RESEARCH ON PMN-PT SINGLE CRYSTAL

Its superiority, opportunity, obstacles and ALPINION's breakthrough

Internal Research paper

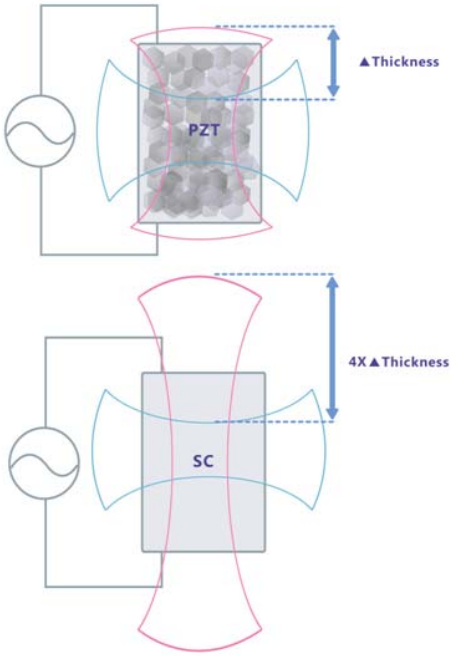
ALPINION
MEDICAL SYSTEMS

We are Ultrasound Professionals

Background

What is difference in PZT and PMN-PT Single crystal ceramic?

In 1960, Clevite Corporation of Cleveland, Ohio, USA patented the use of the ferroelectric mixed-metal oxide ceramic known as PZT for use in acoustic transducers.
It displays a superior electromechanical coupling coefficient, high dielectric constant and good thermomechanical stability, and so it has found wide use in speakers and transducers ever since. The very success of PZT has ended up becoming a limitation to further development in the acoustic transducer industry, since no viable alternative piezoelectric materials have made it much beyond the research stage until now.



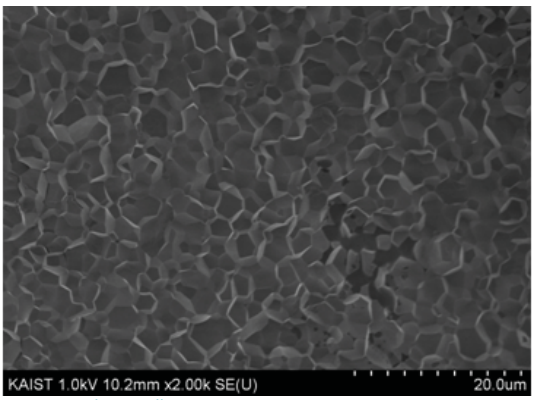
A wholly new ferroelectric material known as PMN-PT (lead-magnesium-niobate lead-titanate) was first reported in 1997, along with the highly specialized method for producing it. Several companies have since commercialized production of this unique solid-solution relaxor piezoelectric material for use in acoustic transducers. But PMN-PT material must be grown and used as oriented single crystals, not as a ceramic like PZT, and so its application is fundamentally different.
But the behavior of PMN-PT in an electric field is also different from that of PZT - and far superior.

So what is different about single-crystal material, PMN-PT, compared to ordinary ceramic PZT? Foremost, it's because ceramics that are made of random microcrystals cannot respond to electrical signals as efficiently, since most of them are not aligned properly to the electric field.

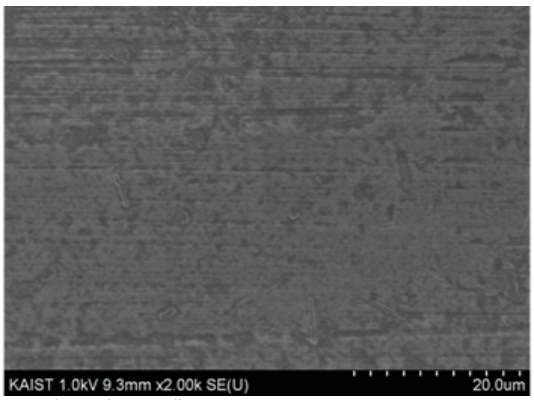
Under an applied electric field, most types of piezoelectric crystals can vibrate most effectively and thus make sound in only one dimension, so a random arrangement of microcrystals like those in a ceramic cannot approach the theoretical performance of an aligned single-crystal piezoelectric.
Figure 1-a shows these random microcrystals in PZT, while the micrograph of a PMN-PT single crystal in Figure 1-b shows no such grains or boundaries; it is as flawless as a gemstone.

Also, a relaxor ferroelectric like PMN-PT has a strain coefficient - that is, a vibration amplitude - which varies quadratically with the applied electric field, not linearly like PZT.
The combination of an oriented-crystal material and its tremendous capacity for electrically induced strain makes PMN-PT qualitatively superior to ceramic ferroelectric piezo materials in general, and to PZT in particular.

