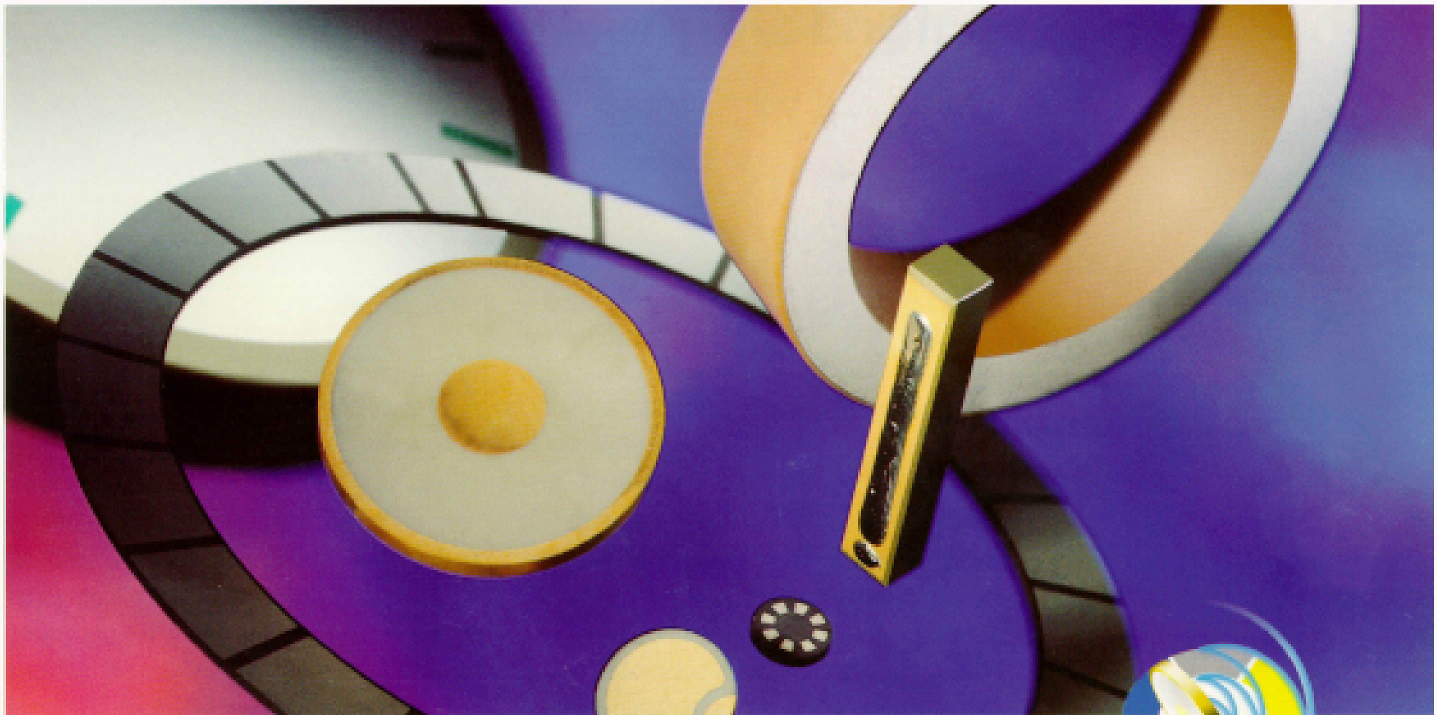


Piezo Applications
Division

Piezoceramics

CeramTec
THE CERAMIC EXPERTS

Competence in Piezoceramic Engineering

High-power ultrasonic transducers

❍

Piezoceramic sensors

❍

Actuators

Piezoceramic devices are used to convert mechanical features such as pressure or acceleration into voltages, or conversely, to convert a voltage into mechanical motion or oscillation. Piezoceramics are used in many types of electromechanical transducers operating in a wide range of frequencies. In sensors, they enable forces, pressures and accelerations to be converted into electrical signals. In sound generators and ultrasonic devices such as transducers they produce oscillations or deformation in response to voltage input.

