasonic scalpels and non/minimally-invasive surgery, and in high-power industrial applications including ultrasonic cleaning, cutting and welding.

Piezoelectric Sensors

Using the direct piezoelectric effect, our piezoelectric sensors convert various mechanical stimuli into electric signals. Capable of measuring force, vibrations or pressure, our sensors are often used as accelerometers or for heavy equipment strain monitoring. They are also highly effective when employed in bone conduction microphones that are particularly sensitive to vibrations in the audible frequency range.



Immersion transducers are used across many industries as they can operate in a wide frequency spectrum

Piezoelectric strain sensor - Often used to monitor heavy industrial equipment

Explore our sensors and transducers!

Scan the code, or click HERE

Our Piezoelectric Materials

PZT Polycrystalline Ceramics

CTS has developed and offers a wide selection of piezoceramic materials, fine-tuned and optimized for specific applications. All materials are of the PZT system, but we employ dopants of various kinds to enhance certain traits.

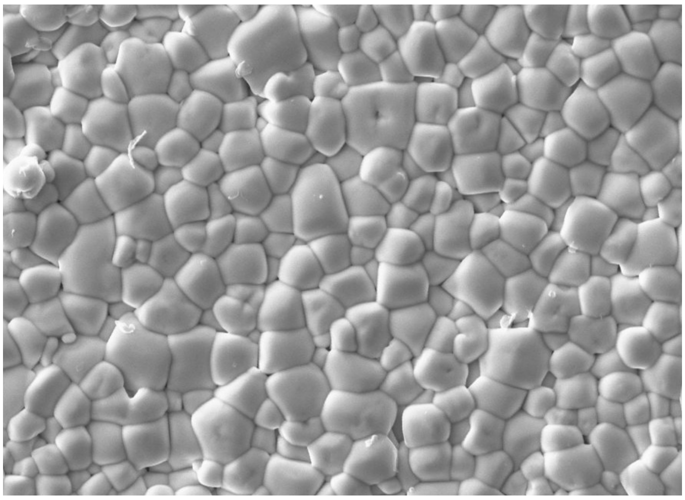
Our soft PZT materials, many of them capable of serving as direct Navy II substitutes, are created by forming A vacancies in their crystal lattices. This increases properties such as permittivity, coupling and resistivity while increasing dielectric loss and reducing stiffness and mechanical quality factor.

Our hard PZT materials, usable as Navy I and III alternatives, are made by forming oxygen vacancies. Conversely, this increases stiffness and mechanical quality factor while lowering dielectric loss at the expense of permittivity, coupling and resistivity.

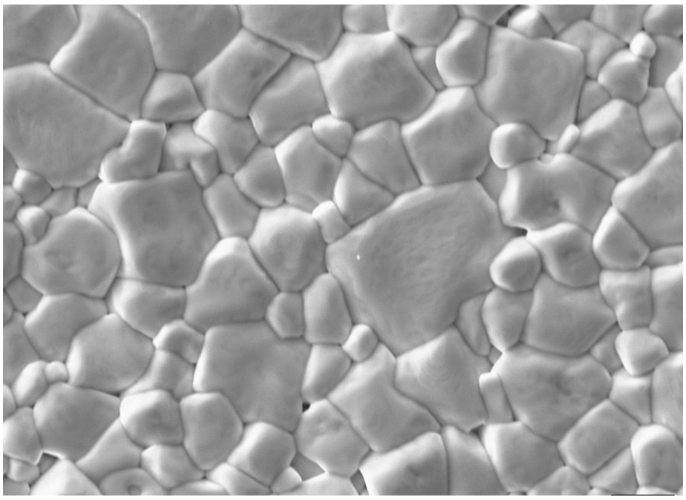
We also offer more specialized ceramic materials for very specific end-uses. For applications where acoustic matching is critical, such as non-destructive testing (NDT), we have a dedicated line of low acoustic impedance ceramics with high thickness coupling and permittivity.

Our very soft materials, on the other hand, feature high sensitivity, dielectric constants and coupling coefficients to meet the demands of high-frequency imaging, shear inkjet printheads, underwater acoustic sensors and precision flow meters.

