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Experimental Study of Vibration of Prototype Auditory Membrane

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Abstract. This experiment report the vibration of Prototype Auditory Membrane (PAM) for a novel implantable auditory membrane. PAM made of PVDF which is fabricated using MEMS technology. The vibration are measured as a response of a pulse sine wave which are applied from one of side of the membrane. The vibrations are analyzed experimentally based on the Fourier analyze theory.

Introduction

Ear is one of the five sense of human and part of auditory system. Ear is also one of the important organs of human for activity. It is not only to hear and receive a sound but also assist in balance and body positions.

Hearing is one of part the communication language to increase the skills of children and human to growth. Children can not make a communication with the other if they have some trouble with their hearing. There are many cause about hearing loss. The malfunction of the inner hairs cell is one of them [1][2]. The inner hair cells that are located inside the cochlea usually can not be repaired. Many researcher and company develop and research about cochlear implant to solve the problem. The problem of frequency selectivity is one of the important things in this case. Manufacturing of the device to realize of the selectivity which are related with cochlea have been reported. Kenji Tanaka et al. (1998) and Fang Yi Chen et al. (2006) report the results of fabricated a trapezoidal beam arrays which are fixed over a trapezoidal channel. The problem of their research about the mechanical strength of the beams structure is not strong enough. Robert D. White and Karl Grosh (2005) also make an experiment of the cochlear model using materials of silicon-nitride Si_3N_4 beams and compared with the biological materials. In this paper we discuss and analyze the behavior of the Prototype Auditory Membrane (PAM) using one pulse sine wave from actuator applied with pulse echo method.

Method and Experiment

Dimension and size of the PAM is 2 to 4 mm width, with the length is proportional changed along x direction. The length of the PAM is 30 mm with the same thickness along the membrane of 40 μm and the membrane is made of polyvinylidene (PVDF) made by Kureha, Japan as shown in Fig. 1.

In this work, we apply one cycle of sinusoidal wave on the PAM using actuator. The dynamics vibrations are observed experimentally. The sinusoidal wave one cycle from actuator is applied on the PAM with magnitude of voltage 2 V and frequency f, of 5 to 20 kHz. All of the frequencies are set in the human auditory. The function generator is used to set and arrange the frequencies and amplitude voltage. The amplifier is used to amplify and increase the magnitude of voltage.

The actuator is placed on the membrane at centre line along of the PAM in x direction, with distance 2 mm from the membrane as shown in Fig. 1. The vibration from actuator as an acoustic wave induces a transverse wave on the BAM which propagate along x. The wave propagation from the narrower side to the wider one, this condition has similarities with that on a basilar membrane in a biological cochlea. Velocity of the vibration that are obtained from LDV converted and analyzed using FFT.

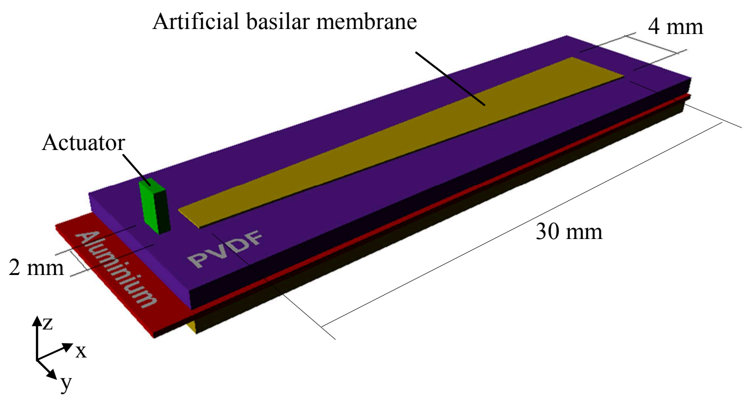
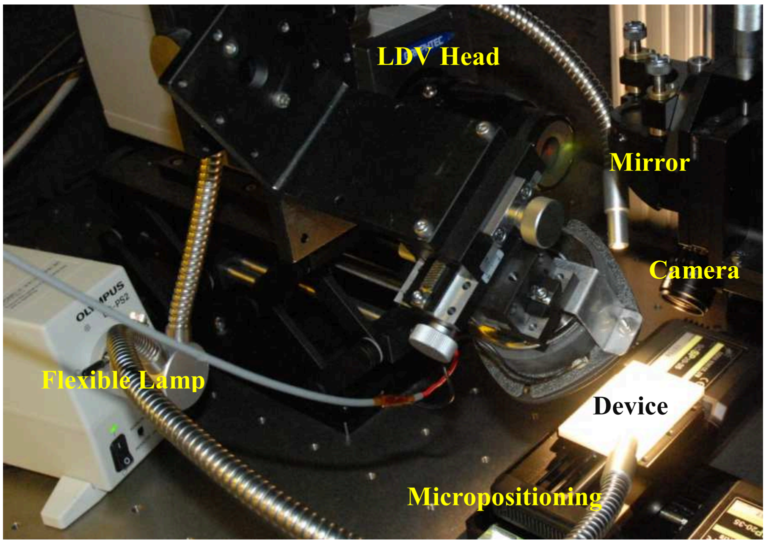


