Thick Film PZT Arrays Vibration Modes

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SUMMARY

In this work we report some electroacustic characteristics of miniature piezoelectric ultrasound transducers, manufactured by screen printing and using thick film technology. To make transducer samples, ink with PZT powder and a glass frit was employed. PZT films of 100-130 µm thick were screen-printed between two gold electrodes over alumina. Electrical impedance and acoustic emission continuous-wave analysis at 1-10 MHz range shows two main vibrating modes, one of PZT layer itself and other with substrate and PZT vibrating as a whole and coupling characteristics of a two elements set and an array.

Keywords: Ultrasound, thick film, piezoelectric.

Subject category: Physical Sensors

INTRODUCTION

In previous work the development of thick film ultrasonic piezoelectric transducers in range from 1 to 10 MHz was reported. They were performed through thick film technology using a piezoelectric ink based on PZT powder. Each transducer element was sequentially manufactured over an alumina layer, with a gold electrode on it, applied with the same technology, a sintered layer of PZT ink disc shaped, and finally another gold electrode on top.

This multilayer transducer has very good electroacoustic characteristics in spit of an important reduction in piezoelectric performance a respect a bulk one, mainly own to the addition of a glass frit as a glue component and porosity inherent to process manufacture. The good behavior obtained with these transducers lies in the modification of source acoustics parameters like sound speed and accordingly acoustic impedance.

As this manufacture process make possible to build new type of transducers and use them in arrays, in this work we examine some aspects related with coupling between two or more of these transducers when they are performed on the same substrate.

FABRICATION

Samples for this study were manufactured using the same process and materials as in monoelements[1], gold electrodes , were screen printed as disc, 4mm in diameter, over an alumina rectangular substrate of 0,64 mm thick. Each layer, after printed, was sintered at 850ºC before process next layer. Thickness of PZT layer is about 120µm and the position of substrate coupled transducers are shown in Figure 1. With the same sequence, a small square array of 4 x 4 elements, each one is a square 1.5 x 1.5 mm and separated 3mm in each direction from the others, was performed.

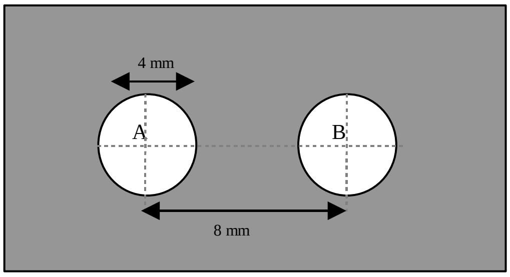

Figure1

EXPERIMENTAL RESULTS

Impedance measurements

We present first impedance measurements performed on each disc individually, with the other on the same substrate and open circuit, both poled. Both discs differ slightly because of minimal constructive differences. Figure 2 shows two peaks set instead a couple of them well defined, as when we have one transducer alone.
These two sets of peaks are coincident with resonance frequencies of the lonely transducer, taking account small differences between them own to a little mismatch in its thickness. The spread peaks is also typical in mechanically coupled resonant elements.

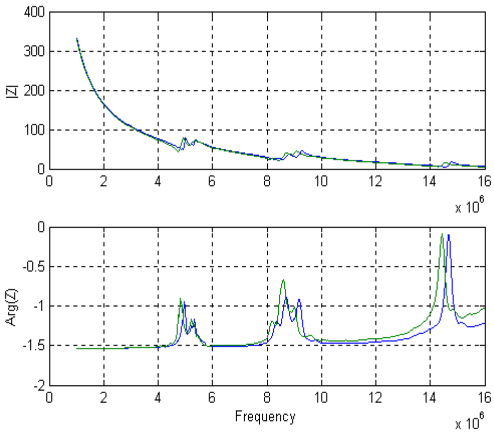

Figure 2: electrical impedance

It is clear that there are two resonance frequencies near 5 and 9 MHz, and a harmonic one at 15 MHz.

Pulse response

Transducer transient response for each transducer was evaluated with the pulse-echo method. It was placed on a steel block and excited with an electric pulse of 80 V amplitude and .1 µs width. Figure 3 shows the initial response to electric pulse and delayed signals corresponding to successive reflecting waves for a transducer 4 mm in diameter. The lower graph is the FFT of one of the echoes.

In this case, only the lower resonance frequency appears to be important since the other resonance and harmonic frequencies around 12 MHz in power spectrum is highly damping by the mechanical system and the low Q_M of the film itself.

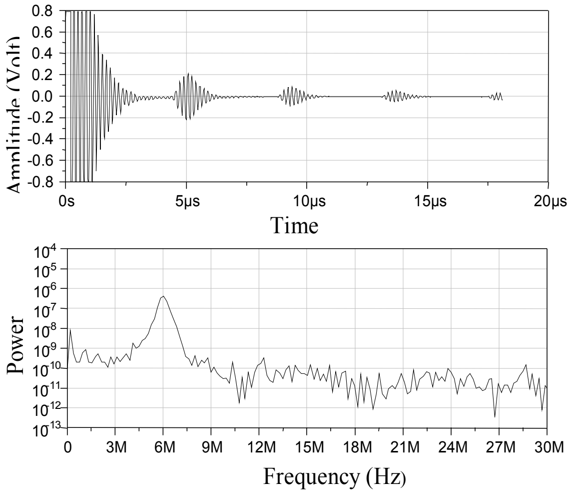

***Fig. 3**: Pulse response and echo FFT of a transducer 170 µm PZT over alumina 0.25 mm thick*

First echo is about 0.2 V_{pk}, that is not so high as in a bulk transducer but is high enough to get a very good signal/noise figure to measure several successive echoes or to ensure good reception where ultrasound signal is absorbed by material characteristics itself. Even is possible to use it on human body where there is signal degradation because of acoustic impedance mismatch between transducer and body.