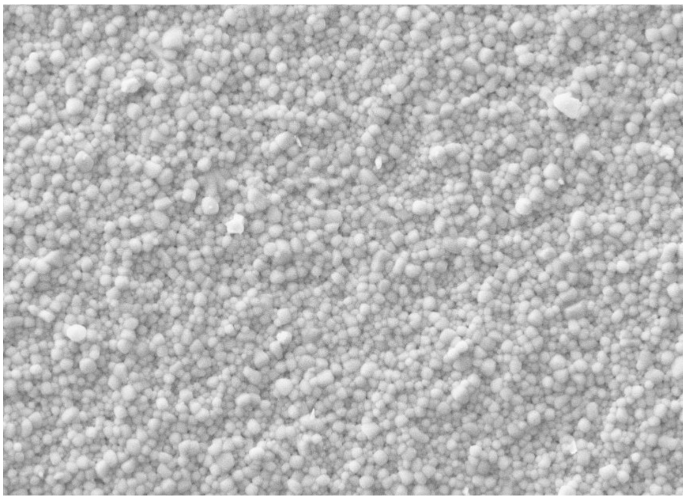
Finally, our high-intensity focused ultrasound (HIFU) materials are intended for high-power operation in combination with the smallest possible ceramic volume. These materials are ideal within the rapidly growing field of medical therapeutic ultrasound and industrial high-power applications e.g., ultrasonic cleaning, cutting and welding.



Microstructure of soft-doped Pz27



Microstructure of hard-doped Pz26



Microstructure of Pz34 (HIFU)

PMN-PT and PIN-PMN-PT Single Crystals

Being the world's largest, fully integrated developer and manufacturer of piezoelectric single crystal components, CTS has several highly optimized material formulations at hand.

We specialize in lead magnesium niobate-lead titanate materials that offer the highest piezoelectric performances in the industry. PMN-PT crystals possess unmatched sensitivity, while PIN-PMN-PT cystals provide the greatest power output. With full in-house manufacturing capabilities, we produce world-class single crystals in high quantities.

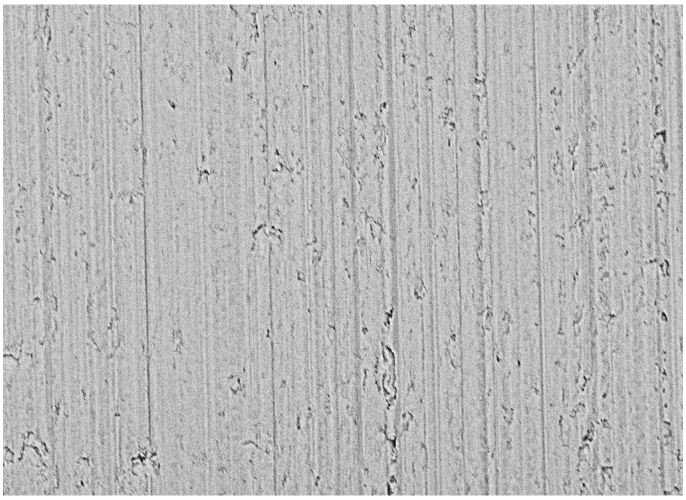
Lead-Free Piezoceramics

In addition to our PZT ceramics, we offer a lead-free program with sodium bismuth titanate-barium titanate (NBT-BT) and potassium sodium niobate (KNN) formulations available. We have also developed a dedicated high-temperature material line based on the lead-free bismuth titanate system.