Fig 1. SEM picture of PZT and PMN-PT single crystal



1-a. Polycrystalline PZT



1-b. Single crystalline PMN-PT

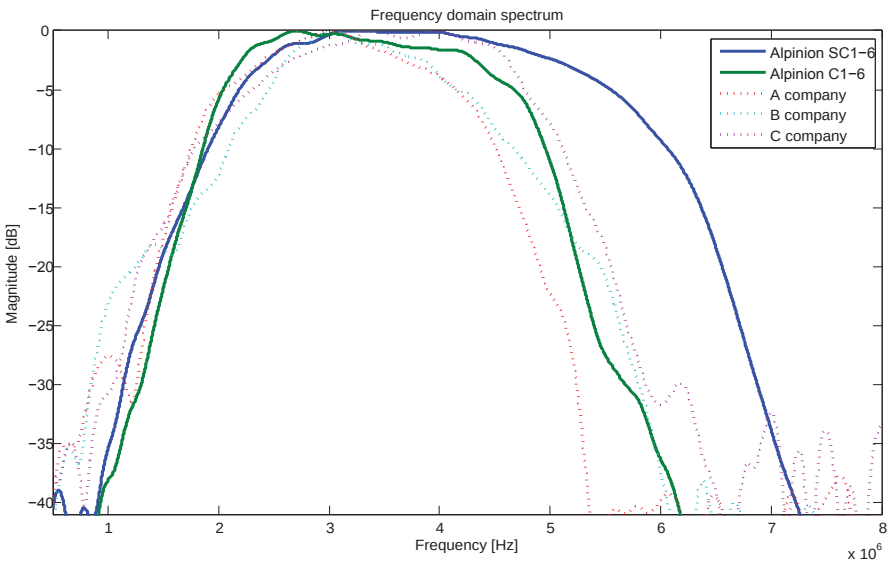
Advantage of PMN-PT single-crystal

The net effects of replacing ceramic PZT with single-crystal PMN-PT in a transducer can be summarized as follows.
First, less applied voltage is needed to make an acoustic signal, resulting in less waste heat and therefore fewer thermally limited modes of transducer operation.
Second, the transmitted and received bandwidths are both wider, meaning that more detailed, lower-noise images can be collected with a simple,conventional array architecture. Simpler arrays reduce the anufacturing cost and complexity compared to PZT transducers that require more components and need more processing to approach the same performance standards.
And finally, the single crystal produces more voltage when receiving an acoustic pressure wave, leading to better sensitivity and a higher S/N ratio. Single-crystal PMN-PT achieves all these benefits over PZT because of its inherent properties; there is no dispute about its advantages.

Challenge and ALPINION's breakthrough

The physics of the ideal single-crystal material has been known for decades, but both the commercial-scale crystal growth of PMN-PT and its application to manufacturable, reliable ultrasound transducers have posed engineering and economic obstacles that few companies attempted to conquer. Any low-level effort to apply PMN-PT to only the most expensive, exotic transducer products is doomed to failure because of the long list of technical hurdles that have to be overcome. The logic goes like this: PMN-PT is expensive and hard to use, so many companies only research its use in expensive products tha t require small crystal sizes, for example the TEE transducer. But the scale of the development required to build a high-yield single-crystal product cannot be justified if the technology is only intended for application to a few transducers. This same self-defeating circular reasoning apparently has operated at all the major ultrasound manufacturers, because nobody wants to take on such a big project when PZT transducers are still selling.

That is, nobody wanted to try until ALPINION was created. The major risk undertaken at the inception of the company cannot be overstated: its whole reason for existence was to apply PMN-PT single-crystal ultrasound transducers universally in every feasible medical sonographic application. Only with great risk is there the opportunity for great reward, and through a combination of technical breakthroughs and hard, slow work the achievement was finally unlocked: The ALPINION learned to build single-crystal PMN-PT medical sonographic transducers efficiently and affordably.



There is no magic formula to ALPINION's remarkable success in manufacturing affordable PMN-PT sonographic transducers; each challenge is met with a technique and specialized tool developed to overcome a particular manufacturing limitation. But where conventional transducer technologies are sufficient, the simplest and most efficient processes are employed. Because of the high cost of PMN-PT components, the prime focus is always on maximizing the yield at each fabrication step.
The ALPINION believe that this strategy of "simplicity first, specialized processes where needed" has shown its value in its successful presentation of the world's first full line of affordable, reliable, and remarkable PMN-PT medical sonographic transducers.

Conclusion

Everybody everywhere acknowledges the benefits of PMN-PT transducers over ordinary PZT and its antiquated cell-phone ringer technology, including greater sensitivity, wider bandwidth, higher conversion efficiency, and lower noise. There is virtually no other way to show these kind of improvements in sonographic imaging except with PMN-PT single-crystal technology. The only conventional PZT transducer which approaches the kind of performance that all ALPINION's single-crystal products achieve is a single example of an expensive, complicated, low-frequency array made with triple PZT layers and triple matching layers that's offered by one major ultrasound transducer manufacturer.
There's a good reason why this kind of elaborate array architecture isn't duplicated in any other transducer.

At ALPINION we match or exceed the performance of the very best competing transducers every single day with our PMN-PT single-crystal products, and we do it with no more construction complexity than what is found in common PZT transducers. What the ALPINION has developed is the way to apply the fragile, expensive PMN-PT crystals with such high yield and reliability that the whole manufacturing process appears hardly more complex than anybody else's.
This major breakthrough in the application of PMN-PT is now being leveraged in every new transducer technique and technology, and we fully expect that it will continue to improve the ALPINION's position in the medical ultrasound industry.