Ultrasound Pressure Field of a Resonating Piezoelectric Membrane with Three Excitation Electrodes

V. Tzanov[1], E. Ledesma[1], F.Torres[1], N. Barniol[1]
1. Department of Electronics Engineering, Universitat Autonoma de Barcelona, Bellaterra, Spain

INTRODUCTION: Micromachined ultrasound transducers can work as a sensor or actuator for measuring fluid speed and direction, mixing and exciting particles (sonication), ultrasonography, non-destructive testing and other purposes in various fields [1]. In this work, a 3D-model of a piezoelectric membrane has been built. It consist of a circular AlN layer in between two top and one bottom Al electrodes, and a conformal SiO_2 top layer. The device has the dynamics characteristics of a circular membrane which boundary is clamped.

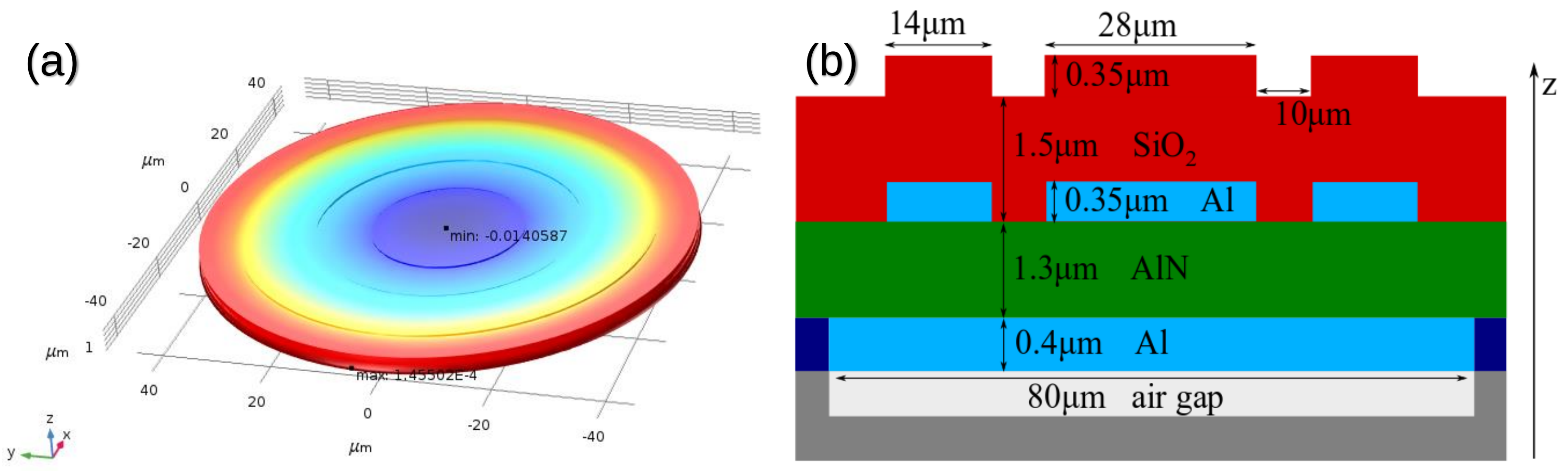

Figure 1. (a) Deformation due to residual stress in micrometers and (b) the schematic of the MEMS device

mode media	0,1 Air	1,1 Air	2,1 Air	0,2 Air	0,1 Fluorinert
frequency Experiment [MHz]	5.64	11,3	18.06	20.34	2.2
frequency Simulation [MHz]	5.57	11.28	18.6	20.87	2.08

Table 1. Resonant frequencies in air and Fluorinert, experimental versus simulated; see [3] for details of the measurements.

Studies performed: The transducer is immersed in a fluid where the pressure field propagates. Hence, our multi-physics model includes Acoustics, Solid Mechanics and Electrostatics [2]. Four studies were performed and compared with experimental results. A "Stationary Study“ (see Fig.1) that computes the initial bending of the membrane due to the fabrication. An "Eigenvalue Study" computes the resonance frequencies of the device in air, see in Table 1 columns 2 to 5. A "Frequency Domain Study" is used for the detection of the fundamental resonance peak in Fluorinert (FC-70), see Table 1, column 6 and Figure 2(a). Finally, a "Time-Domain Study" represents the experimental setup in our lab where six voltage pulses were applied to the terminals and a probe is measuring the acoustic signal at 3.8mm from the transducer, see Fig. 2(b-d).

In Table 2 the simulated and the measured pressure, and membrane displacement are compared.

