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PiezoStar® Crystals

A New Dimension in Sensor Technology

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A New Dimension in Sensor Technology

For more than 40 years, Kistler has been developing and manufacturing piezoelectric sensors that can be used to measure pressure, force and acceleration, even under extreme conditions. Nowadays, the sensor elements are increasingly being made from new types of crystals.

Market trends towards miniaturization and higher operating temperatures resulted in a need for new types of crystals capable of satisfying the demand for greater sensitivity and higher temperature. To this end, research was conducted for over ten years in cooperation with universities and institutes throughout the world to investigate new crystal compounds and develop growing processes. The fruit of this research is a whole family of crystals with outstanding properties for piezoelectric sensors. Since 1998, crystals measuring up to 65 mm in diameter and weighing up to 2,5 kg, have been grown and processed by Kistler to form sensor elements, thus creating a new group of pressure, force and acceleration sensors with superior properties.

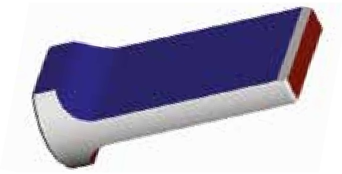
Kistler has optimized the PiezoStar crystal elements for use in sensors for demanding applications, thus strengthening its technological edge in sensor technology. Crystals KI85 and KI91 from the PiezoStar group are currently being used in sensors.

Milestones in the History of PiezoStar Crystals

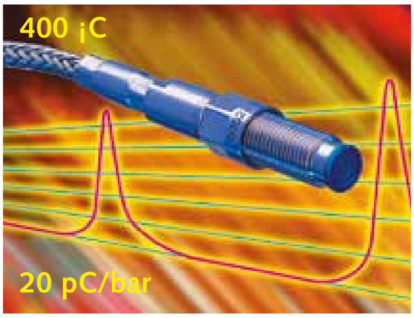
- 1995 1995 First miniature pressure sensor (20 pC/bar) with a KI85 crystal
- 1995 First high-temperature force sensor with KI85 crystal
- 1998 First KI85 crystal grown at Kistler
- 1999 First miniature pressure sensor (temperature-compensated) with a KI91 crystal
- 2002 First KI91 crystal grown at Kistler

PiezoStar®

Single crystal



Measuring element

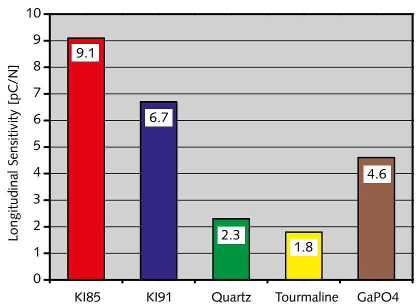


High-temperature pressure sensor

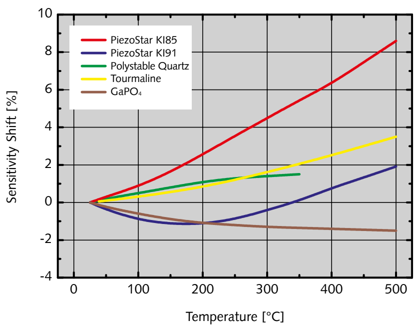
The Outstanding Properties of KistlerÕs PiezoStar Crystals Include:

- High piezoelectric sensitivity (up to 5x higher than quartz)
- Low temperature dependence
- High stability of the properties
- Can be used at temperatures of up to more than 600 °C
- No phase transition up to the melting point (above 1300 °C)
- No twin formation
- Growing process can be reproduced on an industrial scale
- Tested and successfully used in high-quality piezoelectric sensors

Piezoelectric Characteristics



Piezoelectric sensitivity of various high-temperature crystals. KI85 and KI91 are crystals from the PiezoStar group.



Sensitivity shift as a function of the temperature of various crystals

Products

Examples of proven and tested sensors with PiezoStar crystal elements:

Miniature M5 high-temperature pressure sensors Type 6052B and pressure probes Type 6055/6057 for use in internal combustion engines

Measuring spark plug M14 Type 6117B and M12 Type 6115A for use in internal combustion engines

High-sensitivity 3-component force sensors (11 pC/N) Type 9017A/9018A in the ForceLink Type 9317A/9318A

Miniature 5mm HighSens force sensor Type 9215 (100 pC/N)

