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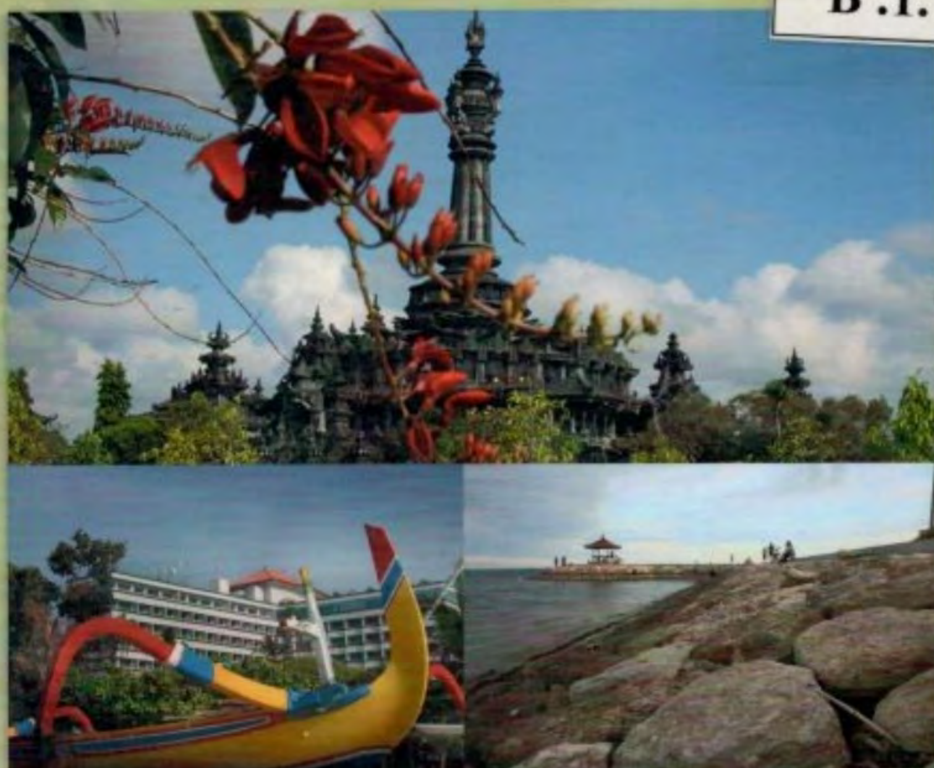

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ELECTRICAL ENGINEERING

Experimental Study of Dynamic Vibration on Prototype Auditory Membrane Made of PVDF

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Abstract: In this paper, we investigate the vibration dynamics of the prototype auditory membrane (PAM) for a novel implantable articial cochlea. The shape of PAM is trapezoidal and elastics membrane which is fabricated using MEMS technology. The dynamics are measured as a echo signals of transient vibrations induced by pulsed sine waves which are applied from top and one side of the PAM. The PAM vibrations are analyzed based on the Fourier analyze, it is found that the PAM can realize the frequency selectivity of the various frequency.

Key Words: *Basilar membrane, Frequency selectivity, PVDF, PAM*

1. INTRODUCTION

Cochlear implants usually use to assist the human when they have deafness caused by the sensorineural hearing loss. We develop the Prototype Auditory Membrane (PAM) as a novel acoustic sensor which is a part of the fully implantable artificial cochlea. In the previous study, we investigate the vibration of the membrane at the periodic steady state using continuously applying acoustic sinus wave. Previously, we use the speaker to apply the sound wave into the membrane. In this research, we report the vibration dynamics of the PAM which is induced by pulse sine waves and sound wave. We develop the PAM which is one of part of the artificial cochlea.

2. DESIGN AND GEOMETRY

In the previous our experiment, we are discuss about investigated frequency selectivity of the membrane using certain frequency. The standing wave and resonance frequency are detected and observed along of the membrane.

In this work, we apply one cycle of sinusoidal wave on the PAM using actuator and speaker. Comparison dynamics vibrations between them are observed experimentally. The sinusoidal wave of actuator and speaker are applied on the PAM with magnitude of voltage 2 V and frequency *f*, of 5 to 20 kHz and 3 to 15 kHz, respectively. All of the frequencies are set in the human auditory. The function generator is used to set the frequency and amplitude voltage and amplifier is used to amplify the magnitude of voltage. The method of pulse echo is apply in the experiment. The basic principal of the method detect and analyze the received vibration signal with time between emission from actuator and reception along of the PAM.

