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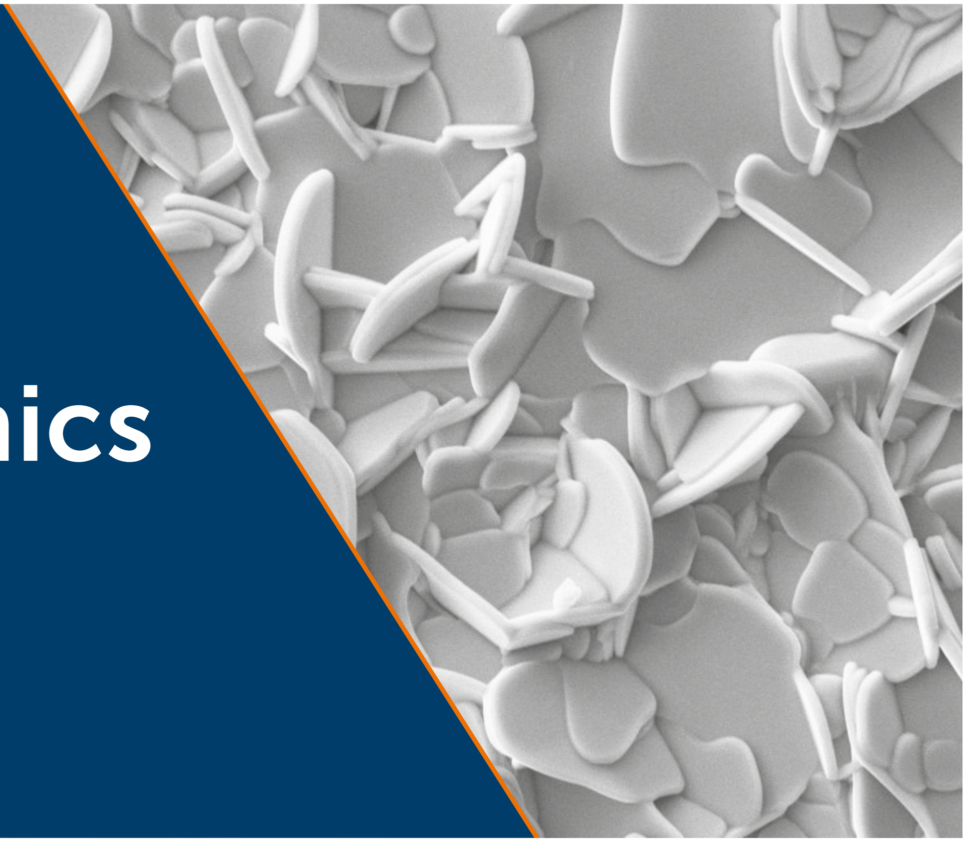

Lead-Free Piezoceramics

Piezoelectric Materials

Material Brochure

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Lead-Free Piezoceramics

The industry of piezoelectricity has since the early 1950's been dominated by a single material group: Lead zirconate titanate, or as it is more commonly known, PZT. Combining strong piezoelectric activity with easy, cost-effective processing and shaping flexibility, the material is used far and wide for piezoelectric components in all shapes and sizes.

In recent years, however, the demand for lead-free piezoceramic alternatives has seen a notable increase across several industries. Driven in part by the RoHS directive and similar lead-restrictive legislation, research into lead-free piezoceramics has taken great strides to the point where the performance of the alternatives in certain areas and applications can compare and even compete with PZT ceramics. While a full lead-free transition is still ways off, the industry is gradually shifting its focus, closely monitoring the lead-free development that shows no signs of slowing down.

As one of the world's premier developers and manufacturers of piezoelectric materials, components and devices, CTS offers a full lead-free materials program for customers who are looking to implement lead-free components into their applications and get a head start on the industry transition. We have several application-optimized material formulations at hand, based on the KNN, NBT-BT and bismuth titanate systems, and can provide lead-free components in standard geometries such as plates, discs and rings.

In the following, you can explore our lead-free materials to find a formulation that fits your particular application requirements.

KNN — Potassium Sodium Niobate

Potassium sodium niobate ($K_{0.5}Na_{0.5}NbO_3$), or simply *KNN*, is among the most thoroughly researched and tested lead-free piezoceramics materials on the market. KNN typically crystallizes in a perovskite lattice structure, shared by many other polycrystalline piezoceramics, including PZT. The structure of KNN is characterized by a framework of corner-sharing NbO_6 octahedra with potassium and sodium ions occupying the interstitial spaces.