Fig. 1 Dimension and Size of Prototype Auditory Membrane

The reflection or pulse echo method is used in this experiment to measure the amplitude and time of the received signal of vibration between sending and receiving of the pulsed waves from the actuator as the sound. This method investigates the standing wave, resonant frequencies, and also the frequencies selectivity along of the PAM.

Figure 2 shows the experimental set-up of the equipment. The velocity of vibration of actuator is received and calculated using LDV equipment. The measurement is started from the actuator is applied on the PAM and is continued with interval 10 ms. The acoustic wave is applied to the device using piezoelectric actuator which is set at (x=-2, y=0) position. Micropositioning device is used to arrange the positions and distance of the PAM with actuator, and also to collect the data automatically each different positions of the PAM.



(a)

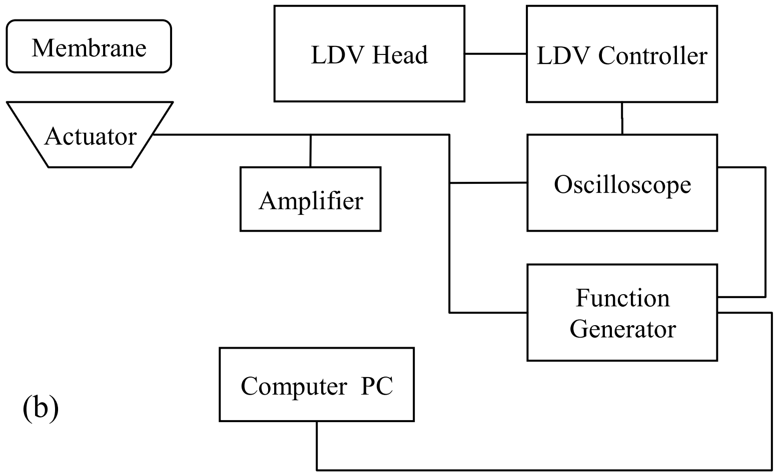
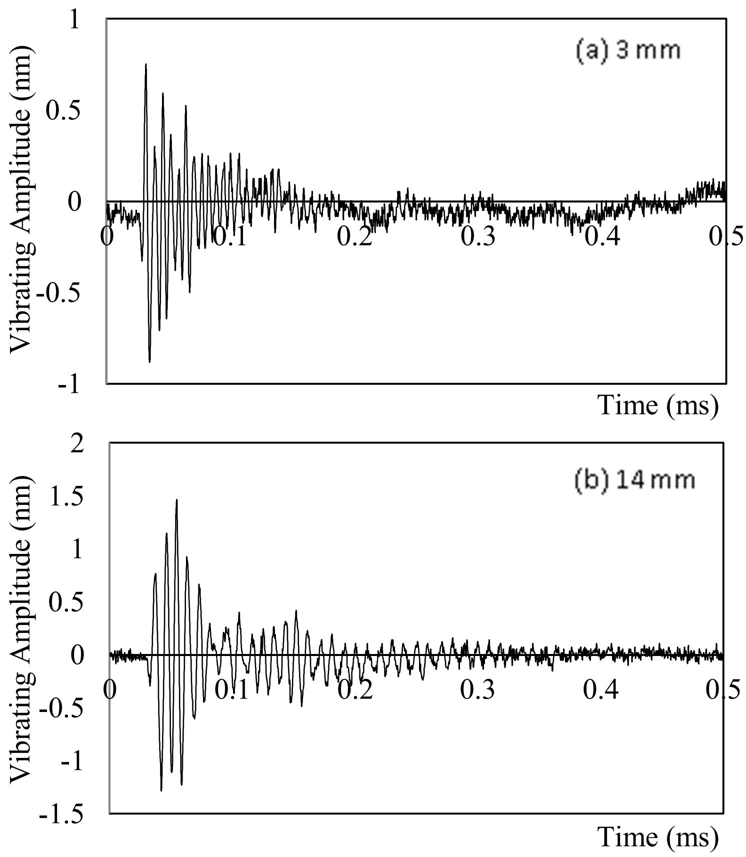