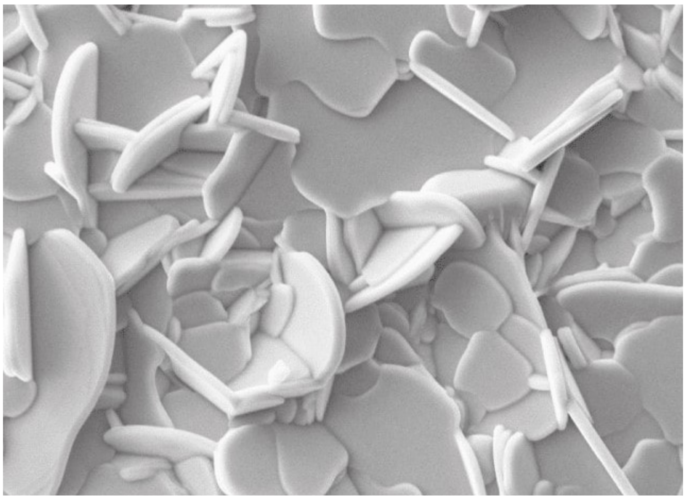
Textured Tape Cast Ceramics

Textured piezoelectric ceramics might just be the next big innovation in the field of piezoelectricity, bridging the gap between PZT ceramics and PMN-PT single crystals in terms of performance and price point. Textured ceramics are created by adding seed crystals to a piezoceramic slurry that will align to provide templates for oriented grain growth under sintering, eventually creating a dense material of highly oriented grains. The result is a piezoceramic product with a high coupling and piezoelectric coefficients.

Offering greater sensitivity than bulk PZT ceramics, yet easier machining than traditional single crystals, textured ceramics is a new and balanced piezoelectric product with great promise.



As-diced surface of PMN-PT material. No defects or grain boundaries due to the homogenity of the crystal



Pz46 lead-free ceramic based on bismuth titanate

Microstructure of T4001 textured ceramic showing typical "brick wall" of oriented grains

Material Applications - Recommended Materials for Your Application

Each application is different. To achieve optimal performance, a technology must be paired with a material that meets the demands of its intended use. The table below shows which of our material types that are suited for specific applications. If in doubt, do not hesitate to contact us.

Material Category	Soft					Very soft			Single Crystal	
Materials	**Pz27, 3195STD, 3195HD, NCE51**	**Pz29,3222HD, NCE56**	**LF22 (Lead-Free)**	**LF41 (Lead-Free)**	**Pz62* (Lead-Free)**	**Pz21, 3203STD, 3221HD, 3203HD, 3241HD**	**Pz94**	**NCE55, 3257HD**	**PMN-PT**	**PIN-PMN-PT**
Underwater and Defense										
Transmitters (High Power)										x
Receivers, Hydrophones	x	x	x	x	x	x			x	x
Generator (Fuze)	x	x								
Medical										
Therapeutic (HIFU/HITU, Surgery, Dental)										
Diagnostic (Imaging, IVUS)	x	x		x	x	x	x	x	x	x
Combined, Doppler	x	x		x	x	x				x
Implantable Devices (Hearing Aids, Pacemakers, Valves etc.)	x	x	x	x					x	
Industrial										
Non-Destructive Testing	x	x	x	x	x	x	x			
Transducers (Flow, Level)	x	x	x		x					
Sensors (Shock, Acceleration)	x			x	x					
Acoustic Emission	x	x		x		x				
Actuators (Positioning, Valves, Inkjet)	x	x	x	x						
High Power Ultrasound (Cleaning, Cutting, Welding)										

***Material in advanced development stage.**

Material Applications - Recommended Materials for Your Application

Material Category	Hard				HIFU		Low Acoustic Impedance	
Materials	**Pz24**	**Pz89, K1000, NCE81. K1100**	**Pz26, K1300, NCE40, NCE41, K1450**	**Pz12*, Pz12X*, LF51, LF52 (Lead-Free)**	**Pz34**	**Pz54**	**Pz36**	**Pz37, Pz39**
Underwater and Defense								
Transmitters (High Power)	x	x	x	x	x	x	x	
Receivers, Hydrophones								x
Generator (Fuze)			x					
Medical								
Therapeutic (HIFU/HITU, Surgery, Dental)	x	x	x	x	x	x	x	
Diagnostic (Imaging, IVUS)								
Combined, Doppler								
Implantable Devices (Hearing Aids, Pacemakers, Valves etc.)								
Industrial								
Non-Destructive Testing					x		x	x
Transducers (Flow, Level)								x
Sensors (Shock, Acceleration)								
Acoustic Emission								
Actuators (Positioning, Valves, Inkjet)			x					
High Power Ultrasound (Cleaning, Cutting, Welding)	x	x	x	x	x	x		