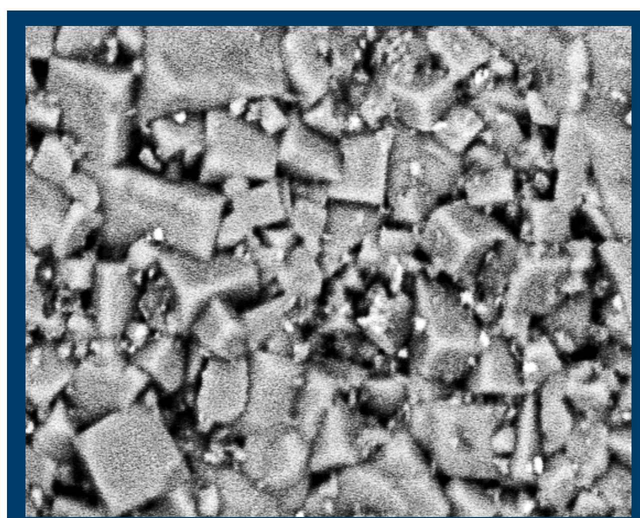
The material generally exhibits decent piezoelectric properties with a piezoelectric charge coefficient in the 100-300 pC/N range. It also shows good thermal stability across varying temperatures. CTS offers five distinct KNN material formulations, each optimized towards specific applications.

LF22

Our LF22 piezoceramic material is created as a lead-free alternative to traditional soft-doped PZT ceramics, exhibiting high sensitivity and a low mechanical quality factor. It also has a greater Curie temperature than the closely related LF41 material. Ideal applications for LF22 include underwater receivers and hydrophones, implantable devices such as hearing aids, flow and level transducers and non-destructive testing.

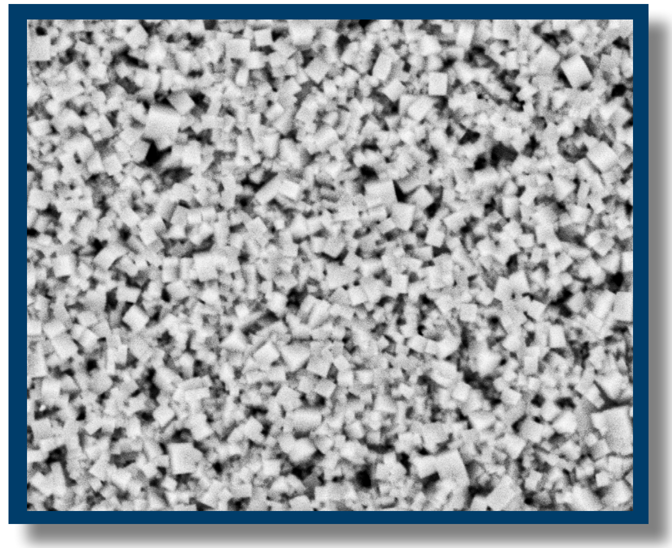
LF41

Also intended as a lead-free substitute to soft-doped PZT, LF41 is the most sensitive material in our lead-free program with a piezoelectric charge coefficent of 300 pC/N in the 33 direction. It is a very soft material with a low mechanical quality factor and a relatively high piezoelectric coupling. It is a good choice for medical imaging applications as well as shock and acceleration sensors, acoustic emission and actuating purposes.



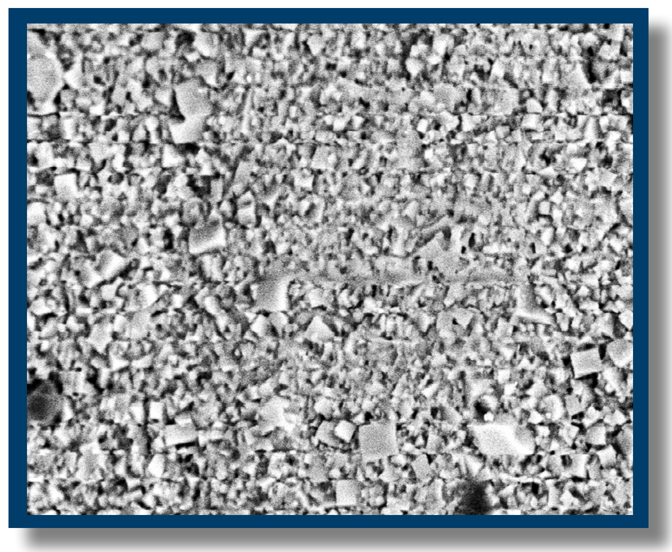
Pz62

Another soft lead-free alternative, but with a higher mechanical quality factor than LF22 and LF41. Pz62 exhibits decent energy coupling and a piezoelectric charge coefficient in the higher end of the scale. It also has the highest Curie temperature among our soft materials, on par with our soft-doped PZT ceramics. It will function well in medical imaging, underwater communication and ultrasonic sensors and transducers.