Fig. 2 Experimental set-up (a) Photograph and (b) Scheme

Results and Discussions

Figure 3 show the characteristic of vibrating amplitude of the PAM using 10 kHz pulse applied on the membrane with location at x = 3, 14, and 29 mm from the narrow side of the membrane. The PAM is showed vibrate and the wave showed move and propagates along of the membrane from narrow to wider side. The figures also show that the amplitudes are detected and clearly observed around 0.75 to 1.5 nm in the data of x = 3, 14, and 29 mm. This signals indicates that the induction of the resonance at those positions.



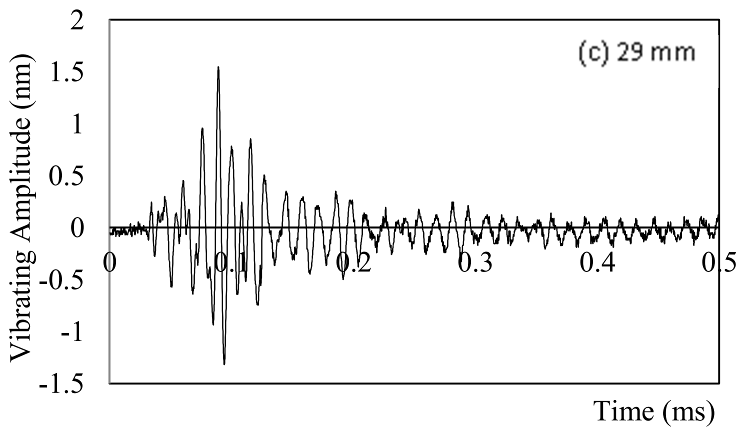
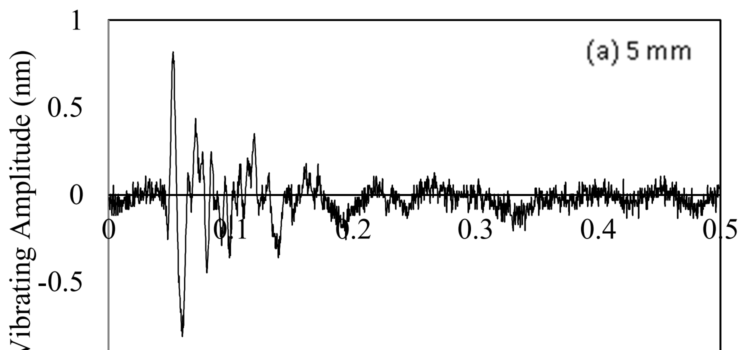
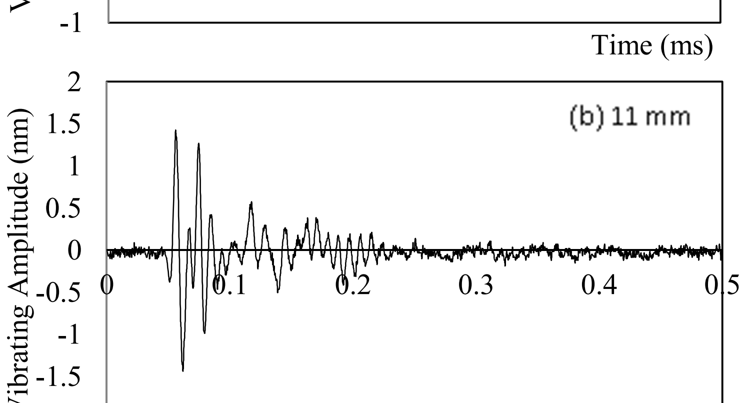