***Material in advanced development stage.**

Material Properties

Property	Symbol	Units	Hard Materials									
			Pz24	K1000	NCE81	K1100	Pz89	NCE40	K1300	Pz26	NCE41	K1450
Relative Free Dielectric Constant (1kHz)	K_{33}^{σ}	-	420	1000	1030	1100	1180	1250	1300	1300	1350	1450
Dielectric Dissipation Factor (1kHz)	$\tan\delta$	-	0.003	<0.004	0.0017	<0.004	0.003	0.0025	<0.005	0.003	0.004	<0.012
Curie Temperature	T_c >	°C	330	325	300	325	320	318	325	330	318	320
Density	ρ	g/cm³	7.7	7.55	7.75	7.55	7.65	7.7	7.55	7.7	7.93	7.55
Mechanical Quality Factor	Q_m	-	>1000	1000	1300	550	>1000	700	550	>1000	1400	350
Coupling Coefficients	k_p	-	0.50	0.56	0.56	0.57	0.53	0.58	0.58	0.56	0.57	0.57
	k_t	-	0.50	0.52	0.47	0.52	0.47	0.48	0.51	0.47	0.5	
	k_{31}	-	0.29	0.33	0.31	0.33	0.32	0.35	0.32	0.33	0.33	0.32
	k_{33}	-	0.57	0.64	0.69	0.66	0.65	0.68	0.7	0.68	0.68	
Piezoelectric Charge Coefficients (Displacement Coefficients)	d_{31}	pC/N	-55	-110	-98	-120	-108	-133	-125	-130	-130	-130
	d_{33}		160	230	255	250	280	304	300	300	310	350
	d_{15}		150				280		500	330		
Piezoelectric Voltage Coefficients	g_{31}	V·m/N x 10^{-3}	-16	-14	-10.8	-12.3	-11	-12	-10.9	-11	-10.9	-10.1
	g_{33}		54	26	28	25.7	23	27.5	26.1	28	25.9	30.4
Frequency Constants	N_p	Hz·m	2400	2270	2300	2180	2350	2170	2200	2230	2280	2080
	N_t		2100	2067	2130	2024	2150	2070	2100	2040	2000	
	N_{31}		1670	1630		1620	1750		1570	1500		
	N_{33}		1600	1550		1520	2060		1500	1800		

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

Material Properties

Property	Symbol	Units	HIFU		High Temperature	Lead-Free						
			Pz34	Pz54	Pz46	Pz12*	LF52	Pz12X*	LF51	Pz62*	LF22	LF41
Relative Free Dielectric Constant (1kHz)	K^{σ}_{33}	-	220	2800	113	660	700	813	1100	1140	1400	2200
Dielectric Dissipation Factor (1kHz)	$\tan\delta$	-	0.014	0.003	0.004	0.03	0.004	0.032	0.01	0.02	0.013	0.019
Curie Temperature	$T_C >$	°C	400	220	650		340		230	333	290	250
Depoling Temperature	$T_d >$	°C				200		85				
Density	ρ	g/cm³	7.65	7.8	6.39	5.74	4.5	5.78	4.59	4.4	4.55	4.45
Mechanical Quality Factor	Q_m	-	>1000	1500	>1000	170	910	200	725	200	100	50
Coupling Coefficients	k_p	-	0.07	0.56	0.02	0.15	0.40	0.32	0.29	0.4	0.47	0.53
	k_t	-	0.42	0.48	0.18	0.39	0.38	0.47	0.30	0.49	0.39	0.47
	k_{31}	-	0.05	0.35	0.01	0.09	0.24	0.19	0.17		0.27	0.30
	k_{33}	-	0.4	0.7	0.17	0.39	0.46	0.55	0.39		0.50	0.59
Piezoelectric Charge Coefficients (Displacement Coefficients)	d_{31}	pC/N	-5	-200	-1.32	-20.6	-55	-56.6	-50		-95	-148
	d_{33}		50	460	18.6	107	110	152	120	270	180	300
	d_{15}		40		7.79	94.7	300		190		260	370
Piezoelectric Voltage Coefficients	g_{31}	V·m/N x 10^{-3}	-3		-1.3	-3.5	-9.4	-7.7	-5.1		-8.1	-7.7
	g_{33}		25	20	18.5	18.3	18.4	21.1	12	26.7	15.4	15.5
Frequency Constants	N_p	Hz·m	2770	2120	2490	3060	3400	2620	3400	2110	3200	2990
	N_t		2170	1980	1910	2460	2900	2370	3000	2280	2900	2560
	N_{31}		2050		1860	2280	2500	1900	2500		2200	2130
	N_{33}				1810	1870	2500	2060	2400		2300	2120