In automotive engineering, piezosensors are used for occupant safety and intelligent engine control solutions. As gas igniting devices in heaters and lighters, piezoceramic components have become well known, high volume product. In ultrasonic systems, piezoceramic devices generate powerful ultrasonic waves used for cleaning, drilling and welding, as well as to stimulate chemical processes. They act as transmitters and receivers in many signal and information processing systems. Other important applications of piezoceramic devices include ultrasonic locating and distance measuring systems, nondestructive materials testing, and medical diagnostic equipment.

The function of piezoceramic actuators is based on the material's ability to produce deformation in the micrometer range. This behavior opens new applications for electromechanical transducers in hydraulic and pneumatic valves, positioning systems, micromanipulators, and flowmeter systems for liquid and gaseous fluids.

Given this great diversity of applications, users are generally advised to work closely with CeramTec's experts from the product development stage. An experienced staff is available to answer your questions. In dialogue with the customer we can help to specify application conditions, requirement criteria and design prerequisites, and to develop high quality cost-effective solutions. Advanced manufacturing techniques enable CeramTec to produce high quality piezoceramic devices including in very large volumes. Our company-wide quality management system assures that our products and services will satisfy the customer's expectations.

Controlling dynamic automotive functions

High Performance Piezoceramic Materials

Piezoceramic devices are subjected to high loads yet expected to perform with strong reliability. CeramTec has addressed this need by developing a range of special high-performance materials suitable for piezoelectric engineering. With their diverse characteristics and application features, our SONOX® material range has earned an excellent reputation in the world of sensors, actuators, and transducers.

Typical applications	Appropriate material
Ultrasonic cleaning Sonar technology	SONOX® P4
Sensor technology Materials testing Medical diagnostics and treatment	SONOX® P5
Ultrasonic welding and drilling	SONOX® P8
Sensor technology Actuator engineering Materials testing	Special material types

Material categories

Piezoceramic materials are classified according to their chemical composition on the one hand and according to specific application conditions on the other. Selection criteria include typical performance parameters as well as specific material behavior under high electrical and mechanical loads.

A basic distinction is made between two material categories:

Group I: SONOX® P4, SONOX® P8, SONOX® P88

These materials are capable of handling high control voltages and high mechanical pressure loads. Main features include the following:

- low dielectric losses
- dielectric constants between 1000 and 1400
- high Q factor (between 500 and 2000)
- high Curie temperatures
- high coercive field strength

These materials are particularly suitable for high-power ultrasonic applications covering frequencies from 20 kHz to Mhz-ranges.