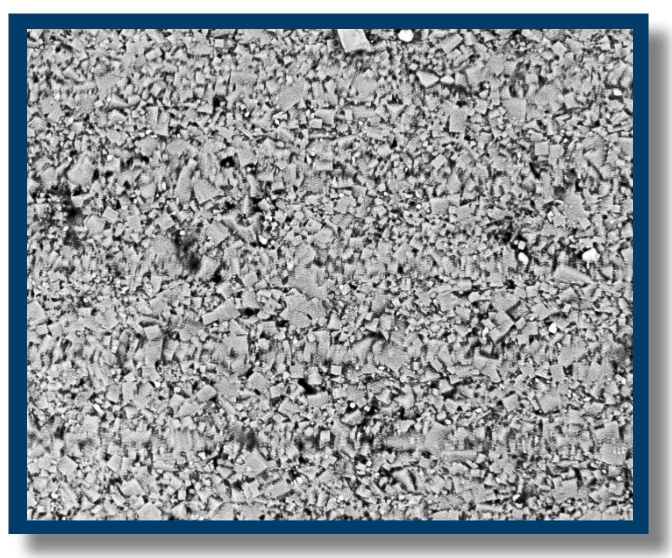
LF51

LF51 is modelled after our hard-doped PZT ceramics with a high mechanical quality factor and a dielectric loss on the lower end of the spectrum. As a lead-free alternative to hard PZT materials, LF51 is well-suited for high-power applications such as underwater transmitters, medical therapeutics and ultrasonic, cleaning, cutting and welding.



LF52

LF52 is the hardest material among our lead-free piezoceramic solutions. As such, it possesses a high mechanical quality factor and shows very low dielectric losses. In addition, LF52 has a greater Curie temperature than any of our hard-doped PZT materials. It is ideal for high-power ultrasound applications including ultrasonic surgery and dental scaling.

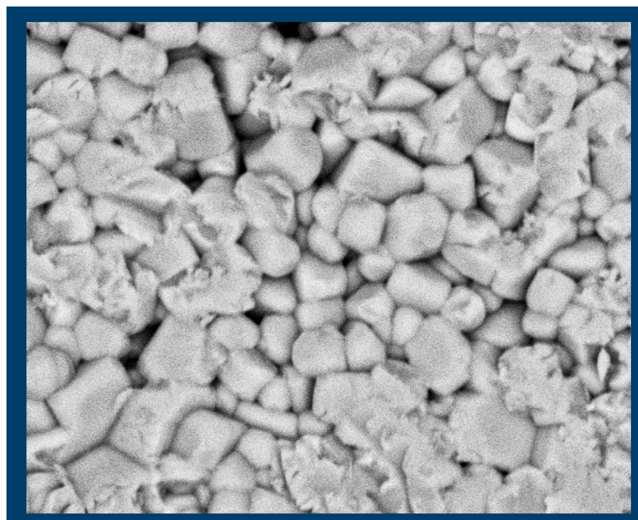


NBT-BT — Sodium Bismuth Titanate - Barium Titanate

Sodium bismuth titanate - barium titanate ($(Na_{0.5}Bi_{0.5})TiO_3$-$BaTiO_3$), abbreviated *NBT-BT,* is another piezoelectric material with the perovskite crystal structure. In order to reduce the coercive field and enhance the piezoelectric properties, NBT is here modified with barium titanate, the first polycrystalline piezoelectric material to be discovered. Important characteristics of NBT-BT include a high k_p/k_t ratio and the ability to withstand driving at very high vibration velocity. On the other hand, the operating temperature is lower than for many other piezoceramics. CTS offers two different material formulations based on the NBT-BT system.

Pz12

Our Pz12 formulation exhibits low dielectric constant and low dielectric dissipation. The low planar coupling of the material allows for clearer thickness vibration modes, making Pz12 ideal for the generation of powerful acoustic waves in the thickness direction using a transducer with a small footprint.



