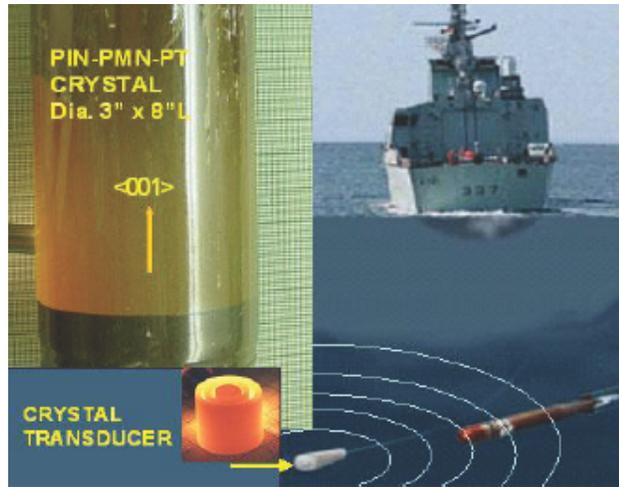


Naval Device Application of Relaxor Piezoelectric Single Crystal

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PROBLEM STATEMENT

Looking through the sea for navigation, threat detection and weapon guidance is critical Navy needs. Potential threats are constantly evolving; quieter, more capable submarines, handling the littoral ASW environment: poor sound propagation, harsh/time varying, reverberation is limited, high traffic density/clutter rates, advanced countermeasures and asymmetric challenges. The reliability of the transducers is also critical. Lying at the heart of most SONAR transducers, piezoelectric crystals and ceramics perform the essential roles of producing strong interrogating sound pulse and also detecting very weak incoming sound waves.

At the present time, large-sized PMN-PT and PIN-PMN-PT piezoelectric crystals, 3" diameter by 8" long, of high quality, can be grown directly from a melt and are commercially available. The superior piezoelectric properties over PZT ceramics have drawn intensive attentions to develop the next generation of acoustic transduction devices since the piezoelectric crystal products commercially available. In 2004, H. C. Materials Corp. discovered a 3-6 shear mode effect on $\langle 110 \rangle$ poled piezoelectric PMN-PT crystals. This is a unique shear mode that the shear coupling k_{36} over 90% and re-pole able as poling direction is the same as working field direction. The 3-6 shear mode transducers can be operating at high drive field with a bias field. It is impossible for other shear mode, such as 1-5 mode, due to the poling direction perpendicular to working electrical field. The above advantages show great promise for use in compact low frequency SONAR projector capable of very high bandwidth.

H. C. Materials Corp. has developed the patented fabrication method of 3-6 shear mode PMN-PT and PIN-PMN-PT piezoelectric crystal elements for the new generation of shear mode single crystal acoustic transducers. This will greatly enhance Navy SONAR

transducer reliability and performance, and reduce the fabrication cost of shear piezoelectric crystal elements.

WHO CAN BENEFIT?

Besides SONAR transducer improvement for the Navy fleet, the technology can be extensively used for coastal underwater security (targeting), adaptive optics (laser-beam correction) for Air Force and Army and for military portable medical ultrasonic imaging units.

In addition, commercial applications such as ocean mapping, nondestructive testing and viscosity meter could benefit.

BASELINE TECHNOLOGY

The legacy PZT piezoelectric ceramics have no 3-6 shear effects. Navy sonar transducers have long been manufactured using PZT piezoelectric ceramics. The cost of PZT ceramics is lower, but the performances of PZT ceramics are much lower than the giant piezoelectric PMN-PT crystals which were developed in the past a few years. However, the PMN-PT crystals have difficulties to be operated under high drive field due to the relatively low coercivity (E_C , $\sim 2\text{kV/cm}$) and low depoling temperature around 90 C. We have developed a new ternary piezoelectric crystal PIN-PMN-PT (with a major composition of lead indium niobate). The new composition has been proved to increase E_C , and to extend the thermal stability to meet the requirement of projectors of Navy sonar transducers. Using PIN-PMN-PT crystal in 3-6 shear modes has showed promise for development of a new group of single crystal shear mode transducers of Navy SONAR systems.

TECHNOLOGY DESCRIPTION

The single crystals of ternary system of lead indium niobate-lead magnesium niobate-lead titanate solid solution, $x*\text{Pb}(\text{In}1/2 \text{ Nb}1/2)\text{O}_3\text{-}y*\text{[Pb}(\text{Mg}1/3\text{Nb}2/3)\text{O}_3]\text{-}z*\text{[PbTiO}_3]$ (PIN-PMN-PT, $x+y+z=1$) are a new generation of piezoelectric materials. The new material was formulated to exhibit very large electromechanical coupling coefficients $k_{33} > 0.9$, high piezoelectric coefficients and low dielectric losses with strength coercive electrical field (6 kV/cm) and high operational temperature (>120 C) that results in improving bandwidth, sensitivity and source level in applications.

Table 1: Features, Advantages, and Benefits

Features	Advantages	Benefits
Cost-effective Fabrication of PIN-PMN-PT piezoelectric crystals and elements	Enhancing performance and reducing size Coupling factor >0.9 Depoling above 120 C Coercive electrical field >6 kV/cm	Navy sonar transducers, especially projectors of Navy sonar

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CURRENT STATE OF DEVELOPMENT

Technology milestones presented below indicate highlight the technology readiness levels (TRLs) already achieved and what will be accomplished as we move forward with the technology.

Milestone	TRL	Risk	Measure of Success	Status
First demonstration of low frequency projector using 36-shear mode PMN-PT crystals	4	Low	Test and comparison with calculated response	01/2008
Increase acoustic power density using PIN-PMN-PT crystals to build up 36-shear mode projectors	5	Low	Test under water	12/2009
Improved design and fabrication method that enhance the reliability and output	6	Low	Test under water	03/2010

REFERENCES

For those interested parties, the contact below can provide technical feedback on H. C. Materials' ability to deliver this product:

ONR TPOC
(703) 696-7021

Additional ONR Persons
(703) 588-1992
(703) 696-0789
(703) 696-0284

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ABOUT THE COMPANY

H. C. Materials Corporation was founded in 1995 as S-Corporation registered in Illinois, owned and operated by Dr. Pengdi Han. Since the discovery in 1996 by ONR sponsored research of a class of single-crystal piezoelectric materials with giant-piezoelectric properties, H. C. Materials Corporation has involved in the crystal growth and commercialization of PMN-PT crystals. Under the support of DARPA and ONR, H. C. Material Corporation has developed a *proprietary* method (US Patent 6,972,730 B2) for the growth of <001> seeded PMN-PT and PIN-PMN-PT single crystals with 3" ~4" diameter. H. C. Materials Corporation has supplied more than 60,000 PMN-PT crystal wafers to clients (more than 20) for the development of transducers for defense applications and commercial products.

For example, in 2004, the first industrial products using H. C. Materials <001> seeded PMN-PT crystals were in the medical ultrasonic imaging "Pure Wave" system developed by Philips Ultrasound Inc. At the present time, H. C. Materials Corporation is the key source in the World for the development and manufacture of PMN-PT based piezoelectric crystal products.

H. C. Materials Corp. dedicated to supply customers with special products. A variety of PMN-PT and PIN-PMN-PT crystal products are available, including, plates, wedges, discs, cylinders, rings, tubes, cubes and single crystal composites. The size of the single crystals is routinely 3 inches, but 4 inches wafers are now under introduction. Three growth orientations and 3 symmetrical poling are available: (001), (110) and (111) for 33-mode, 31-mode, 15-shear mode and our unique 36-shear mode, respectively.