Group II: SONOX® P5, SONOX® P51, SONOX® P52, SONOX® P53

These materials are characterized by

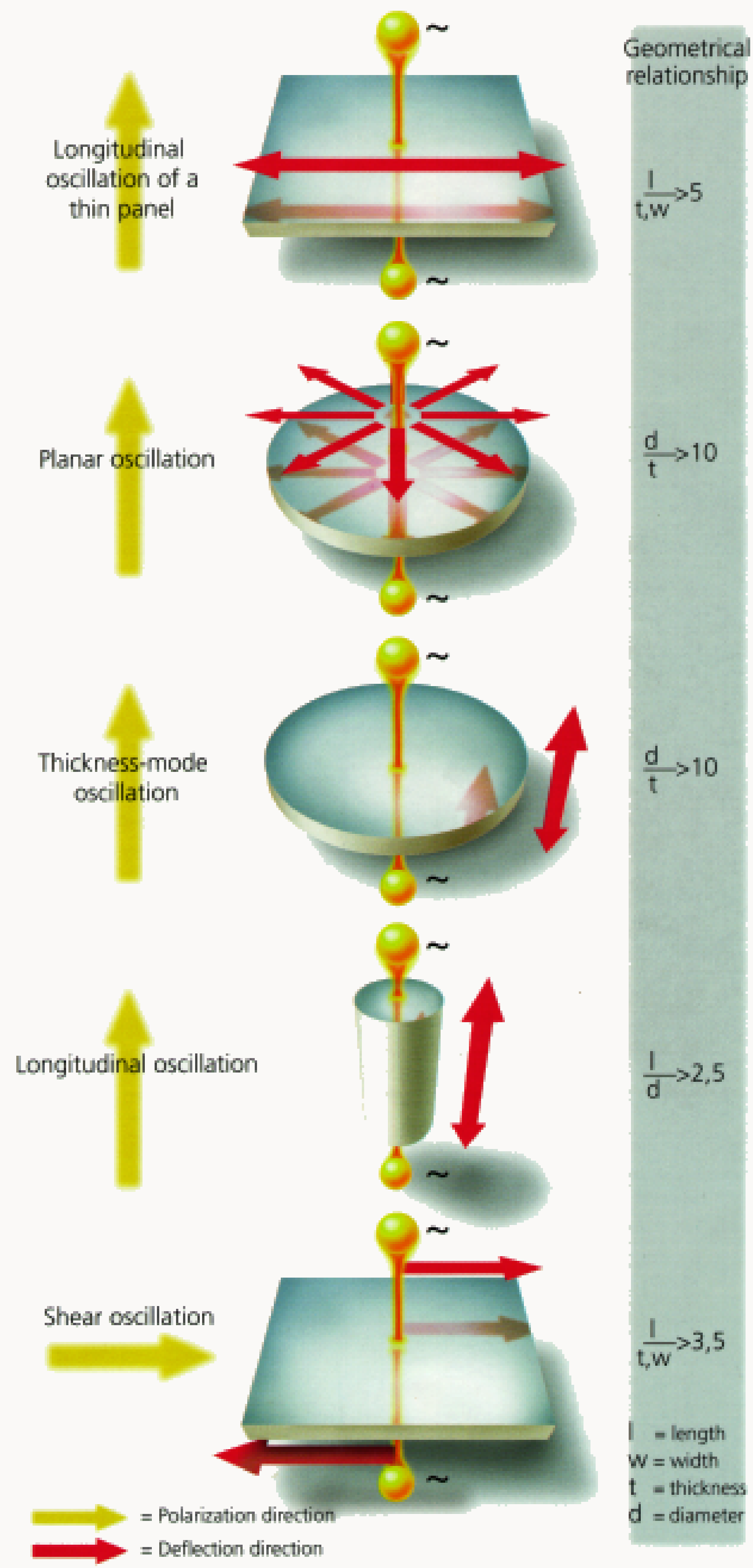
- dielectric constants between 1000 and 4000
- high piezoelectric activity ($d33 > 400 * 10^{-12}$ C/N)
- low Q factors (≤ 100)

Group II materials are used in a wide range of sensors and actuators.

High Performance Ceramics for Engineered Products

Basic oscillation modes of piezoelectric resonators

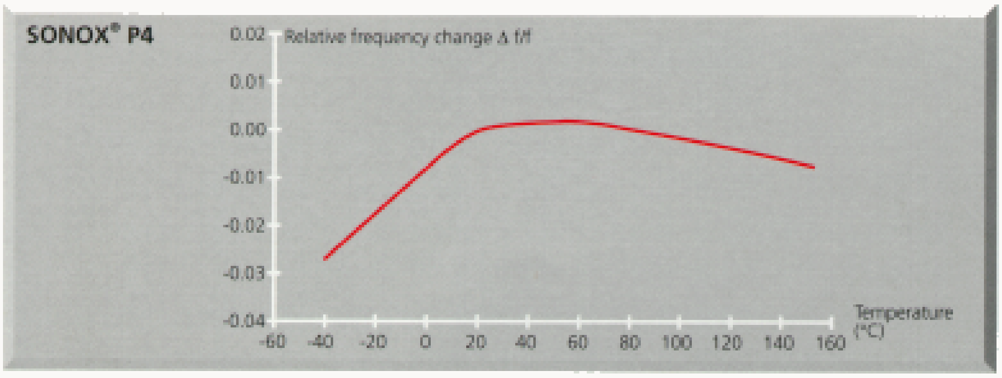
The piezoelectric material specifications depicted in the following data tables are expressed in terms of specific parameters. The values of these parameters are determined under small-signal conditions using standard test specimens, and are subject to variation with time and temperature. Measurements are therefore commonly conducted between 20° C and 25° C at 24 hours after polarization. To facilitate the interpretation of the data, the illustration on the right offers an overview of the geometrical boundary conditions used in testing for the various oscillation modes.

