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Analysis of Vibrating Amplitude and Electric Signal on MEMS Device of Artificial Cochlea

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1. INTRODUCTION

There are many causes for hearing impairment. The sensorineural hearing loss and malfunction of the hair cells in the cochlea are one of them. In a medical treatment, the cochlear implants are often used to solve the problem [1]. In our research, we develop an acoustic sensor for a of fully self contained artificial cochlea using MEMS technology. The experiment is carried out for the measurements of vibrating amplitude and electric signal on the electrodes. Comparison between them are made to obtain the basic knowledge and the design data.

2. METHOD

Artificial cochlea in our experiment consists of piezoelectric ABM (Artificial Basilar Membrane) with trapezoidal shape to realize the frequency selectivity and 24 detecting electrodes on the surface of the membrane as shown in Fig.1. The trapezoidal shape is made of plate with trapezoidal channel. The ABM is flexible to be deformed by externally applying acoustic waves. Vibration of the ABM is converted to the electric signal due to the piezoelectric effect. The ABM is made of PVDF film with a thickness of 40 µm. The 24 detecting electrodes are fabricated on the upper side of ABM with thickness of 500 nm. All of the detecting electrode arrays are made of aluminum, which are fabricated using standard photolithography and etching process. The electrodes are numbered from 1 to 24 along x axis. Dimensions of the detecting electrodes are 0.5 × 1 mm rectangle and 0.5 mm in space. The width of ABM in y axis is changed proportionally from 2 to 4 mm along x direction, with the total length of 30 mm.

3. EXPERIMENT

Velocity of the vibration of the ABM is measured using LDV. By integrating the velocity data and analyzed using FFT, the amplitude of the displacement is obtained. The sinusoidal acoustic waves are produced from a speaker (FOSTEX - JAPAN) with magnitude of 75 dBSPL. The frequency is controlled from 1 to 20 kHz, where these frequencies are in the auditory range of human. Distance between speaker and the surface of ABM is set to be 120 mm with a tilt of 45 deg.

The detecting electrodes are used to measure the electric signal on the ABM. The electric signals are measured using an amplifier and a digital oscilloscope. The electric signal data of ABM from amplifier are analyzed using FFT to obtain the voltage. The voltages of each electrode are generated by vibration of ABM due to piezoelectric effect of PVDF. The voltages of detecting electrodes are investigated using various sound pressure level of 60 to 85 dBSPL.

4. RESULTS AND DISCUSSION

Figure 2 show the vibrating amplitude on the centerline along x direction at f = (a)6, (b)9, and (c)12.8 kHz, respectively. The frequencies at the maximum amplitudes correspond to the resonant frequency on the local area of the ABM. The location of the maximum amplitude changes to the smaller x position with increasing the frequency. This corresponds to the fact that the resonant frequency increases as the width of the ABM decreases.

Figure 3 shows the frequency dependence of the vibrating amplitude and electric signal of electrode (a) 2, (b) 14, and (c) 22 at various frequency. The maximum amplitudes of the vibration and electric signal are found at same frequencies. It can be successfully said that the frequency selectivity of the electric signals are induced by the local resonance of the vibration. There are some other peaks which are caused by the generation of the standing wave in x direction due to the edge effect of x direction.

Figure 4 shows the distribution of local resonant frequencies along x for vibration and electric signal. The square and circle show the local resonant frequencies for vibration and electric signal, respectively. The local resonant frequencies decrease with increasing x. Electrode 1 and 24 have the biggest and the smallest local resonant frequencies of 4.4 kHz and 14.4 kHz, respectively.

Figure 5 shows the voltage of ABM with various sound pressure at electrode 2, 14, and 22. The magnitude of electric signals linearly increases as the sound pressure increases. This indicates that the piezoelectric artificial cochlea can change the magnitude of electric signal in response to the sound pressure.

5. CONCLUSION

The resonant frequencies of both the vibration and electric signal are observed at the same frequencies. The resonant frequency of the artificial basilar membrane ranged from 4.4 to 14.4 kHz along x direction of the membrane.

ACKNOWLEDGEMENT

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[1] Graeme Clark, Cochlear Implant: Fundamentals and Applications, Springer Science, New York, 2003.

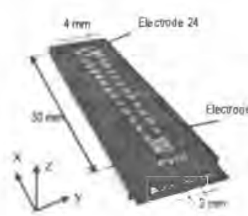

Fig. 1. Schematic of artificial cochlea

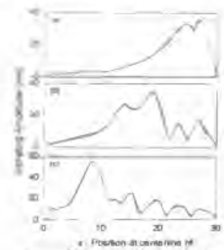

Fig. 2. Vibrating amplitude on centerline along x direction at f = (a) 6, (b) 9, and (c) 12.8 kHz.

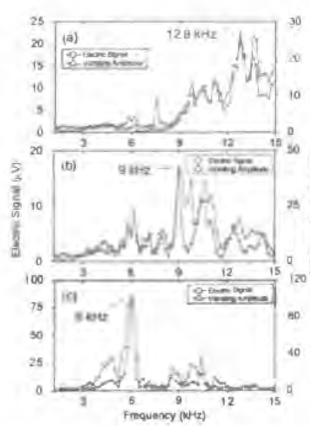

Fig. 3. Frequency dependence of vibrating amplitude and electric signal at electrode (a) 2, (b) 14, and (c) 22.

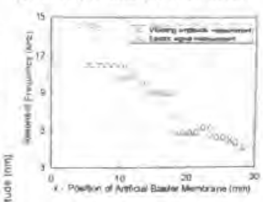

Fig. 4. Local resonant frequency of ABM along x direction.

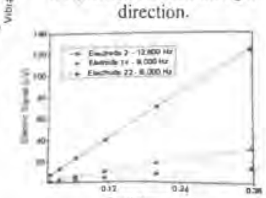

Fig. 5. Magnitude of electric signal at various sound pressure from electrode 2, 14, and 22.

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