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***Material in advanced development stage, specifications are subject to change.**

Material Properties

Property	Symbol	Units	Soft Materials									
			Pz23	**Pz27**	**3195STD**	**3195HD**	**NCE51**	**3222HD**	**Pz29**	**NCE56**	**3203STD**	**3221HD**
Relative Free Dielectric Constant (1kHz)	K_{33}^{σ}	-	1500	1800	1800	1900	1900	2650	2820	2900	3250	3450
Dielectric Dissipation Factor (1kHz)	$\tan\delta$	-	0.015	0.017	<0.02	<0.02	0.015	<0.02	0.019	0.014	<0.02	<0.02
Curie Temperature	$T_C >$	°C	350	350	350	350	360	270	235	242	225	242
Density	ρ	g/cm³	7.7	7.7	7.7	7.95	7.85	7.9	7.45	7.65	7.7	7.87
Mechanical Quality Factor	Q_m	-	100	80	80	80	80	80	90	75	50	50
Coupling Coefficients	k_p	-	0.51	0.59	0.63	0.68	0.65	0.72	0.62	0.64	0.69	0.74
	k_t	-	0.43	0.47	0.49	0.49	0.5	0.53	0.51	0.5	0.56	0.54
	k_{31}	-	0.29	0.33	0.35	0.4	0.39	0.45	0.37	0.38	0.41	0.46
	k_{33}	-	0.65	0.7	0.7	0.72	0.74	0.74	0.75	0.74	0.7	0.78
Piezoelectric Charge Coefficients (Displacement Coefficients)	d_{31}	pC/N	-130	-170	-175	-190	-208	-270	-240	-250	-270	-300
	d_{33}		330	440	350	390	443	485	575	580	530	600
	d_{15}		420	500	360	460		850	700		790	1000
Piezoelectric Voltage Coefficients	g_{31}	V·m/N x 10^{-3}	-10	-11	-11	-11.3	-12.4	-11.5	-10	-9.7	-9.4	-9.8
	g_{33}		25	27	24.2	23.2	26.3	21.3	23	22.6	18.4	19.7
Frequency Constants	N_p	Hz·m	2160	2010	2020		1925	1910	1990	1950	1920	1830
	N_t		2030	1980	2025	2110	2000	2050	1960	2020	1870	2020
	N_{31}		1480	1400	1420	1440		1420	1410		1400	
	N_{33}		1600	1500					1500			

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Material Properties

Property	Symbol	Units	Very Soft Materials						Low Acoustic Impedance		
			Pz21	3203HD	3241HD	Pz94	NCE55	3257HD	Pz36	Pz37	Pz39
Relative Free Dielectric Constant (1kHz)	K_{33}^{σ}	-	3650	3800	4100	4300	5000	5700	850	1200	1750
Dielectric Dissipation Factor (1kHz)	$\tan\delta$	-	0.018	<0.02	<0.02	0.025	0.022	<0.03	0.003	0.017	0.019
Curie Temperature	$T_C >$	°C	220	225	223	185	160	155	330	350	220
Density	ρ	g/cm³	7.8	7.87	7.88	7.9	7.92	8.22	6.3	6.4	6.4
Mechanical Quality Factor	Q_m	-	65	50	50	60	70	75	500	50	70
Coupling Coefficients	k_p	-	0.58	0.75		0.59	0.65	0.7	0.37	0.38	0.28
	k_t	-	0.47	0.55	0.55	0.46	0.5	0.5	0.51	0.52	0.53
	k_{31}	-	0.34	0.43	0.44	0.38	0.37	0.41		0.15	
	k_{33}	-	0.69	0.78	0.77	0.7	0.72	0.76		0.6	
Piezoelectric Charge Coefficients (Displacement Coefficients)	d_{31}	pC/N	-250	-320	-325	-305	-320	-360			
	d_{33}		580	650	640	670	694	730	260	380	230
	d_{15}		620	1000	880			850			
Piezoelectric Voltage Coefficients	g_{31}	V·m/N x 10^{-3}	-7	-9.5	-8.9	-7	-7.2	-7.1			
	g_{33}		18	19	17.6	15	15.7	14.5	40	40	28
Frequency Constants	N_p	Hz·m	2030			1980	1970	1940		1800	1920
	N_t		1970	2000	2000	1970	1990	2090	1530	1450	1550
	N_{31}		1375			1380		1430			
	N_{33}		1325			1830		1590			

