Parametric Simulation of PZT Diameter to Hole Ratio for Optimized Membrane Displacement

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Introduction

The loud-speaker design has not changed for approximately 90 years. Nevertheless, improvements to digital components in the audio reproduction cycle has been implemented and the only missing device to catch up with the digital era advancements is the acoustic transducer. The concept of Digital Sound Reconstruction could help with existing problems tagged along with the current speaker design such as: the frequency response and linearity. This concept needs an array of micro membranes to be implemented. In this simulations we focus on the actuation of a single element of this array. The membranes are composed of a bottom electrode, a piezoelectric layer, a top electrode and a structural layer using polyimide, as shown in Fig. 1.

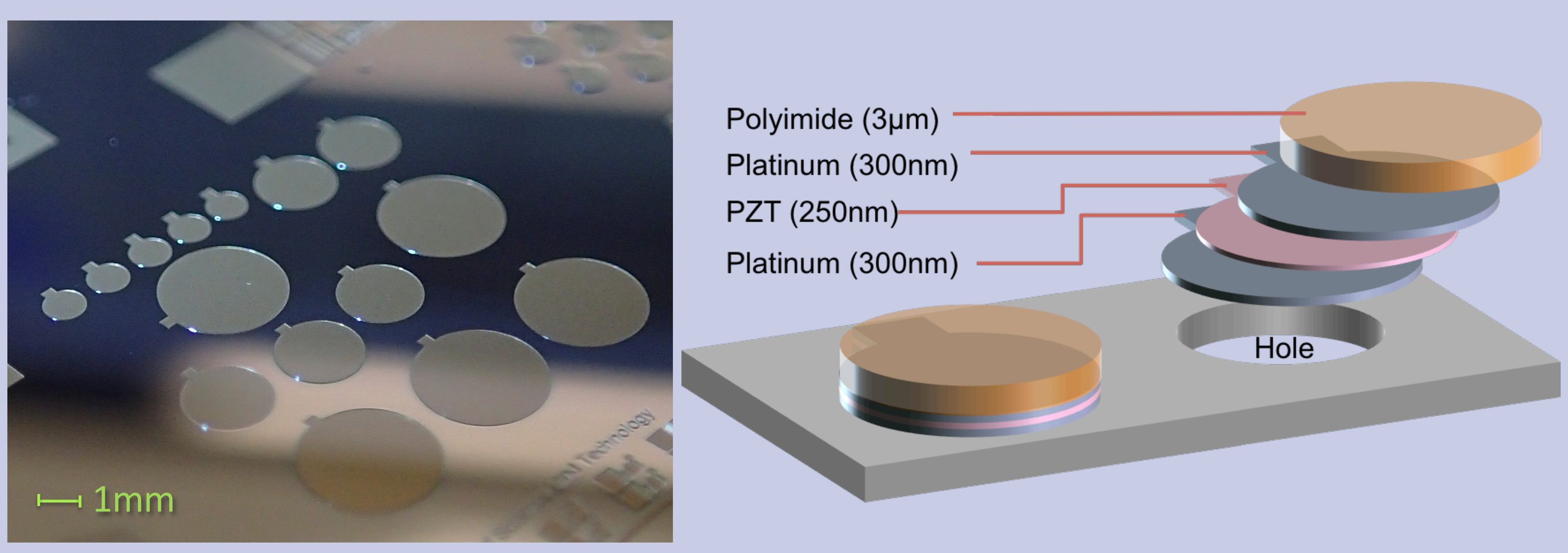
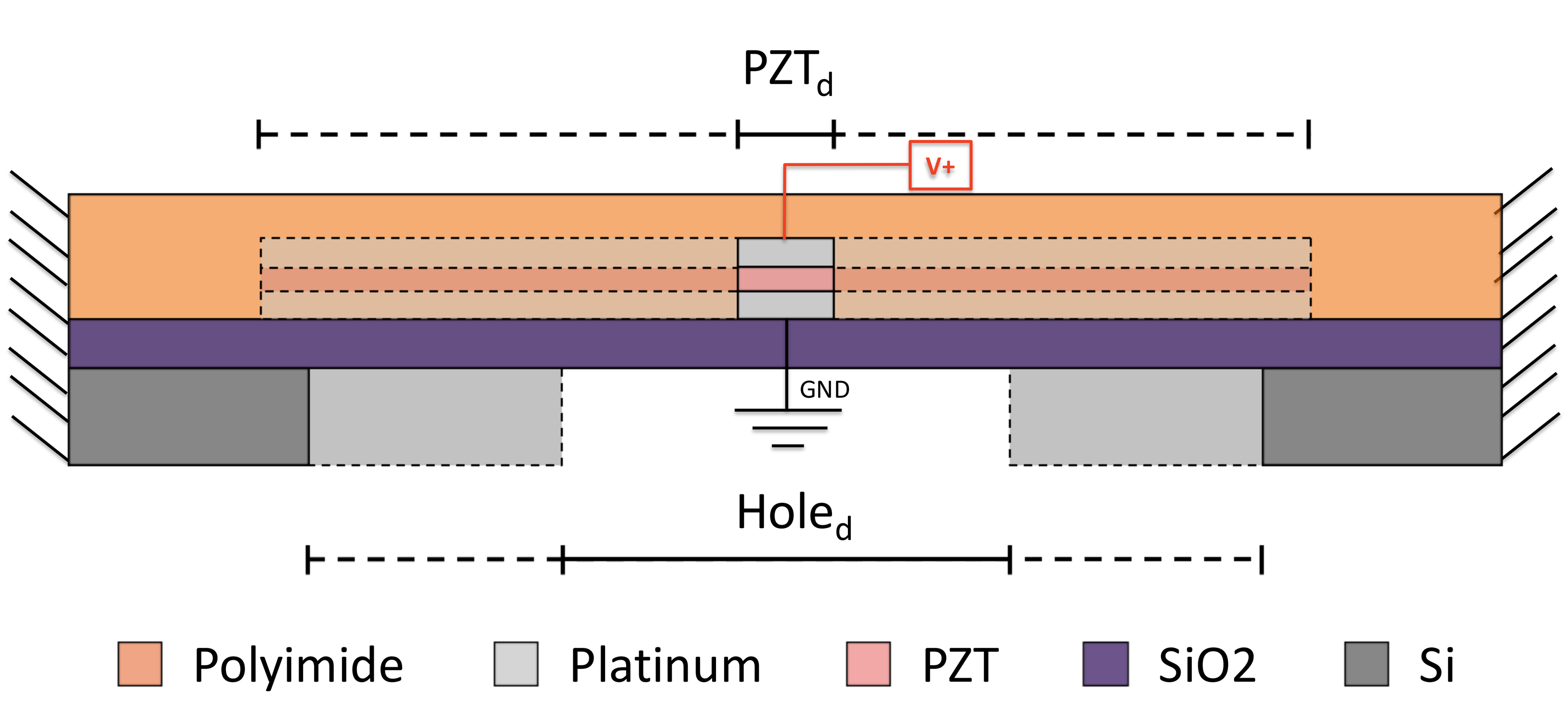