Fig. 3 Vibrating amplitude of 10 kHz at x = (a) 3, (b) 14, and (c) 29 mm

The each graph of x = 3, 14, and 29 mm show that the vibrating amplitude are changed propagates from the minimum to maximum amplitude increasing as the time increase. The local maximum of vibrating amplitude is indicated as the resonant frequency of the membrane at the certain frequency. The positions of the local maximum of vibrating amplitude at each frequency are different. At the distance of 3, 14, and 29 mm show the local maximum of vibrating amplitude along the PAM for one-sinusoidal wave and investigated at 0.032, 0.0548, and 0.0892 ms, respectively. This indicates that the frequency selectivity can be realized on the PAM.

Figure 4 show the characteristic of vibrating amplitude of 15 kHz pulsed applied for x = 5, 11, and 24 mm from the narrow side of the membrane. These graphs show that the vibrating amplitude at x = 5, 11, and 24 mm are 0.8185, 1.4252, and 3.8215 nm, respectively. These amplitudes are observed higher at x = 24 mm than x = 5 mm. The maximum of amplitudes of x = 5, 11, and 24 mm are observed at 0.0528, 0.056, and 0.0764 ms, respectively.





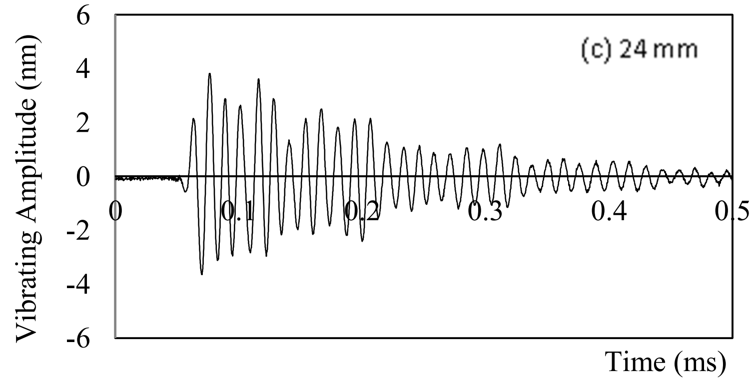


Fig. 4 Vibrating amplitude of 15 kHz at *x* = (a) 5, (b) 11, and (c) 24 mm

Figure 5 show the vibrating amplitude of PAM along of *x* direction for 10 kHz and 15 kHz, respectively. The position of the maximum amplitude at 10 kHz and 15 kHz are around 27 mm and 18 mm in *x* direction, respectively. This conditions indicate that the maximum amplitude is changed to the smaller *x* direction with increasing the frequency. This phenomena also show that the resonant frequency are investigated increasing as the width of the PAM decrease. The dynamics of the wave propagation is clearly show travel toward the larger *x* with changing the amplitude. The vibration phenomena of the PAM is very similar with the basilar membrane vibration in the biological cochlea. This phenomena describe that the PAM can realize the natural hearing.