HighSens strain sensor Type 9232A and strain transmitter Type 9234A

Miniature 3-component dynamometer MiniDyn Type 9256A for micromachining

Crystal Properties

PiezoStar crystals belong to the family of calcium gallogermanates quartz isotypes, such as langasite ($La_3Ga_5SiO_{14}$). The first crystal of this family ($Ca_3Ga_2Ge_4O_{14}$) was discovered at Moscow State University as long ago as 1979. Since then over 100 different compounds from this family have been grown. Only for few of them the piezoelectric properties have been measured. As the crystals belong to the same crystallographic class (32) as quartz, it is possible to obtain the same crystal cuts (longitudinal, transversal and shear). However, unlike quartz or gallium orthophosphate, crystals from the langasite family do not have a phase transition point below melting point and this explains their excellent stability up to extreme temperatures.

Bibliography: B.V. Mill and Yu.V. Pisarevsky, Proc. IEEE International Frequency Control Symposium, 2000, p. 133-144.

Apart from their use in sensor technology, these crystals can be applied in resonators and surface acoustic wave devices for oscillators, frequency filters and delay circuits for mobile communications and television sets.

KI85 crystal, ø55 mm, 1,8 kg

Advantages of PiezoStar Crystals

Easy and economical to grow, good yield, good stability, high sensitivity, no twin formation, no phase transition below the melting point, usable at extremely high temperatures, no pyroelectric effect.

Disadvantages

Lower mechanical strength and higher cost than quartz.

Disadvantages of Tourmaline

Only natural crystals can be obtained (varying quality, uncertain availability), low sensitivity.

Disadvantages of GaPO4

Very expensive to grow, only small crystals can be obtained, low yield, twin formation, phase transition at 970 °C.

Disadvantages of Quartz

Low sensitivity, twin formation, phase transition at 573 °C.

Comparison of Various Piezoelectric Materials

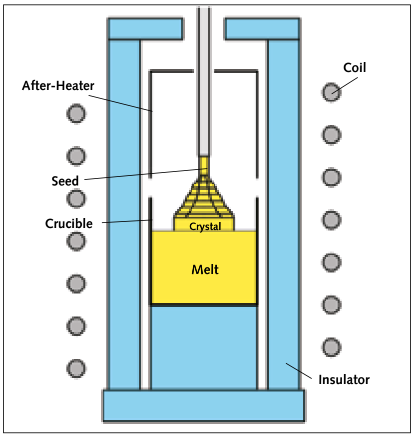
	Peculiarity	Pyroelectric effect	T_{max}*	Production Process	Production Volume	Production Costs
Quartz	High mechanical strength	No	573 °C	Hydrothermal	Large	Low
KI85	High sensitivity	No	Tm	Czochralsky	Average	High
KI91	Low temperature coefficient	No	Tm	Czochralsky	Average	High
GaPO4	Low temperature coefficient	No	970 °C	Hydrothermal	Small	High
Tourmaline	High temperature stability	Yes	>900 °C	Natural	Small	High
Piezoceramic (PZT)	High sensitivity	Yes	250 °C	Sintering	Large	Low

* Phase transition temperature. Tm = no transition below the melting point.

Czochralsky Growth (or Crystal Pulling)

The Czochralsky process has been known since 1917. Kistler uses it to grow large, high quality crystals within a relatively short period of time (for example, our KI85 crystal (ø55 mm, 1.8 kg) is grown within one week). The individual components (mostly oxide powder) are mixed in a crucible and heated up to the melting point (induction heating). As this temperature is approximately 1400 to 1500 °C, the crucible must be made of a noble metal (platinum or iridium). A seed crystal (i.e. a piece of crystal of the same compound) is dipped into the melt. The temperature of the melt has to be controlled very precisely: if it is too hot, the seed crystal will melt down, while if it is too cold, there is a risk that the melt will quickly solidify. Once the crystal growth process has started, the seed crystal is pulled very slowly (approximately 1 mm/h). The size (diameter) of the crystal is automatically controlled by means of the heating power and the pulling speed.

Though the process is simple in theory, its practical application is complicated by complex and chaotic phenomena occurring in 3 dimensions. In particular, the temperature must be controlled very precisely. If the crystal grows too quickly, there is a risk that cracks or imperfections will form in the crystal structure. Thus, growing a perfect crystal requires precise control of the heating power and considerable experience on the part of the operator.



Schematic representation of the Czochralsky process

KI91 crystal ø65 mm, 2,5 kg

Crystal growing system according to the Czochralsky process (photo by Kistler)

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