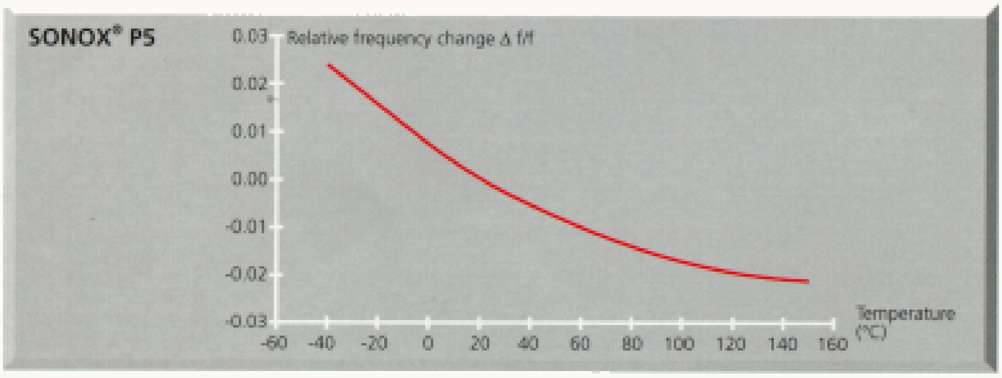


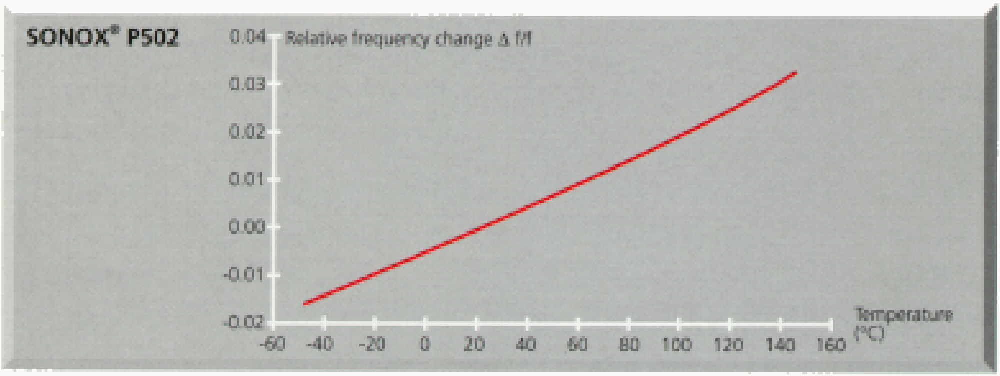
Properties of CeramTec-Piezoceramics

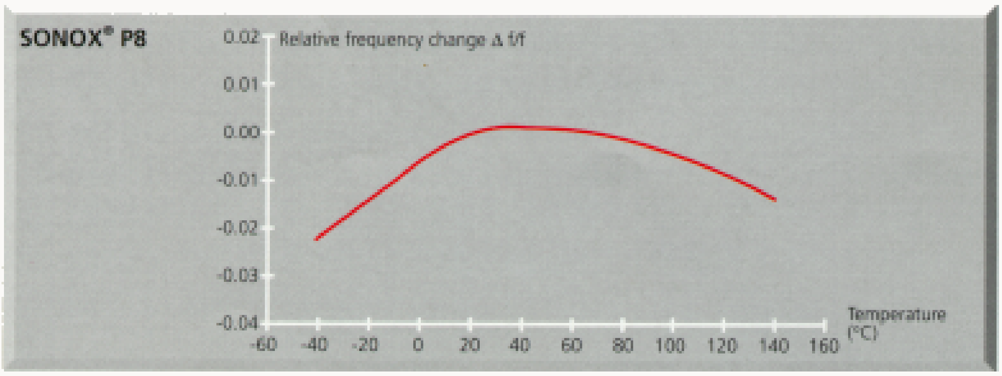
Material	Symbol	Unit	Sonox® P4	Sonox® P6	Sonox® P8	Sonox® P88	Sonox® P5	Sonox® P502	Sonox® P51	Sonox® P53
Dielect Properties										
Dialectic constant	$\varepsilon_{33}{}^{T}/\varepsilon_0$		1300	650	1000	1250	1850	1850	3100	3800
	$\varepsilon_{33}{}^{S}/\varepsilon_0$		660	490	540	630	865	875	1265	1265
	$\varepsilon_{11}{}^{T}/\varepsilon_0$		1535	440	1250	1320	1850	1950	3050	3580
	$\varepsilon_{11}{}^{S}/\varepsilon_0$		885	350	800	760	1220	1260	1290	1670
Dielectic dissipation factor	$\tan\delta$	10^{-3}	3	4	2	4	20	12.5	16	16
Curie temperature	T_c	°C	325	390	305	320	340	335	200	215
Electromechanical Properties										
Frequency constants		kHz.mm								
	N_p		2210	2540	2280	2200	2030	2020	2000	1960
	N_t		2000	2095	2020	2050	1900	2030	1930	1885
	N_l		1480	1670	1600	1490	1380	1325	1430	1420
	N_3		1340	1560	1490	1280	1310	1250	1280	1190
Coupling coefficients	k_p		.57	.35	.55	.60	.62	.62	.67	.65
	k_{31}		.31	.21	.30	.34	.34	.33	.39	.38
	k_{33}		.68	.48	.68	.70	.73	.72	.75	.74