The PAM is fabricated using microelectromechanical system (MEMS) technology. Design and geometry of the PAM is shown in the figure 1. The PAM has 40 μm thickness of polyvinylidene (PVDF) membrane made by Kureha, Japan. The Young's modulus and density of the membrane are 4 Gpa and 1790 kg/m^3, respectively. The width of PAM is 2 to 4 mm propotional change along x direction and placed on the trapezoidal channel. The purpose of the trapezoidal shape is to detect and realize the frequency selectivity on the membrane. Total length of the membrane is 30 mm and there are 24 detecting electrodes on the top surface of the membrane. The electrodes are fabricated using etching method and standard photolithography. Each electrodes has 500 nm thick and 0.5 × 1 mm rectangle dimension with space of 0.5 mm. Shcematic and dimension of the PAM is shown in the Figure 1.

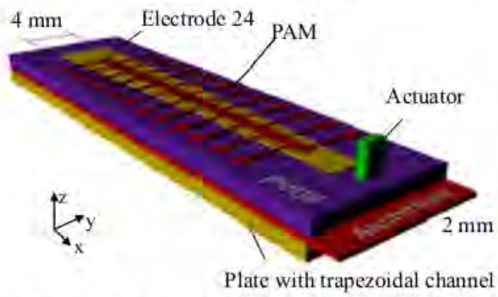

Figure 1. Schematic and dimension of PAM

3. METHOD

In this work, two kind of signal applied on the PAM. First, the continous wave is applied on the PAM using speaker and second using actuator. The sinusoidal acoustic wave from speaker is applied to the membrane at 75 dBSPL. The distance between speaker and the membrane is set of 150 mm with tilt angle of 60 deg. The applied frequency is controlled from f of 1 to 15 kHz. One cycle of sinusoidal wave from actuator is applied on the PAM with magnitude of voltage 2 V and various frequency from f of 5 to 20 kHz. The both method were investigated the standing wave and resonant frequency along of the PAM, also the frequeny selectivity is observed on the PAM. In this experiment, we use function generator and amplifier. Both of the equipment are used to arrange the amplitude voltage and increase the magnitude of voltage, respectively. Pulse echo method is used to detect and characterize the received signal of vibration with time between emission from actuator and reception along of the PAM. The actuator is placed on the one of side of the PAM. Position of the actuator is standing on the top surface and centerline along x direction of the PAM. Vibrating dynamics of the PAM are investigated using laser Doppler vibrometer (LDV). LDV read the displacement of the membrane from the velocity of vibration. The velocity data is analyzed by FFT to obtain the amplitude of the oscillation of the membrane.

3.1. Model of PAM

The PAM can be modeled as a plate bending model and it can be assumed as a thin plate. This assumption based on the deflection of the membrane very small compared with the thickness. We use the theoretical prediction of the oscillatory dynamics of the membrane and the deformation as a thin plate bending.

$$\frac{Eh^3}{12\left(1-\upsilon^2\right)}\left(\frac{\partial^4 w}{\partial x^4}+2\frac{\partial^4 w}{\partial x^2\,\partial y^2}+\frac{\partial^4 w}{\partial y^4}\right)+\rho h\frac{\partial^2 w}{\partial t^2}=p \qquad (1)$$

4. RESULTS AND DISCUSSION

In this experiment, we investigate the basic vibrating characteristic of the PAM using sinusoidal wave applied from speaker and actuator in the atmosphere. Figure 2 shows the vibrating amplitude of the PAM compared with the time at x = 16, 27, and 29 mm for 7 kHz. The transversal wave can be detected and traveling from narrow side to the wider side of the PAM. These conditions have relationship with the position of the actuator that is placed near the narrow side of the PAM. The phenomena can be identified from the change of maximum amplitude with time along x direction. The local maximum of vibrating amplitude along of the PAM at the certain frequency is indicated as the resonant frequency. The positions of the local maximum vibrating amplitude at each frequency are different. In Figure 2 the maximum amplitude is investigated at x = 27 mm in the 0.0804 ms along of the PAM. This indicates that the frequency selectivity can be realized on the PAM.

