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White Paper

PMN-PT AND PIN-PMN-PT PIEZOELECTRIC SINGLE CRYSTALS

FOR NEXT GENERATION UNDERWATER SONAR TRANSDUCERS WITH HIGHER SENSITIVITY AND BROADER BANDWIDTH

Author:
Hakki Yegingil, Ph.D.
Piezo Product Manager

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PMN-PT and PIN-PMN-PT single crystals are among the most important technological advancements for underwater acoustics in recent years. PMN-PT and PIN-PMN-PT crystals provide greatly increased sensitivity and much wider bandwidth for underwater transducers. This is due to single crystals' much higher electromechanical coupling coefficients, as well as few times higher electromechanical strains compared to standard PZT piezoelectric ceramics. This leads to much higher performing underwater transducers when they utilize PMN-PT and PIN-PMN-PT single crystals, compared to utilizing standard PZT.[1] Therefore, utilizing single crystal material could provide the performance breakthrough for underwater sonar applications.

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Author:

Hakki Yegingil, Ph.D.

Piezo Product Manager
hakki.yegingil@ctscorp.com
www.ctscorp.com

Main Advantages

The main advantages of utilizing PMN-PT or PIN-PMN-PT single crystal over traditional PZT material for sonar applications can be summarized as;

Broader Bandwidth

It has been proven consistently by industrial applications, as well as in published research that one of the biggest advantages of utilizing PMN-PT for sonar transducers is the increased bandwidth. Design and performance of sonar transducers can be greatly improved due to the much higher electromechanical coupling coefficients (20% higher, on average, compared to traditional PZT) and higher electromechanical strains provided by PMN-PT, compared to traditional PZT.

Smaller Form Factor

The design of the single crystal transducers is critical for fully utilizing the potential advantages of single crystals. Because of its magnitude higher piezoelectric performance, single crystal piezoelectric crystals allow smaller form factor transducer design by decreasing the number of piezoelectric elements necessary. As a result, this not only provides a simplified design, but also provides weight and power advantages. Also, when packaged correctly, it has been proven that they are as strong to shock tests as traditional PZT materials are.

System Level Advantages

Single crystal materials not only provide advantages at the transducer level, but also at the system level. Next generation sonar transducers with piezoelectric single crystals can utilize smaller number of components, compared to traditional PZT, while improving the performance greatly. As a result, higher performance can be achieved at lower power consumption levels. Lower power consumption also helps increase the battery life of the overall sonar system upon deployment. Once the sonar system is deployed, increased battery performance not only provides longer active life for the system, but also improves deployment cycles, maintenance time and cost.

Our Expertise

CTS Corporation is the global leader for high volume single crystal (PMN-PT and PIN-PMN-PT) manufacturing. Utilizing the fully integrated manufacturing facilities in Illinois, United States, CTS can provide high volume, single crystal plates (un-diced, diced composite), discs or rings that can be utilized in underwater sonar applications. CTS single crystal materials are manufactured to high quality standards in a ISO-9001:2008 certified facility.

CTS has collaborated with leading defense contractors to co-develop next generation single crystal sonar transducers that can overperform current generation sonar transducers that utilize standard PZT material. Among defense contractors that utilize piezoelectric single crystals, CTS has been the supplier of choice due to:

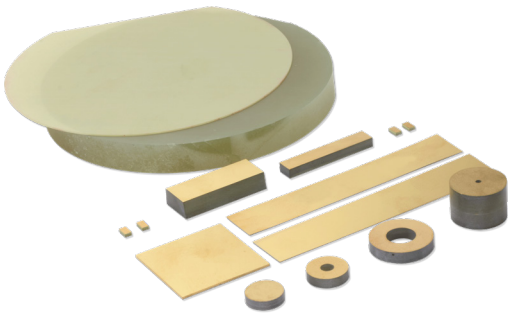
i. High quality and high yield PMN-PT and PIN-PMN-PT materials

ii. Ability to provide unique component shapes (e.g. rings, plates with wedges)

iii. High tolerance manufacturing techniques

iv. Flexibility to provide tighter dielectric range components

v. Support from a team of experienced Ph.D level piezoelectric single crystal scientists and well-diversified process engineers.



CTS Corporation PMN-PT and PIN-PMN-PT Single Crystals in Wafer, Plate, Disc and Ring Shapes

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CTS PMN-PT and PIN-PMN-PT Critical Material Properties Chart

PROPERTY	SYMBOL	UNITS	MATERIAL TYPE		
			PMN-28% PT (TYPE A)	PMN-32% PT (TYPE B)	PIN24%-PMN-PT
DENSITY	d	kg/m^3	8,100	8,100	8,122
PHASE TRANSITION TEMPERATURE	T_{rt}	°C	90 - 100	80 - 90	100 - 115
CURIE TEMPERATURE	T_C	°C	120 - 130	130 - 140	140 - 170
COERCIVE FIELD	E_C	kV/cm	2.5	2.5	4.5 - 6
PIEZOELECTRIC CONSTANTS	d_{15}	pC/N (10^{-12} C/N)	135	192	122
	d_{31}		-568	-760	-646
	d_{33}		1,190	1,620	1,285
DIELECTRIC CONSTANTS	ε^S_{11}	ε_0	1,467	1,368	1,611
	ε^S_{33}		895	700	868
	ε^T_{11}		1,600	1,620	1,728
	ε^T_{33}		5,500	7,000	4,753

All properties listed are for [001] poling.