	k_t		.50	.38	.48	.46	.49	.48	.51	.51
	k_{15}		.65	.46	.60	.65	.72	.74	.76	.73
Charge coefficients		10^{-12} C/N								
	d_{33}		310	135	240	325	450	440	640	680
	d_{31}		-130	-55	-95	-135	-180	-185	-260	-275
	d_{15}		455		380	395	550	560	730	770
Voltage coefficients	g_{33}	10^{-3} Vm/N	26.9	21.5	27.1	29.0	27.5	25.5	20.0	19.0
	e_{33}	C/m^2	15.2	10.0	13.3	13.9	16.3	16.7	20.9	23.8
Mechanical properties										
Elastic compliance		10^{-12} m^2/N								
	$s_{11}{}^{E}$		14.9	11.6	11.4	14.3	17.1	18.5	15.6	15.8
	$s_{33}{}^{E}$		18.1	13.7	13.7	19.5	19.0	20.7	19.6	22.9
Elastic rigidity		10^{10} N/m^2								
	$c_{33}{}^{D}$		15.9	16.1	16.2	16.4	14.5	15.7	15.0	15.2
	$c_{55}{}^{D}$		4.8			5.5	5.8	6.5	6.2	6.1
Density	γ	10^3 kg/m^2	7.65	7.70	7.70	7.83	7.65	7.74	7.82	7.83
Mechanical quality factor	Q_m		500	1100	1000	1600	90	80	100	75
Stability										
Temperature coefficients* *range:20...80°C	α_k	10^{-4} K^{-1}	-5.0	-3.4	-2.6	-2.0	-1.8	-5.2	4.2	-1.0
Aging rates		%/decade								
	c_ε		-3.4	-0.5	-1.8	-1.4	-2.0	-0.3	-2.0	-0.8
	c_f		1.1	0.2	1.0	0.4	0.40	0.15	1.1	0.2
	c_k		-3.2	-1.2	-2.2	-1.0	-0.30	0.20	-0.5	-1.0

