

# 3rd East Asian Pacific Student Workshop

*by* Fakultas Teknik

---

**Submission date:** 09-Dec-2019 11:06AM (UTC+0700)

**Submission ID:** 1230238981

**File name:** ent\_Workshop\_Experimental\_Study\_on\_Vibrating\_Characteristics.pdf (909.13K)

**Word count:** 2067

**Character count:** 9719

B.1.5



# 3<sup>rd</sup> East Asian Pacific Student Workshop on Nano-Biomedical Engineering

21 - 22 December, 2009

Engineering Auditorium  
National University of Singapore  
Singapore



Tohoku University



#### **Workshop Committee Office**

Department of Biomedical Engineering, Graduate School of Biomedical Engineering, Tohoku University  
6-6-01 Aoba, Aoba-ku, Sendai 980-8579, Japan  
Tel: +81-22-795-7005 Fax: +81-22-795-5031 E-mail: [aid\\_workshop@nanobme.org](mailto:aid_workshop@nanobme.org)  
URL: [http://www.nanobme.org/3rd\\_student\\_workshop](http://www.nanobme.org/3rd_student_workshop)

#### **Publication Office**

Tohoku University Global COE Programme  
Global Nano-Biomedical Engineering Education and Research Network Centre

Department of Biomedical Engineering, Graduate School of Biomedical Engineering, Tohoku University  
6-6-01 Aoba, Aoba-ku, Sendai 980-8579, Japan  
Tel: +81-22-795-7005 Fax: +81-22-795-5031 E-mail: [secretary@nanobme.org](mailto:secretary@nanobme.org)  
URL: <http://www.nanobme.org>

ISBN 978-4-904157-10-7

## Programme

<b>Monday 21 Dec 2009 Oral Presentations</b>			
Time	Title of Presentation	Speaker	Page
8:30-8:45	Welcome Address		
	<i>Keynote Lecture I</i> Chair: Bai Jianhan (National University of Singapore)		
8:45-9:30	Hemocompatible Biomedical Implants	Prof. Freddy Boey, Nanyang Technological University	3
	<i>Session 1: Biomechanics</i> Chair: Daisuke Tsuchimi (Tohoku University)		
9:30-9:45	Dynamic Characteristics Analysis of Disease Circulatory System with Lumped Parameter Model 1 <sup>st</sup> Report: Heart Valve Disease	Ryu Kôzumi, Tohoku University	6
9:45-10:00	The Change of Intervertebral Disc Rheology with Degeneration Degree	Ya-Wen Kuo, National Taiwan University	8
10:00-10:15	Design of a Micro-Tensile Tester for Probing Smooth Muscle Cell Viscoelasticity	C. W. Chung, National University of Singapore	12
10:15-10:30	A Mathematical Model of the Regulation of Active Stress Production in Gastrointestinal Smooth Muscle	Vivika Galandrian, National University of Singapore	16
10:30-11:00	Tea Break & Poster Session		
	<i>Session 2: Biomechanics</i> Chair: Kantale Chaitanya Sushir (National University of Singapore)		
11:00-11:15	Experimental Observation of Behavior of Neutrophil-like HL60 Cells on Oriented Endothelial Cells	Haruka Uramura, Tohoku University	22
11:15-11:30	Localized Phosphorylation of Paxillin in Endothelial Cells in Response to Cyclic Stretch	WeiJing Huang, Tohoku University	24
11:30-11:45	Cyclic Stretch Increases Matrix Metalloproteinase-9 Production of Macrophages under Hypoxia	Koki Oya, Tohoku University	26
11:45-12:00	Basic Study on Sensing Mechanism of Substrate Elasticity by Cells: Effects of Substrate Elasticity and Thickness on the Behavior of Rat Aortic Smooth Muscle Cells	Naohiko Matsui, Nagoya Institute of Technology	28
12:00-13:20	Lunch Break & Poster Session		
	<i>Keynote Lecture II</i> Chair: Ramesh Rajaji (National University of Singapore)		
13:20-14:05	Micro-Fabrication Factory of Complex Tissues	Prof. Henry Yu, National University of Singapore	32
	<i>Session 3: Bio-MEMS</i> Chair: Hsiao-Feng Chieh (National Cheng Kung University)		
14:05-14:20	Development of Si Neural Probe with Microfluidic Channel for Drug Delivery	Sochiro Kanno, Tohoku University	36
14:20-14:35	Development of Pillar Electrode Array for Retinal Stimulation with High Efficiency	Hiroaka Takeshita, Tohoku University	38
14:35-14:50	Electrical and Mechanical Characteristics of Si Double-sided Neural Probe and Its Application to <i>in-vivo</i> Recording	Sanghoon Lee, Tohoku University	40
14:50-15:05	Measurement on Electrophoretic Flow Dynamics of $\lambda$ DNA in Nanochannel	Satoshi Uekata, Osaka University	42
15:05-15:20	Experimental Study on Vibrating Characteristics of Piezoelectric Artificial Cochlea in Air and Liquid	Hiro Tohujaya, Osaka University	44
15:20-16:00	Tea Break & Poster Session		
	<i>Session 4: Biomechanics</i> Chair: Takashi Saito (Tohoku University)		
16:00-16:15	Analysis of the Frequency Characteristics of Normal Middle Ears using a Sweep Frequency Impedance Meter	Naoya Seshimo, Tohoku University	48
16:15-16:30	Measurement of Human Skin Condition using a Haptic Sensor	Daisuke Tsuchimi, Tohoku University	50
16:30-16:45	Monitoring Bone Cement Leakage by Cone CT Scanning	Chun-Kai Chiang, National Taiwan University	52
16:45-17:00	Surface Modified Upconversion Nanoparticles for Biomedical Applications	Suanderya Nagarajan, National University of Singapore	54
	Banquet		