Acoustic spectroscopy measurements

Acoustic spectroscopy methods allow us to relieve displacement of a piezoelectric surface and obtain the electromechanical transfer function of each point on it. The advantage of our implementation is that employ the transfer module of HP4194A.

Acoustic spectroscopy is a good alternative to traditional method of optical interferometry, which requires a mirrorlike surface on the face to relieve. In general this is not the case with the transducers employed in this work, so it would be necessary to build up special samples to make measurements. Besides, sometimes the electrodes not cover entirely the PZT surface, making more difficult to obtain a mirrorlike surface.

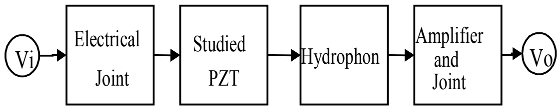

Figure 4: Acoustic spectroscopy block diagram

Measurements were made exciting with a sine wave the PZT transducer, and their vibration is picked up with a hydrophone coupled to the sample with oil or water. Figure 3 shows a block diagram of the electrical configuration. Is important to rebound that excitation level of a few Volts, correspond to amplitudes of a few tenth of nanometers. This vibration can be detected because HP4194 makes a synchronic detection that allows amplitude ratios until –120 dB. Resolution in amplitude is 0.001 dB and 0.01 Deg in phase.

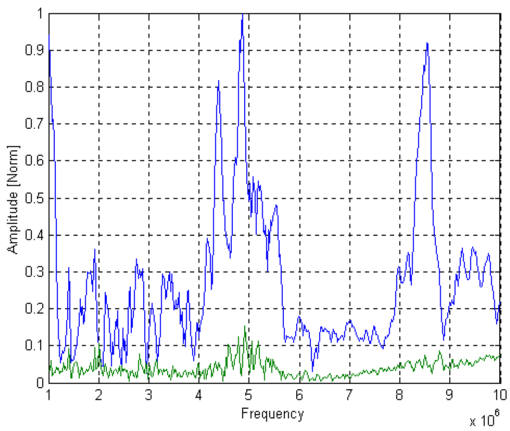

Figure 5: Comparative normalized amplitude of an excited (blue) and a passive (green) element.

Crosstalk interference

In crosstalk determination we have used two techniques, electric transfer between elements and acoustic spectroscopy detailed before. Electric transfer consist in excite with a continuous wave, one piezoelectric element and measure voltage amplitude at the other. We obtain the information about amplitude and phase with the same system as in acoustic spectroscopy.

Using this set up we have to take account that coupling is produced in three different ways, mechanically through the acoustic propagation in the substrate, electrically through the electric field created at hearing electrode zone by input signal and electromagnetically as emitted and received signal by wires. This last effect was minimized shielding the device and wire signals.

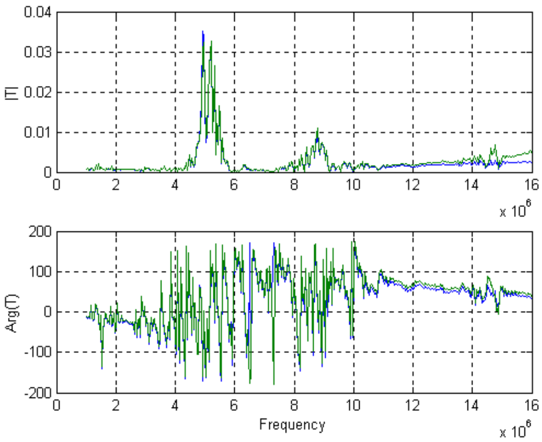

Figure 6: Coupling of two elements

Plot in figure 6 shows two elements coupling, where the blue one corresponds to transference from A to B: T_{AB} and the green is from B to A: T_{BA}. It is clear that both are very similar showing that system of two elements is symmetric. Besides, as to invert input and output we must change elements wires, it follow that the electromagnetic coupling is minimum. Coupling is produced at resonance frequencies for both samples.

Acoustic field coupling

An important test to evaluate coupling behavior is how it looks in water medium. In picture we can see a Schliering image of the acoustic field using the 4 x 4 array as the source field. In this case only one of the array elements was c.w. excited at the lowest resonance frequency. Transducers are on the right side of the picture. It is clear the emission of 4 elements of the firs line and is also possible to see back element emission between beams of the first line. Changing excited frequency of the element is possible to tune resonance frequency of other elements with a slightly different resonance frequency zone.

Figure 7: Acoustic field image showing coupling in a 4 by 4 array.

CONCLUSIONS

We have showed that fabricated thick film PZT ceramic has a good behaviour as ultrasonic emitters and receptors. Transducer has good signal/noise figure and intense acoustic field in spite of small size. There is an important electrical coupling and through the substrate that must be clarified to get better arrays. Besides these, is possible to make it in batch process and integration with emission and reception electronics are of great interest.

At the present time, after transduction properties were proved, we are working in array transducers with impedance adaptation and backing, looking for decoupling elements interaction.

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