Published Research Has Proven;

a. Sonar transducer utilizing PMN-PT crystal has outperformed traditional PZT material in reception mode, in terms of both voltage output and bandwidth.[2]

b. PMN-PT and PIN-PMN-PT single crystals show significantly greater K^T_{33} values (electromechanical coupling coefficients) over the entire electric field range, compared to traditional PZT.[3]

c. Thickness coupling coefficient for 1-3 composite for ultrasound transducer fabricated out of PMN-PT has increased by more than twice compared to that of standard PZT.[4]

d. In a single element transducer made with a single-phase active material, PMN-PT material has proven to outperform PZT-5H ceramic in all transduction modes (transmit-receive mode voltage output is of higher magnitude for PMN-PT single crystal).[3]

e. PMN-PT single crystal, compared to traditional PZT, provides greatly improved projector performance in a smaller package size. The 650% higher piezoelectric constant provides either 10-15 dB more source level at the same drive, or the same source level at 10-15 dB lower drive. The 50% higher coupling factor for PMN-PT provides 6 times greater bandwidth, while providing better amplifier matching.[5]

ADVANTAGES OF SINGLE CRYSTAL PIEZOELECTRIC MATERIALS FOR SONAR APPLICATIONS

- Higher piezoelectric constant (Higher transmit voltage)
- Higher electromechanical coupling coefficients (Increased sensitivity and wider bandwidth)
- Lower modulus (Smaller projector size)
- Higher sensitivity both in transmission and reception modes[1]
- Improved power consumption at the system level (Improved down-time)

APPLICATIONS:

- Maritime Security (Sonar applications)
- Anti-Submarine Warfare (ASW)
- Hydrophones
- Oil and Gas Exploration
- High Resolution Underwater Acoustic Imaging

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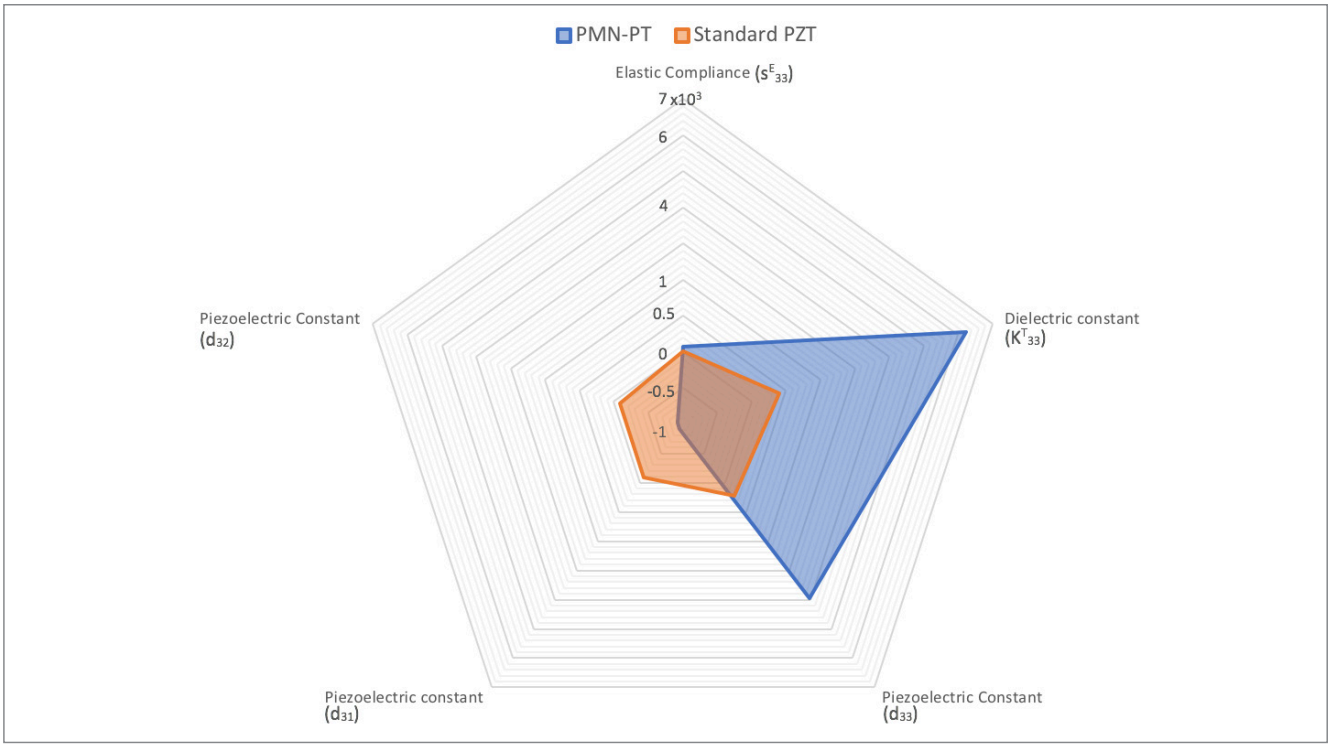
PMN-PT vs. Standard PZT Property Comparison In Sonar Transducer Applications



Comparison of Critical Parameters

Chart above compares, at a high level, sonar transducer related piezoelectric critical parameters for PMN-PT and that of traditional PZT. Data proves that PMN-PT has exceeded traditional PZT properties by at least 5 folds, as also summarized in the table below. This translates to much higher performing sonar transducers, while potentially requiring less components if traditional PZT were to be utilized, as previously explained in greater detail.

PROPERTY	DESCRIPTION	MAGNITUDE DIFFERENCE (PMN-PT OVER TRADITIONAL PZT)
S ($x10^{-12}$ m^2/N)	ELASTIC COMPLIANCE	5x
K^T_{33}	DIELECTRIC CONSTANT	8x
d_{33} (pC/N)	PIEZOELECTRIC CONSTANT	9x
d_{31} (pC/N)	PIEZOELECTRIC CONSTANT	10x
d_{32} (pC/N)	PIEZOELECTRIC CONSTANT	10x

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