Pad printed thick-film transducers for focused, high frequency, high-power applications

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Fabrication

The basic structure of the transducer is depicted in Figure 1a and a cross section of the active structure is seen in Figure 1b. Top and bottom electrodes and the active film were deposited using pad printing on the curved face of the cylinder and contact electrodes were added along the side of the cylinder using screen-printing. A thorough description of the manufacturing method can be found in [1].

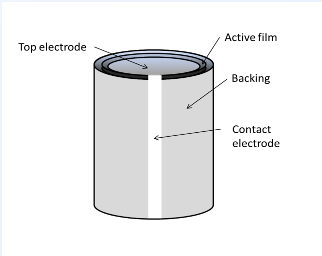

Figure 1a

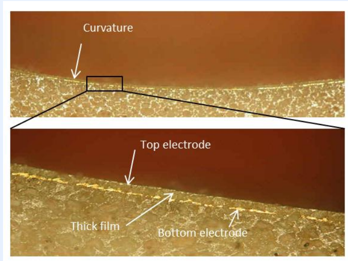

Figure 1b

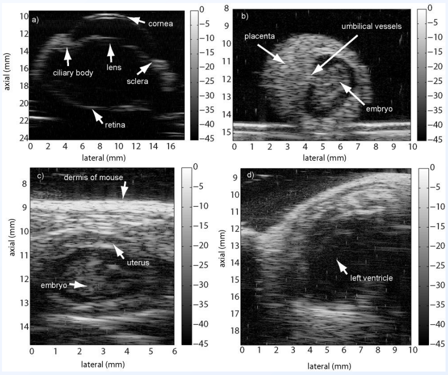

Figure 2

Results imaging

The pulse/echo response was characterized. The response revealed a centre frequency of 19.5 MHz and -6 dB bandwidth of 135%.

Figure 2a shows an image of an ex vivo rabbit eye with the key anatomical features indicated. Figure 2b shows an externalized, in vivo mouse embryo with the embryo, umbilical vessels, and placenta visible. Figure 2c shows another image of a mouse embryo, this time with the embryo in utero. Finally, Figure 2d shows the left ventricle of an adult mouse heart.

Acoustic pressure measurements in high power using a hydrophone (Figure 3).

The piezoelectric thick-film transducer delivered high-pressure values over 3 MPa for an input voltage of 140 Vpp and a fairly linear pressure versus voltage curve with no saturation was observed (Figure 4). Considering that the thickness of the film was around 30 µm, the corresponding electrical field was around 5 kV/mm.

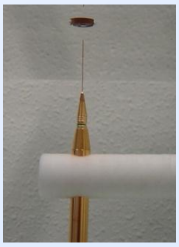

Figure 3

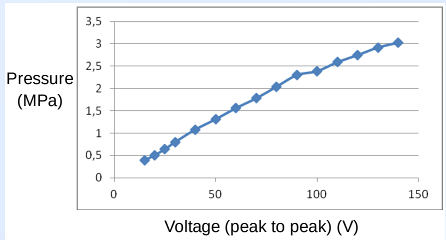

Figure 4

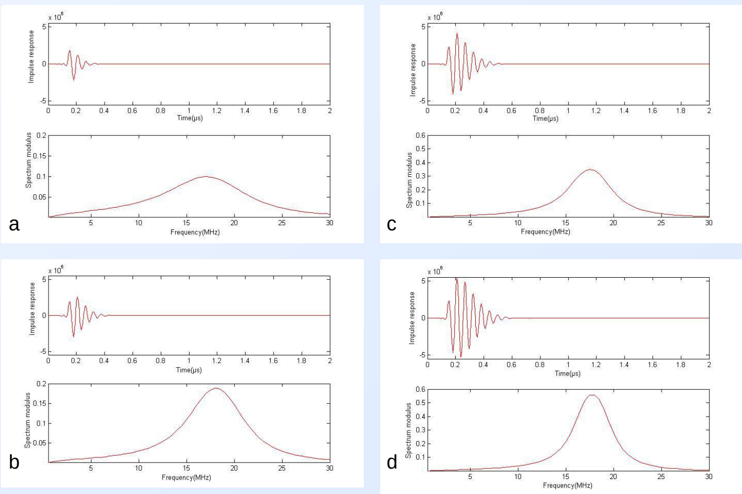

Figure 5. Pulse-echo impulse response and spectrum of:

a) a reference transducer (designed for Imaging). Bandwidth 60%, efficiency 11%.

b) a transducer with high porosity backing and standard rear électrode. Bandwidth 37%, efficiency 15%.

c) a transducer with standard backing and thick rear électrode. Bandwidth 31%, efficiency 23%.

d) a transducer with high porosity backing and thick rear électrode. Bandwidth 25%, efficiency 31%.

Simulation

In order to further explore the potential of such thick-film structures for combined imaging and therapy applications, the intrinsic performance of four transducer structures have been simulated using a KLM-based model (Fig 5). The impulse response in pulse-echo mode and its frequency domain curve were calculated as well as the efficiency in transmit mode. The efficiency is defined as the total acoustic power generated by the transducer in water divided by the input electrical power. Configurations were defined by using two backings, i.e. one is the current material, the other is a higher porosity ceramic with an acoustic impedance of 10 MRa. The thickness of the gold back electrode was either around 4 micrometers or lager around 15 micrometers.

Conclusion

In conclusion, piezoelectric thick-film structures on porous ceramic substrates, which have proven to be well adapted to high resolution imaging applications, can be optimised for therapy applications through changes of substrate porosity and back electrode thickness. Some of the configurations explored in this simulation study could lead to devices that would operate with satisfactory performance in both applications, i.e. lower but still acceptable axial resolution combined with higher efficiency as compared to the reference device. Such a transducer will be fabricated in the near future.

References

[1] F. Levassort, E. Filoux, R. Lou-Møller, E. Ringgaard, M. Lethiecq, A. Nowicki, ŕCurved piezoelectric thick films for high resolution medical imagingò IEEE International Ultrasonics Symposium, 2361-2364 (2006).