Pz12X

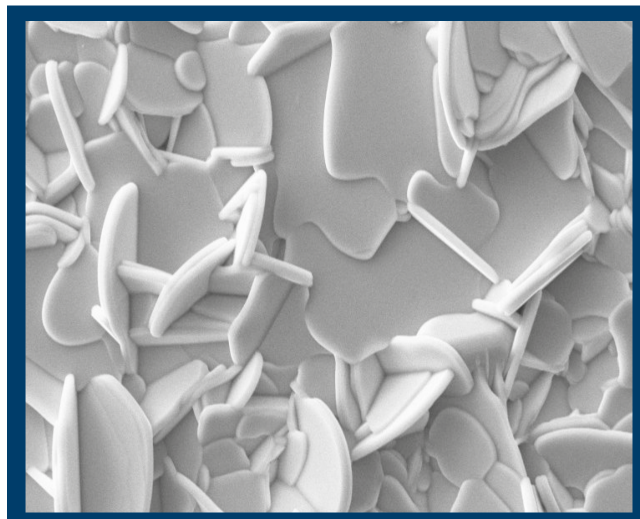
Pz12X is a variant of Pz12, where the mechanical quality factor and the thickness electromechanical coupling have been increased at the expense of temperature capability. The material finds use in intermittent acoustic power generation, although its intermediate mechanical quality factor makes it suitable as a receiver as well, enabling sonar applications built around a single transducer.

Bismuth Titanate

Bismuth titanate belongs to a group of piezoelectric materials also known as bismuth layer-structured ferroelectrics (BLSF) or Aurivillius phases. In these materials, blocks of TiO_6 octahedra (like in perovskites) are separated by bismuth oxid layers, which makes the structure very anisotropic (cf. the microstructures shown below with characteristic platelets). Their main advantage as piezoelectric materials is their very high Curie temperature, which allows for operation at high temperatures - well above what traditional PZT ceramics are capable of - and their stable performances at low temperatures. While their sensitivity is lower than seen for other commercial piezoceramics, they resist high driving fields and show very low mechanical and dielectric losses. They are ideal for sensor applications utilizing the direct piezoelectric effect, e.g. high-temperature accelerometers.

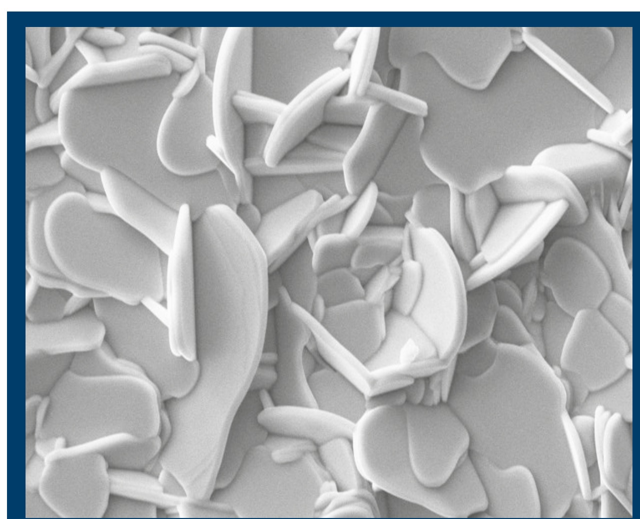
Pz46

Pz46 is CTS' dedicated high-temperature piezoceramic material. Exhibiting a Curie temperature above 650°C, Pz46 is the go-to material for applications that are intended for operation in extreme temperatures under which other piezoelectric materials would depolarize. In addition to its temperature capabilities, Pz46 has very low dielectric loss.



Pz48

Of all our piezoceramic materials, lead-free or not, Pz48 possesses the highest Curie temperature. Not depolarizing until above 770°C, Pz48 has unparalleled temperature capabilities and also offers very stable performances in the low temperature range. It is the harder material compared to Pz46, with a mechanical quality factor of around 2000, and has even lower dielectric loss.



Material Applications

Application	Pz46	Pz48	Pz12	Pz12X	LF52	LF51	Pz62	LF22	LF41
Underwater and Defense									
Hydrophones							x	x	x
Acoustic Communication							x	x	
Transmitters					x	x			
Combined Emitter/Receiver				x		x	x		
Medical									
Sonication, Lysis			x	x					
Nebulizer							x	x	
Therapeutic Ultrasound			x		x	x			
Hearing Aids							x		x
Industrial									
Power Ultrasound			x	x	x				
Flow Metering								x	x
Acoustic Emission							x	x	x
Drop-on-Demand Inkjet									x
High-Temperature Applications	x	x							