Resonance Frequency Variation over Temperature

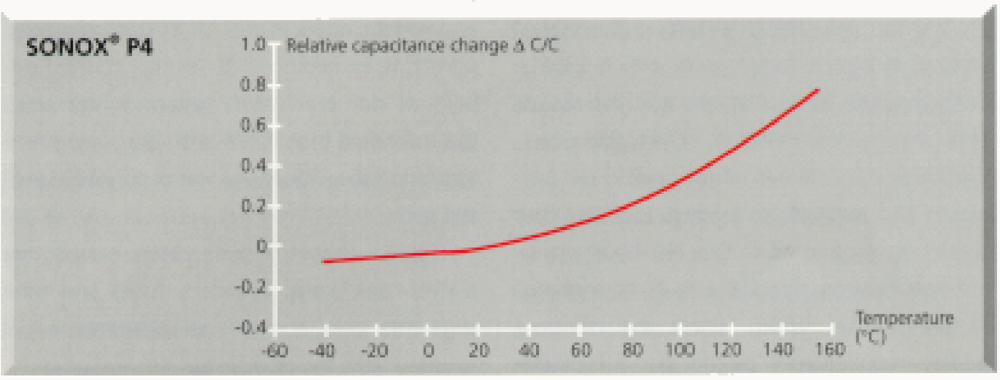


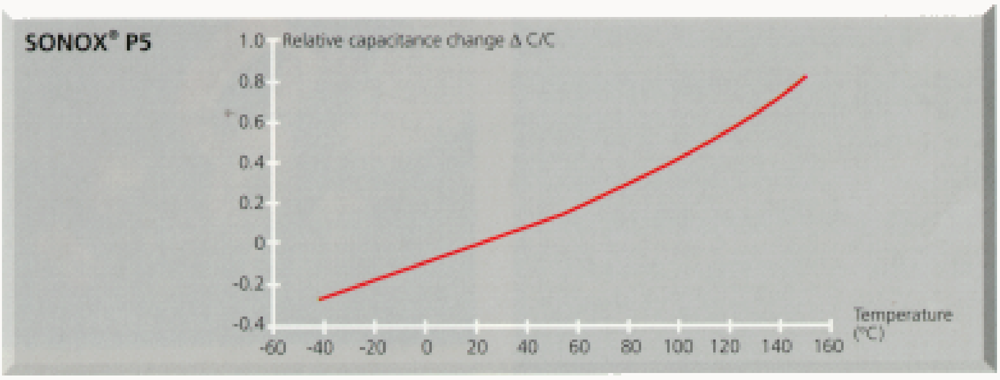


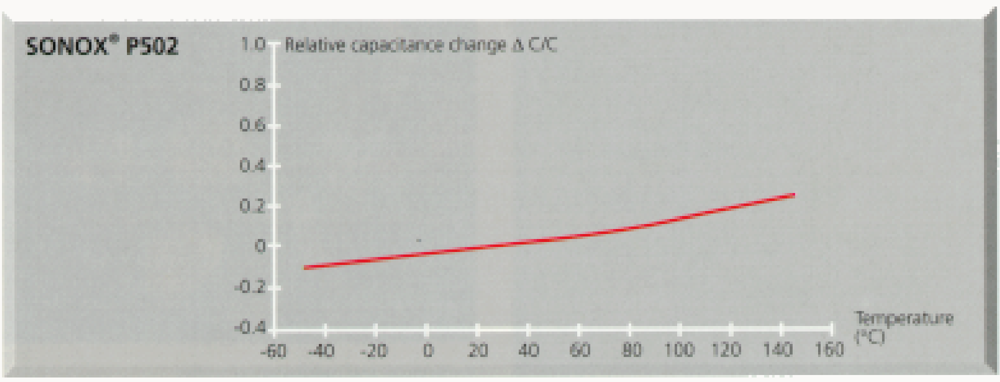


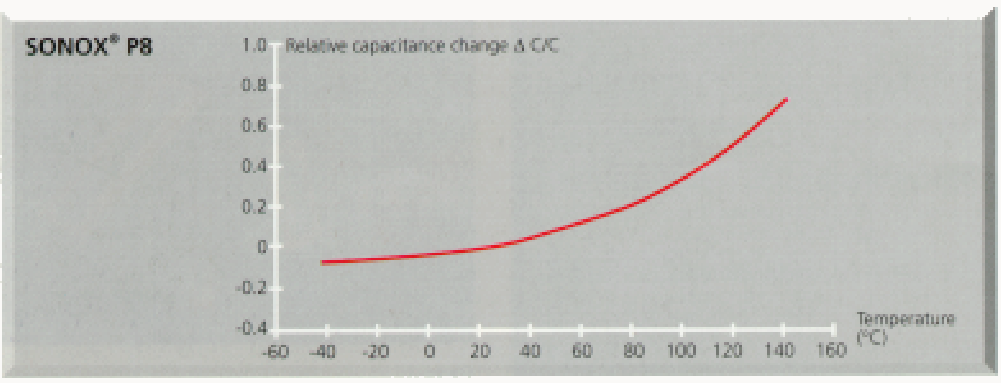


Capacitance Variation over Temperature









Proven Manufacturing Expertise

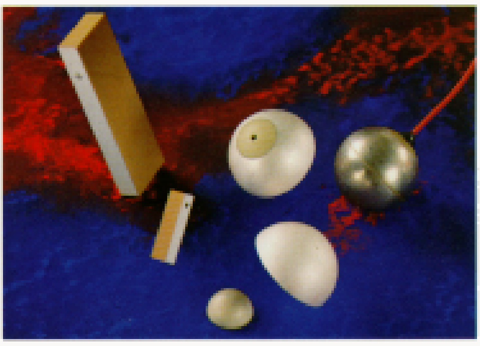
The forming methods used in the manufacture of piezoceramic parts are as diverse as their range of applications and the associated engineered materials. Over the years, CeramTec has refined these individual processes and methods to perfection. Operating sequences monitored to DIN ISO 9000 standard specifications form the basis of a manufacturing effort which meets the stringent quality requirements placed on automotive and safety applications. A customer-specific parts rate exceeding 90% testifies to the flexibility of our production system, which turns out individual prototypes with the same precision and reliability as volume-produced standard parts.

Typical shapes include discs, rectangular plates, rods, rings, cylinders, tubes and tube segments, balls, and spherical elements.

Shapes	**Typical dimensions***	
Discs and rings	Diameter:	5 mm - 120 mm
	Thickness:	0.2 mm - 30 mm
Cylinders	Diameter:	5 mm - 120 mm
	Height:	< 30 mm
Rectangular bodies	Length:	3 mm - 176 mm
	Width:	2 mm - 120 mm
	Height:	0.2 mm - 30 mm
Hemisphere	Maximum radius: approx. 50 mm	
Stacks	Length:	10 mm - 40 mm
	Width:	2 mm - 10 mm
	Number of layers:	100 - 400

*Guideline values only. Parts with larger or smaller dimensions may be produced.

Discs, rings, and cylinders



