FULLY MICROMACHINED LIFESIZE COCHLEAR MODEL

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A life-size hydrodynamical cochlear model is demonstrated. The structure is fully micromachined and suitable for batch fabrication. Laser Doppler Velocimetry (LDV) measurements show cochlear-like traveling fluid structure waves with a phase lag of approximately 3 cycles (6π radians) and displacement magnitude of 0.2-0.5 nm/Pa at the location of maximum response. The device responds in the 10-70 kHz band.

To date, three groups have reported the construction of life-sized physical cochlear models [1,2,3]. These systems use a polymer membrane on a micromachined support as the "basilar membrane" (BM), and use casting, milling, or small-scale electro-discharge machining (EDM) to create two fluid ducts on either side of the membrane.

The device described in this paper is fully micromachined, has fluid on only one side of the BM, and is driven by airborne sound. The BM is 3 cm long, made of a stacked thin film structure ($Au/Cr/Si_3N_4/SiO_2/Si_3N_4$), and tapers exponentially in width from 170 μm to 1.9 mm. The three-layer dielectric is used to partially compensate the high tensile residual stress in the Si_3N_4. The metals are for optical reflectance. The fluid duct is 6.25 mm wide, 0.5 mm high, and filled with 200 cSt silicone oil. The high viscosity fluid was needed to suppress the formation of standing waves. Figure 1 shows a drawing of the device and the fabrication process.

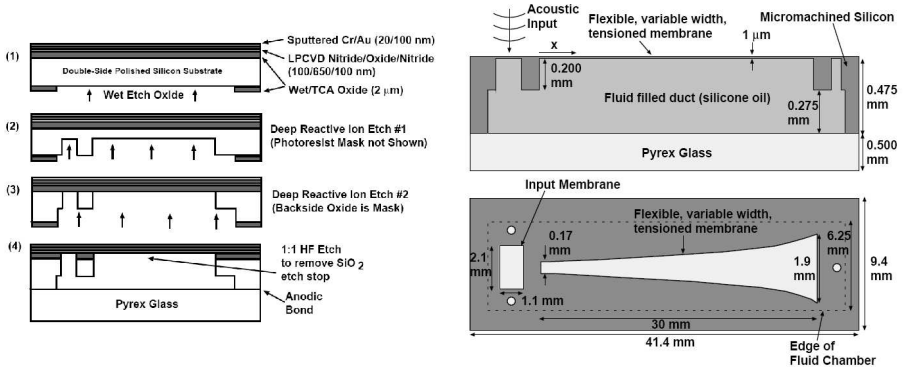

Figure 1. Left: Fabrication process. (1) Surface films are deposited and backside oxide mask is etched. (2) DRIE etch #1 defines the membrane shape. (3) DRIE etch #2 defines the duct shape and stops on the SiO_2 etch stop. (4) The etch stop is removed in 1:1 HF, and the structure is anodically bonded to Pyrex glass. Right: Device structure (not to-scale). Top: cross-section along centerline. Bottom: plan view.

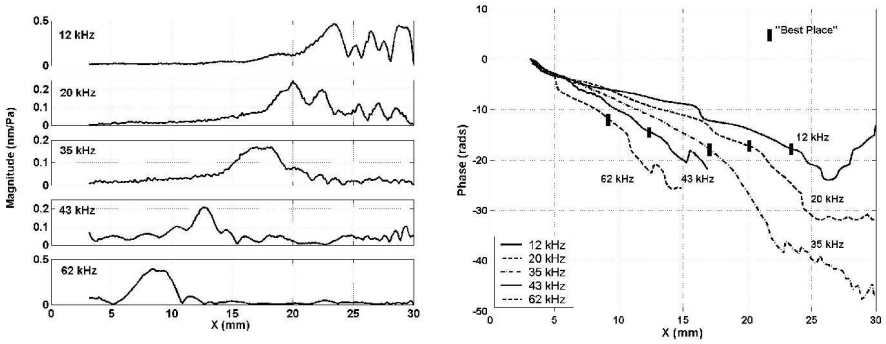

Figure 2. Laser Doppler Velocimetry (LDV) data showing the magnitude (left) and phase (right) of the membrane displacement along the centerline for 5 different pure tones present in the environment. Phase lag is approximately three cycles (6π radians) at the "Best Place". The magnitude of the response is 0.2-0.5 nm/Pa at the "Best Place".

LDV results show traveling waves with similarity to those seen in the insensitive cochlea. The device responds at high frequencies (10-70 kHz) due to the low compliance of the BM (residual stress is 500MPa). The magnitude of the observed displacements (0.2-0.5 nm/Pa) is smaller than those observed physiologically, due to the lack of a middle ear, lower BM compliance, and lack of any OHC-like structures. A complete description of a similar device including mathematical models can be found in a recent work by the authors [4].

Acknowledgments

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References

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