Ferroelectret Transducers for Water Immersion and Medical Imaging.

Ultrasounds for Biological Applications and Materials Science

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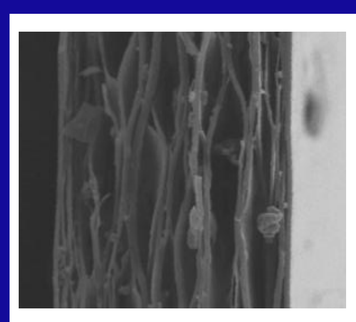
Abstract—The possibility of using ferroelectret films to produce wideband ultrasonic transducers for applications in water immersion and medical imaging is investigated. Ultrasonic transducers with different sizes were fabricated using a polypropylene ferroelectret film as active component. They were characterized in pulse-echo operation mode in water immersion. Measured useful frequency bandwidth goes from 0.3 to 2.5 MHz with a 6 dB relative bandwidth of 175% and minimum two-way Insertion-loss of -65 dB . The use of matching layers to improve the Insertion loss figure is also investigated. The application of these transducers to discern between different echoes coming from layered reflectors is tested, in particular, the simple case of a rubber plate attached to a steel reflector is studied. Pulse-echo mode and both time domain and resonant frequency domain techniques have been tested and discussed.

0. FE film

Polypropylene film



One surface Al electroded
Thickness: 70 μm
Density: 540 kg/m^3
Sound veloc. (thickness direction): 80 m/s
Resonant frequency: 650 kHz

I. Transducer design.

Elements of the transducer:

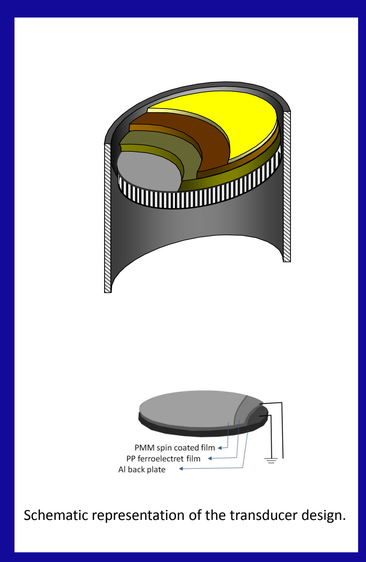
Polypropylene ferroelectret film: λ/2
resonant frequency: 650 kHz
Aluminum back plate
PMMA spin coated protective layer
(Solution of 5% PMMA in Anisole)

Ferroelectret film diameter:
22, 17 and 10 mm

Cylindrical housing

Lateral or back connector:
SMB or BNC

Matching layer (optional):
λ/4 layer, Z= 0.45 MRayl



Schematic representation of the transducer design.

Built transducer prototypes:
22, 17 and 10 mm diame

Pictures of the fabricated prototypes:
Aperture: 22 mm (up) and BNC back connector, 17 mm (centre) and SMB lateral connector , 9 mm (bottom) and back SMB connector

II. Transducer characterization (pulse-echo and water immersion).

Pulse-echo operation mode.

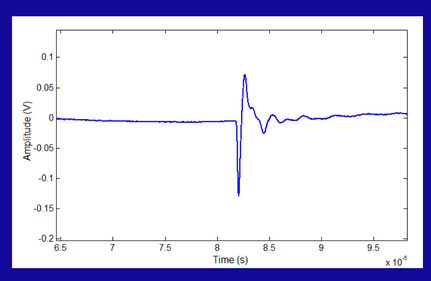
Olympus 5058 pulser/receiver:
Pulse amplitude: 900 V,
Gain 40 dB,
Damping: 500 Ω

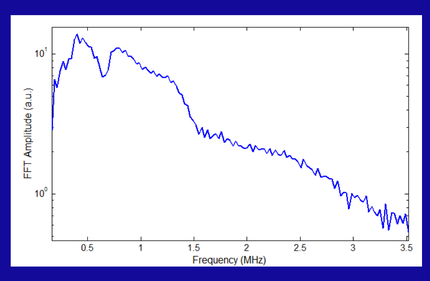
22 mm aperture transducer

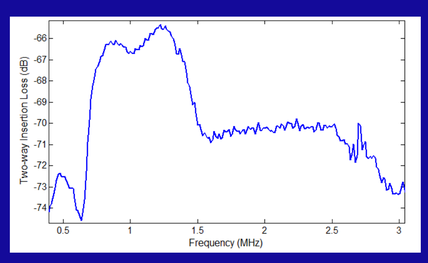
Steel reflector located at ~60 mm.

Results.

Peak to peak amplitude: 200 mV.
FFT peak @ 400 KHz
SNS peak -65 dB @ 1.2 MHz
6dB bandwidth (in SNS): 175%







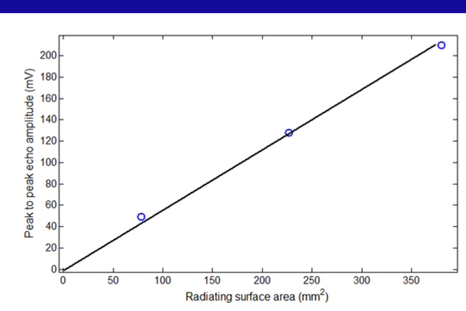


Fig. 5. Peak to peak amplitude of the reflected echo vs transducer radiating surface area for the three different transducer desing tested (transducer circular aperture and diameter of 22, 17 and 10 mm, respectively). Solid line represent a liner fitting.