Rectangular and hemispherical bodies

Stacks

Glossary

Curie temperature

Temperature at which the permittivity of ferroelectric ceramics reaches its peak. Above this temperature the ceramic material will not exhibit piezoelectric properties.

Dielectric constant

Ratio of the permittivity of the material to the permittivity of free space (ε_0).
$\varepsilon_0 = 8{,}85 \times 10^{-12}$ F/m.

Dielectric dissipation factor (tan δ)

Ratio between power loss and reactive power in a specimen subjected to a sine-wave input at a frequency far below its first self-resonant frequency (usually measured at 1 kHz).

Free capacitance

Capacity of a piezoelectric resonator measured at a level far below its lowest self-resonant frequency (usually 1 kHz).

Electromechanical coupling coefficient

Factor representing the ratio between the energy converted and stored and the energy absorbed by a piezoceramic part. Depending on the boundary conditions, there are five different coupling factors reflecting the component's shape factor and oscillation mode.

Piezoelectric charge coefficient

Ratio of the electrical charge generated per unit area to an applied force; expressed in Coulomb/Newton.

Piezoelectric voltage coefficient

Ratio of electric field produced to the mechanical stress applied; expressed as Voltmeter/Newton.

Mechanical quality factor Q_m

Amplitude magnification of oscillating piezoelectric parts in a resonant state. This is a non-dimensional factor indicating the mechanical loss of the component under dynamic operating conditions.

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