Figure 3 show the vibrating amplitude of the PAM compared with the time at x = 15, 24, and 27 mm for f = 17 kHz. The local maximum of vibrating amplitude along the PAM is investigated at the distance x = 24 mm at the time of 0.096 ms. Comparing with figure 2, the local maximum amplitude of the vibrating amplitude is obtained on the shorter distance along x direction of the PAM. This indicates that the location of the local maximum vibrating amplitude changes to the smaller x position with increasing the frequency.

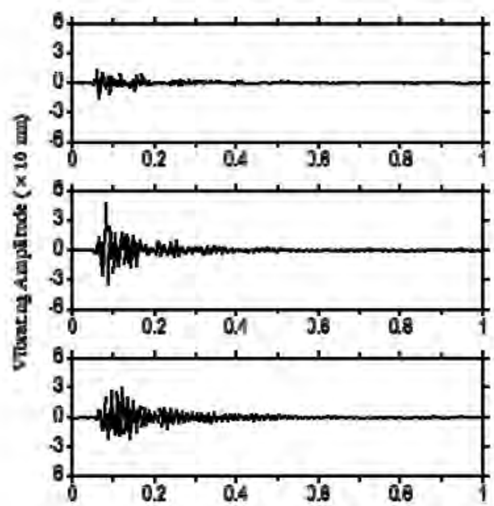

Figure 2. Vibrating amplitude of PAM with time for f = 7 kHz at
x = (a) 16, (b) 27, and (c) 29 mm

Figure 4 show the vibrating amplitude of PAM along x direction for f = (a) 7, and (b) 17 kHz. Position of the maximum amplitude at frequency 7 kHz are observed at 0.06, 0.084, and 0.1204 ms at the distance x = 16, 27, and 29 mm, respectively. For f = 17 kHz are 0.0556, 0.096, and 0.095 ms at x = 15, 24, and 27 mm, respectively. The location of the maximum amplitude is changed to the smaller x direction. This indicates that the resonant frequency is observed increases as the width of the PAM decrease.

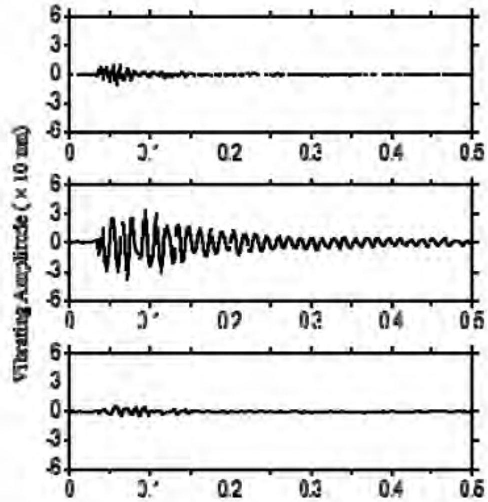

Figure 3. Vibrating amplitude of PAM with time for f = 17 kHz at x = (a) 15, (b) 24, and (c) 27 mm

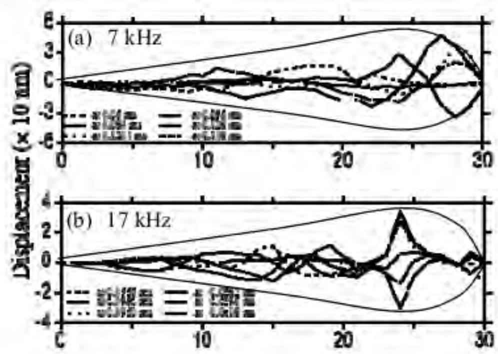

Figure 4. Vibrating amplitude of PAM along x direction for f = (a) 7, and (b) 17 kHz

5. CONCLUSIONS

Prototype auditory membrane can realize the frequency selectivity at f = 5 kHz to 20 kHz. The maximum vibrating amplitude at specific frequency is conformed as the resonant frequency. The resonant frequency at f = 7 and 17 kHz are investigated at x = 27 and 24 mm in 0.0804 and 0.096 ms, respectively.

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