	Pressure peak-to-peak at 3.8 in/out/differential	Displacement peak-to-peak of the membrane in/out/differential
Experiment	0.8/2.7/4 [Pa/V_{pp}]	0.1/0.29/0.38 [nm/V_{pp}]
Freq.-domain simulation		0.07/0.12/0.18 [nm/V_{pp}]
Time-domain simulation	0.84/1.57/2.46 [Pa/V_{pp}]	0.07/0.12/0.18 [nm/V_{pp}]

Table 2. Experimental versus simulated frequencies and displacement in Fluorinert.

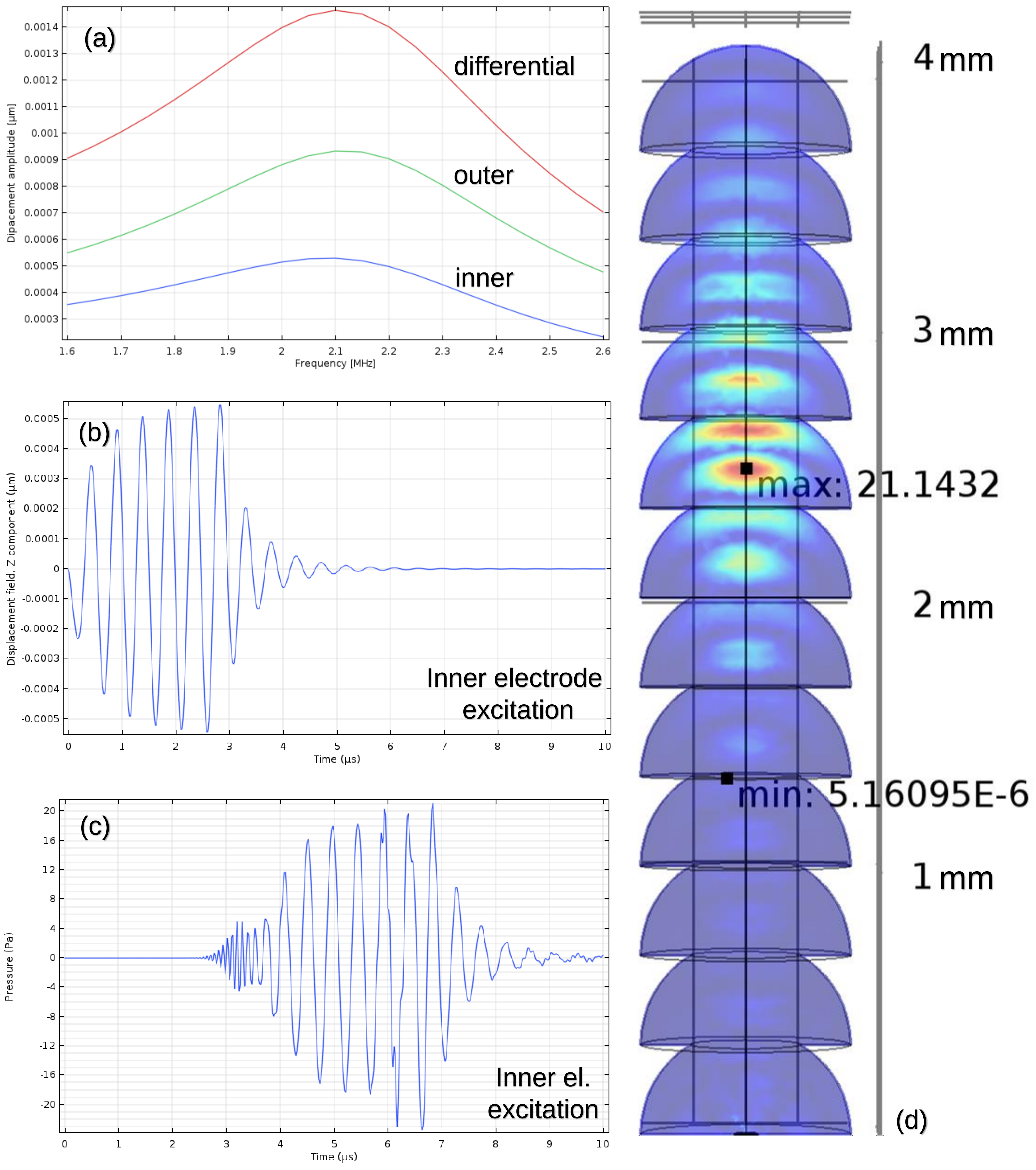

Figure 2. (a) Membrane displacement at the center (frequency domain), (b) membrane displacement at the center (time domain), (c) pressure field at 2.5mm (time-domain), (d) Snapshot of the pressure field forward propagation at 6.84 microseconds (time-domain).

CONCLUSIONS: The model is able to compute the pressure field at a distance that is an order of magnitude larger than the diameter of the source without sacrificing from the sophistication of the transducer’s design.