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Material Properties

Property	Symbol	Units	Single Crystal		
			PMN-28% PT Type A	PMN-32% PT Type B	PIN-24% PMN-PT
Relative Free Dielectric Constants (1kHz)	K^{σ}_{11}	-	1600	1620	1728
	K^{σ}_{33}		5500	7000	4753
Phase Transition	Trt	°C	90-100	80-90	100-115
Coercive Field	*Ec*	kV/cm	2.5	2.5	4.5-6
Density	ρ	g/cm^3	8.1	8.1	8.122
Coupling Coefficients	k_{15}	-	0.28	0.39	0.26
	k_t	-	0.6	0.62	0,5
	k_{31}	-	0.43	0.44	0.46
	k_{33}	-	0.9	0.93	0,89
Piezoelectric Charge Coefficients (Displacement Coefficients)	d_{31}	pC/N	-568	-760	-646
	d_{33}		1190	1620	1285
	d_{15}		135	192	122
Compliance Coefficients	s^E_{11}	m^2/N x 10^{-12}	45.86	58.85	45.76
	s^E_{12}		-28.11	-36.58	-19.60
	s^E_{13}		-15.43	-20.80	-23.16
	s^E_{33}		36.15	49.18	49.04
	s^E_{44}		15.53	16.53	14.33
	s^E_{66}		16.64	18.15	16.10

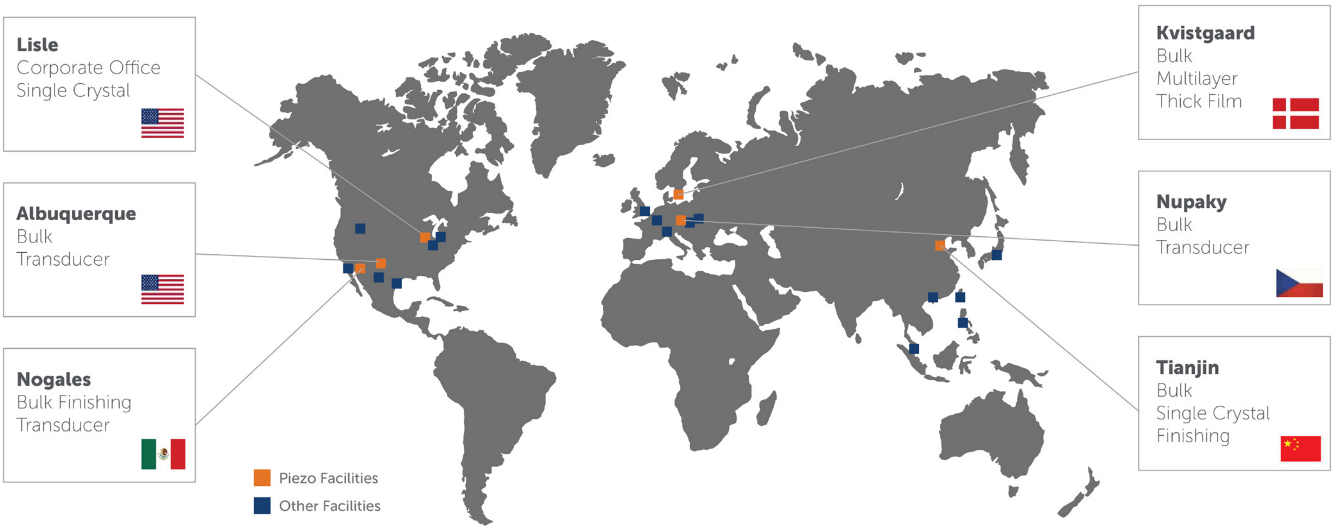
Data represent typical material values. Actual production values may vary +/- 10% for dielectric properties and +/- 5% for electromechanical and physical properties.

Notes

CTS Corporation

Headquartered in the USA, CTS Corporation (NYSE: CTS) is a leading designer and manufacturer of products that Sense, Connect, and Move. The company manufactures sensors, actuators, and electronic components in North America, Europe, and Asia, and provides engineered products to customers in the aerospace/defense, industrial, medical, and transportation markets.

Our Piezo Facilities around the World



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