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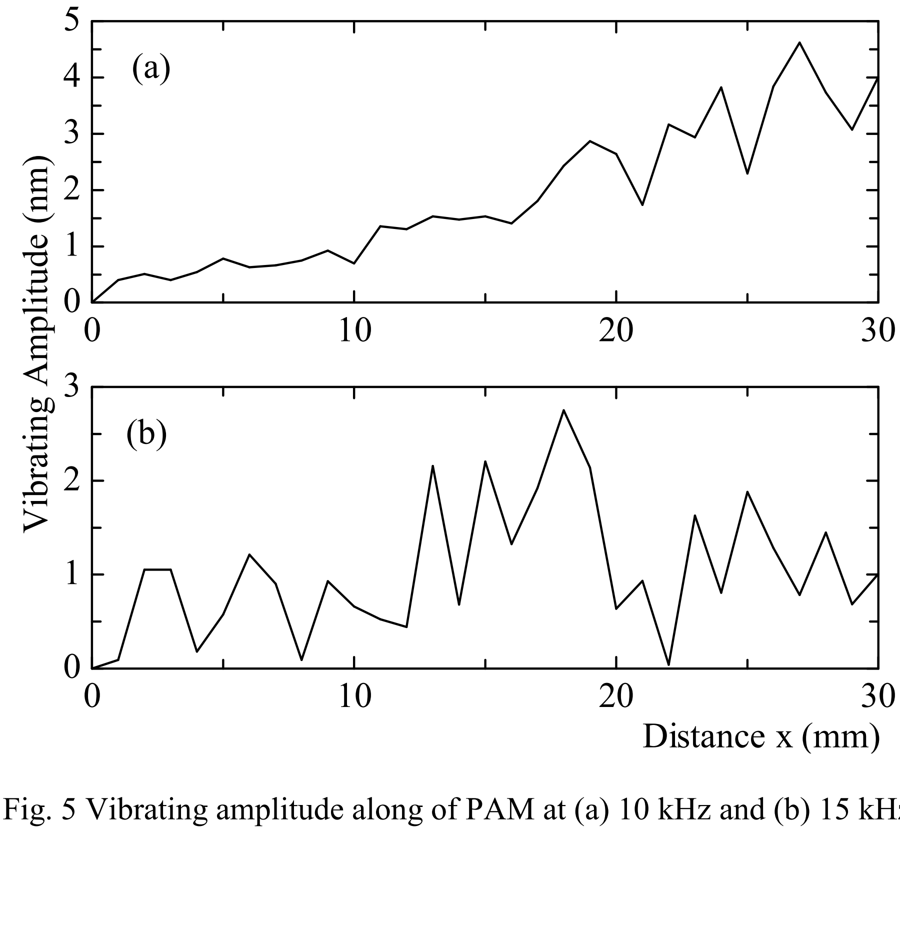

Fig. 5 Vibrating amplitude along of PAM at (a) 10 kHz and (b) 15 kHz

Summary

Prototype auditory membrane can realize the frequency selectivity at 10 kHz and 15 kHz. The maximum vibrating amplitudes of 10 kHz is investigated at x = 3, 14, and 29 mm for 0.032, 0.0548, and 0.0892 ms, respectively with the amplitudes of 0.75 to 1.5 nm. The location of maximum vibrating amplitudes of 15 kHz is observed at x = 5, 11, and 24 mm from the narrow side of the membrane for 0.0528, 0.056, and 0.0764 ms, with the amplitudes of 0.8185, 1.4252, and 3.8215 nm, respectively. Experimentally, the resonant frequencies are investigated decreasing as the the width of the membrane increase.

References

[1] Georg v Békésy, Experiment in Hearing, Mc. Graw Hill, NY, 1960.

[2] Wever E. G., Lawrence, M., Physiological Acoustic, Princeton Univ. Press, NJ, 1954.

[3] Fang Yi Chen, Howard I. Cohen, Thomas G. Bifano, Jason Castle, Jeffrey Fortin, Christopher Kapusta, David C. Mountain, Aleks Zosuls, and Allyn E. Hubbard, A hydromechanical biomimetic cochlea: Experiments and models, Journal of Acoustic Society of America, Vol.119, No.1(2006), pp. 394-405.

[4] Kenji Tanaka and Mototsugu Abe, A novel cochlea “Fishbone” with dual sensor/actuator characteristics, IEEE/ASME Transactions on Mechatronics, Vol.3, No.2 (1998), pp.98-105.

[5] Robert D. White and Karl Grosh, Microengineered hydromechanical cochlear model, Proceedings of the National Academy of Sciences of the United States of America, Vol.102, No.5(2005), pp. 1296-1301.