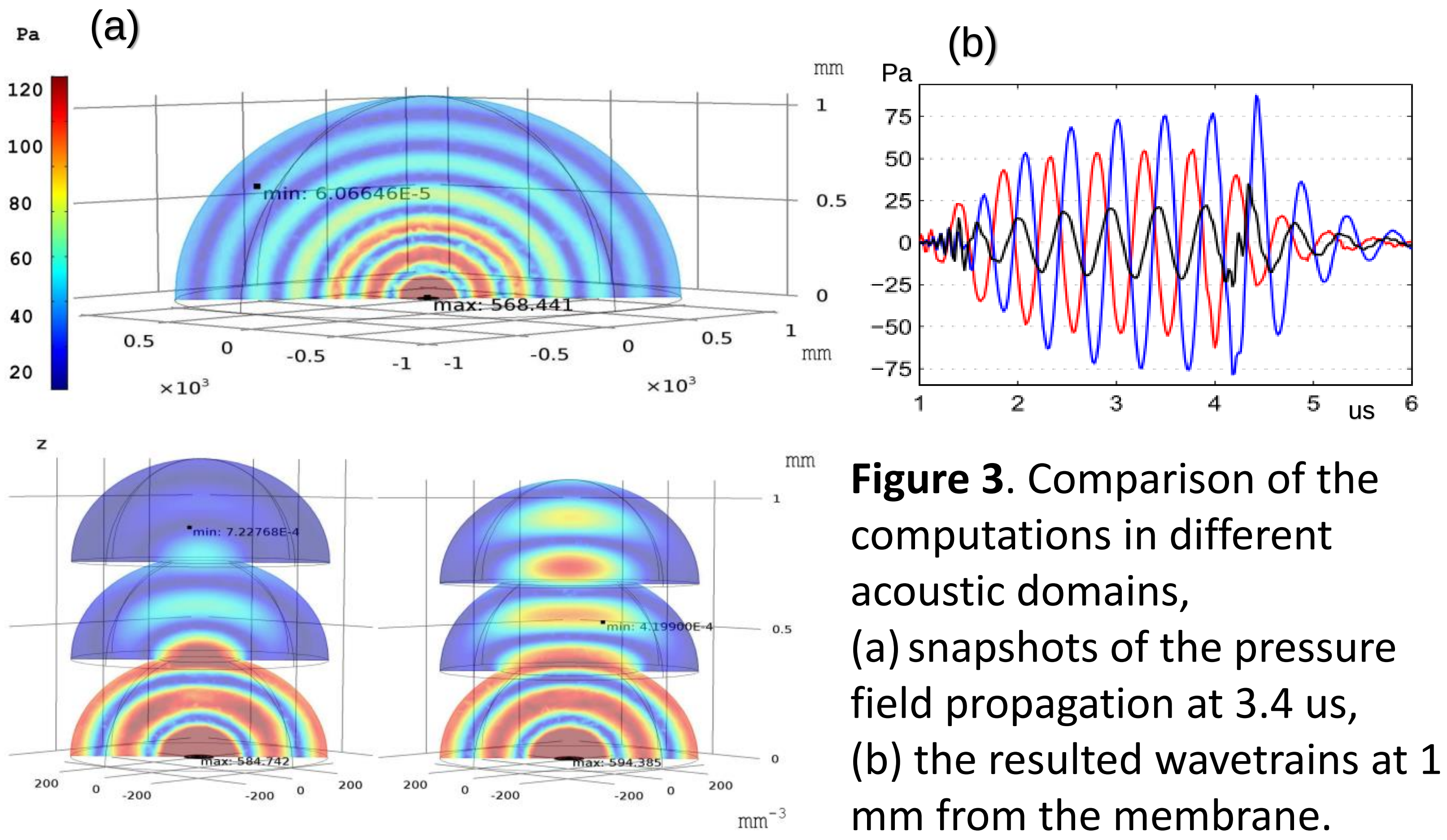

Figure 3. Comparison of the computations in different acoustic domains,
(a) snapshots of the pressure field propagation at 3.4 us,
(b) the resulted wavetrains at 1 mm from the membrane.

REFERENCES:

1. D. Horsley, Piezoelectric MEMS: materials, devices, and applications, University of California, Davis, 2014.
2. V. Tzanov et al., Ultrasound Pressure Field Of A Resonating Piezoelectric Membrane With Three Excitation Electrodes, Proceedings of COMSOL Lousanne conference, 2018.
3. J.Muñoz et al., Monolithical AlN PMUT on pre-processed CMOS Substrateii Proceedings of IEEE International Frequency Control Symposium 2018.

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