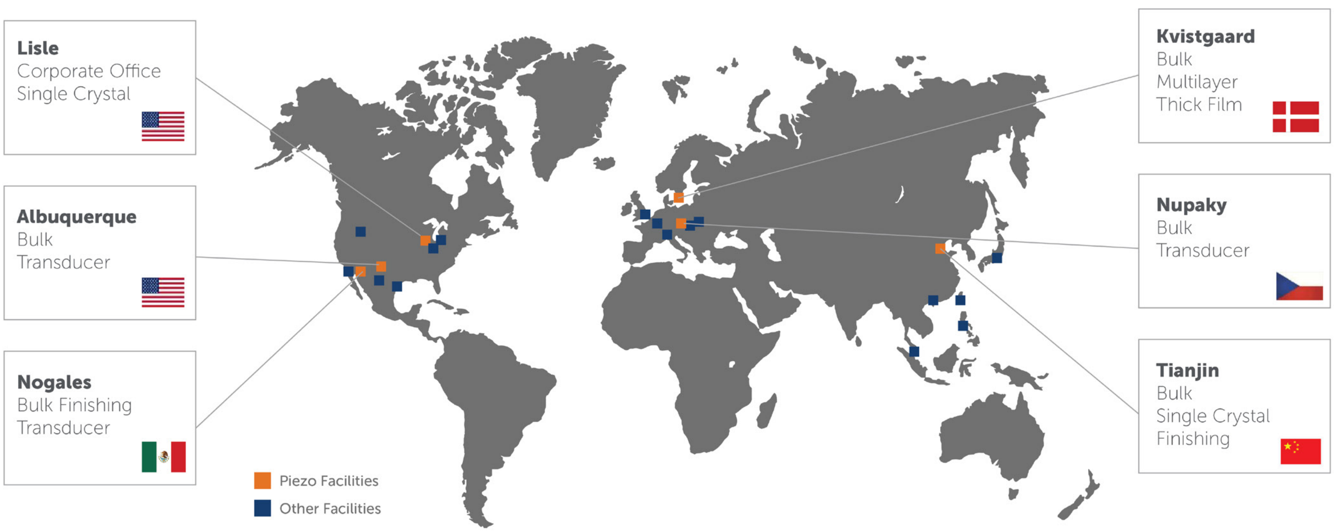
Material Properties

Property	Symbol	Unit	Pz46	Pz48	Pz12	LF52	Pz12X	LF51	Pz62	LF22	LF41
Relative Free Dielectric Constant (1kHz)	K_{33}^{σ}	-	113	126	660	700	813	1100	1140	1400	2200
Dielectric Dissipation Factor (1kHz)	$\tan\delta$	-	0.004	0.003	0.03	0.004	0.032	0.01	0.02	0.013	0.019
Curie Temperature	$T_C >$	°C	650	770		340		230	333	290	250
Depoling Temperature	$T_d >$	°C			200		85				
Density	ρ	g/cm^3	6.39	6.85	5.74	4.50	5.78	4.59	4.40	4.55	4.45
Mechanical Quality Factor	Q_m	-	>1000	>2000	170	910	200	725	200	100	50
Coupling Coefficients	k_p	-	0.02	0.07	0.15	0.40	0.32	0.29	0.40	0.47	0.53
	k_t	-	0.18	0.20	0.39	0.38	0.47	0.30	0.49	0.39	0.47
	k_{31}	-	0.01	0.04	0.09	0.24	0.19	0.17		0.27	0.30
	k_{33}	-	0.17	0.21	0.39	0.46	0.55	0.39		0.50	0.59
Piezoelectric Charge Coefficients (Displacement Coefficients)	d_{31}	pC/N	-1.32	-3.61	-20.6	-55	-56.6	-50		-95	-148
	d_{33}		18.6	20.1	107	110	152	120	270	180	300
	d_{15}		7.79		94.7	300		190		260	370
Piezoelectric Voltage Coefficients	g_{31}	V·m/N x 10^{-3}	-1.3	-3.2	-3.5	-9.4	-7.7	-5.1		-8.1	-7.7
	g_{33}		18.5	18.1	18.3	18.4	21.1	12	26.7	15.4	15.5
Frequency Constants	N_p	Hz·m	2490	2850	3060	3400	2620	3400	2110	3200	2990
	N_t		1910	2240	2460	2900	2370	3000	2280	2900	2560
	N_{31}		1860	2160	2280	2500	1900	2500		2200	2130
	N_{33}		1810	2090	1870	2500	2060	2400		2300	2120

About CTS Corporation

CTS is a leading designer and manufacturer of products that Sense, Connect, and Move. We manufacture sensors, actuators and electronic components in North America, Europe, and Asia, and provide solutions to OEMs in the aerospace & defense, medical, industrial, communications, information technology and transportation industries. Our piezoelectric products come in a variety of compositions, geometries, and dimensions with high quality standards to meet demanding requirements. Our portfolio encompasses bulk and multilayer ceramics, single crystal and printed piezos as well as sub-assemblies, composites and transducers based on these products.

Our Piezo Facilities



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