Figure 1 (Left) Fabricated membrane array of the first design of the micro-membrane. (Right) Conceptual exploded design of the fabricated membrane.

Design and Simulation

For our simulation we used the Piezoelectric module. The structure was set with (clamped) fix constraint boundaries to both ends. The bottom electrode was set to be the ground for the electrostatic physics and the top electrode was set to be a Terminal with potential of 10V. A parametric sweep study was set to change the geometry, the parameters to change was the hole diameter ($Hole_d$) and the piezoelectric stack layer (PZT_d).



$$PZT_d = a * Hole_d$$

Figure 2 Schematic of the cross-sectional view of the piezoelectric membrane. The PZT diameter is controlled proportionally to the ratio “a”.

Results

The first version of the fabricated devices did not meet the expected performance. Through the analysis and modelling in COMSOL we were able to see that the design was out of the optimal range for larger membrane displacement, see Fig. 3. In Fig. 4, a modified version of the membrane is shown, where the desired PZT/Hole ratio “a” should be between 0.8 to 0.9, **i.e. the Pt/PZT/Pt layers must have a diameter between 80%-90% of the hole diameter**.

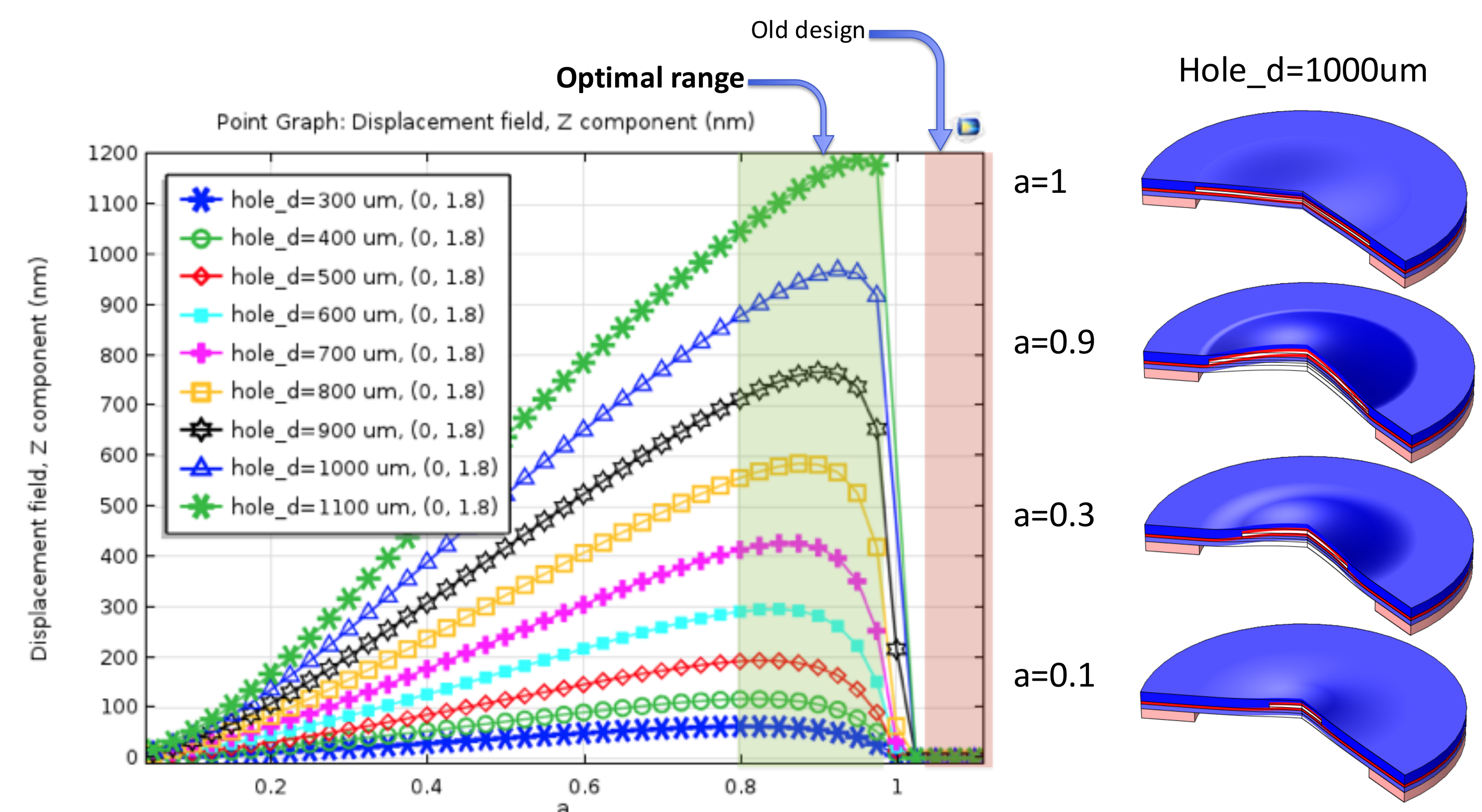


Figure 3 Displacement vs Diameter to Hole Ratio of Pt/PZT/Pt layer stack. The original design is in the red zone at the right of the graph.