III. Application to pulse-echo measurements of a layered plate in water.

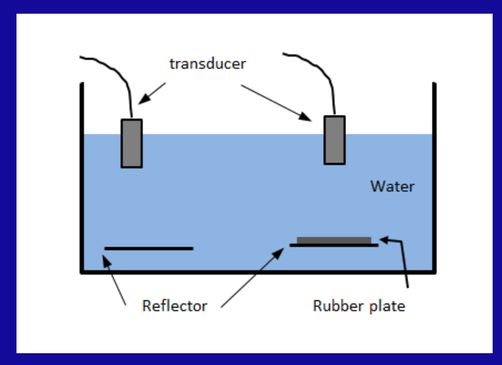
Pulse-echo operation mode.

Two rubber plates: 1.05 and 2.00 mm thick
Attached to a steel reflector

Olympus 5058 pulser/receiver:
Pulse amplitude: 900 V,
Gain 40 dB,
Damping: 500 Ω

22 mm aperture transducer

Steel reflector located at ~60 mm.



Time domain analysis: determination of tof

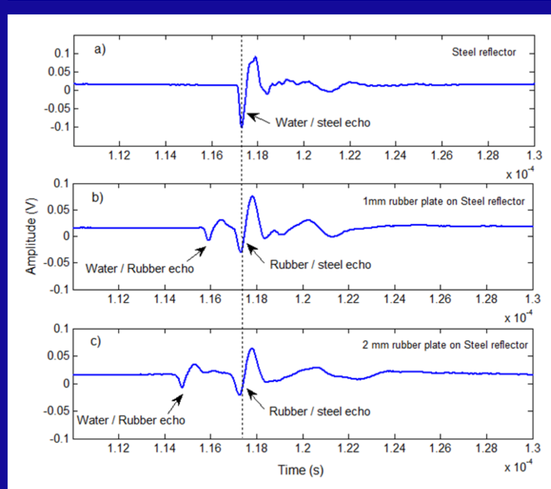


Fig. 7. Received echo from: a) the steel reflector, b) the 1 mm rubber plate placed on the steel reflector c) the 2 mm thick rubber plate on the steel reflector.

Time domain:

tof in the rubber plate 1.4 and 2.5 μs, respectively
Obtained tickness of the rubber plates:
1.085 ± 0.035 mm and 1.94 ± 0.06 mm

Frequency domain.

Resonant frequencies in the rubber plate:
612, 993, 1404, 1815, 2226, 2602 kHz (2mm thick)
1.13, 1.883 and 2.692 MHz (1 mm thick)
Obtained ttickness of the rubber plates:
1.033 ± 0.008 mm and 1.93 ± 0.02 mm

Frequency domain analysis: determination of resonant frequencies. (λ/4 x (2n-1) series).

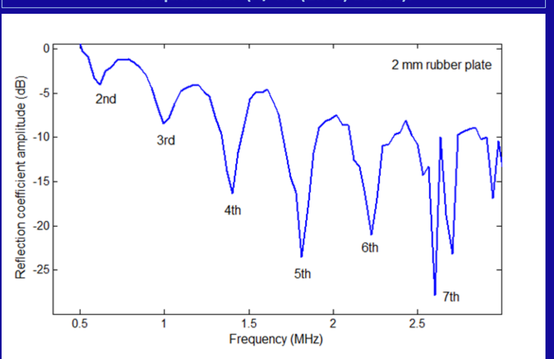


Fig. 8. Amplitude of the reflection coefficient of the 2 mm thick rubber plate attached to the steel reflector (normalized to the amplitude of the echo received from the steel reflector without the rubber plate).

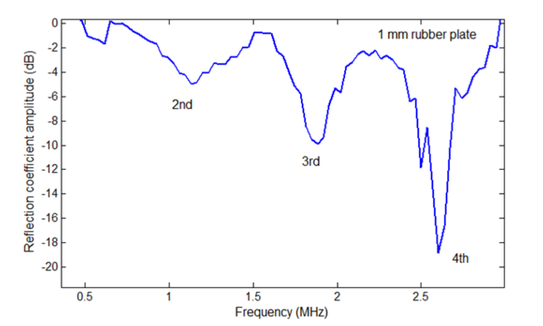


Fig. 9. Amplitude of the reflection coefficient of the 1 mm thick rubber plate attached to the steel reflector (normalized to the amplitude of the echo received from the steel reflector without the rubber plate).

IV. Conclusions.

Water immersion transducers can be made using ferroelectret films as active element.
Frequency band goes from 0.43MHz up to 2.5 MHz. 175% 6 dB band
Peak sensitivity is about -65 dB at 1.2 MHz
Peak sensitivity decreases lineraly with the decrease of the FE film surface.
Though expected working frequency is 650 kHz, SNS presents a minimum value at this frequency.
Use of matching layers presents no advantage, probably due to the coupling fluid used to attach the ML to the FE film.
These transducers can be used to study layered samples in water using a pulse-echo technique and both in time domain (tof) and in frequency domain (resonances).

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