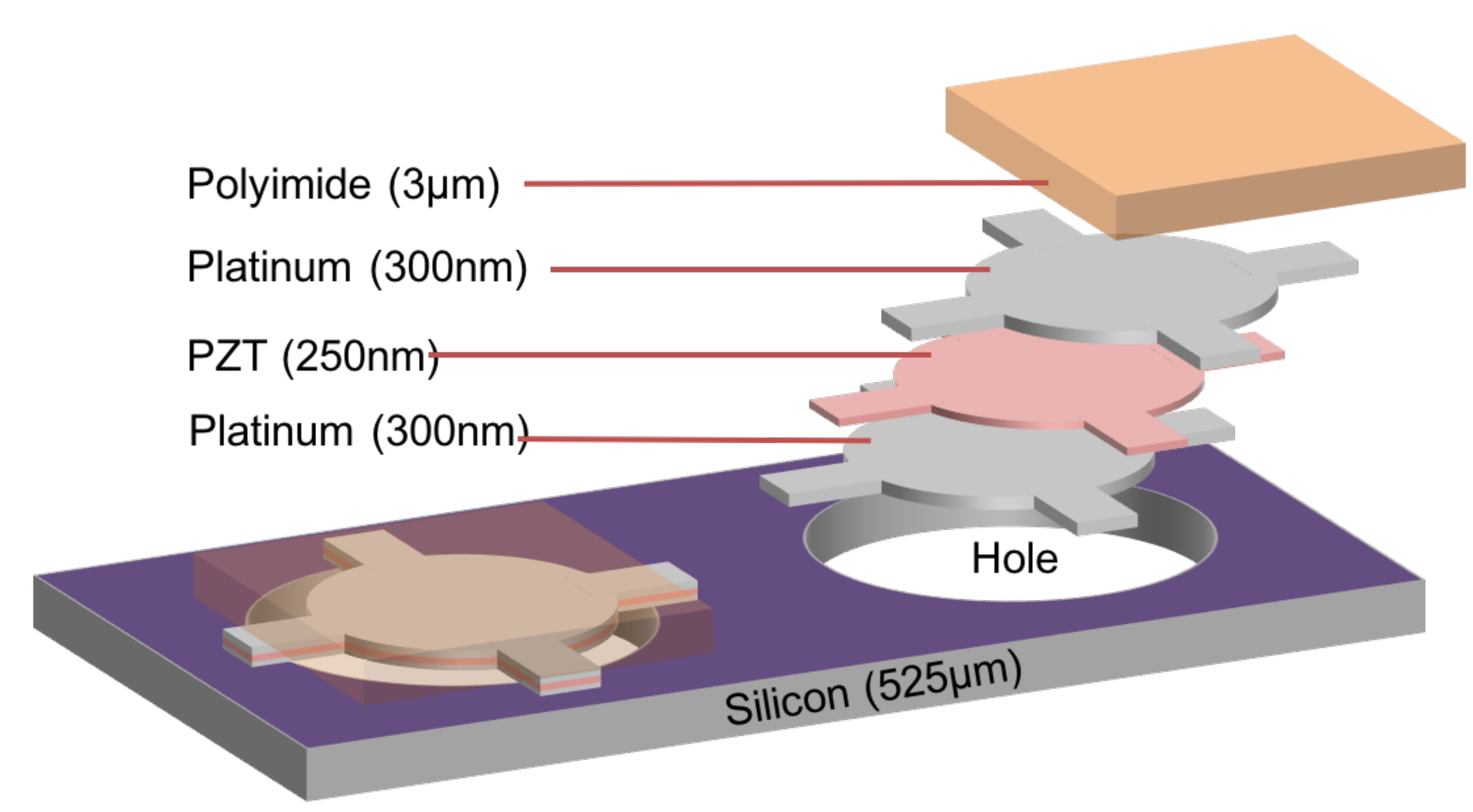


Figure 4 New membrane design for the Pt/PZT/Pt layer stack for optimized membrane displacement.

Conclusions

New designs are needed for a better array device. Future simulations would be on the acoustic energy generated by these transducers. Also looking into the beam forming pattern, which is an inherit characteristic of the final transducer array. The directivity pattern, has a great potential for a wide range of applications for our digital MEMS micro-loudspeakers, such as: separate multi-user intensity and signal control of the audio source and private audio, among others.

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