## Experimental Study on Vibrating Characteristics of Piezoelectric Artificial Cochlea in Air and Liquid

Harto Tanujaya<sup>\*1)</sup>, Hirofumi Shintaku<sup>1)</sup>, Takayuki Nakagawa<sup>2)</sup>, Dai Kitagawa<sup>1)</sup>, Sayoyuki Kawano<sup>1)</sup>, and Juichi Ito<sup>2)</sup>

1) Department of Mechanical Science and Bioengineering, Graduate School of Engineering Science, Osaka University, Japan

2) Department of Otolaryngology, Head and Neck Surgery, Graduate School of Medicine, Kyoto University, Japan

E-mail: harto@mbox.me.es.osaka-u.ac.jp



### Abstract

In this paper, we report the basic vibrating characteristics of the piezoelectric artificial cochlea which consists of piezoelectric and trapezoidal membrane. The width of the membrane is linearly changed from 2.0 to 4.0 mm and the length is 30 mm. The geometry is theoretically designed to realize the frequency selectivity from 0.7 to 3.6 kHz in the lymph liquid. The measurement on the vibrating characteristics is conducted to clarify the effect of the fluid-structure interaction. Consequently, it is found that the fluid with the higher density decreases the resonant frequency of the membrane by increasing the effective mass for the vibration.

Keywords: Artificial cochlea, Frequency selectivity, Vibration, Resonant frequency

### 1. Introduction

Cochleae are one of the important organs for hearing in the human and animals. In particular, children who have some problems in their hearing get into trouble in their growth and the quality of life.

In this research, we developed a novel piezoelectric artificial basilar membrane for a fully implantable and self contained artificial cochlea. This artificial basilar membrane can detect the frequency and magnitude of acoustic waves. To clarify the vibrating characteristics of the membrane, we carried out the some experiments. The experiments are divided into the two parts. First experiment is the measurement of the vibrating characteristic in the atmosphere and the second one is that in the silicone oil. Comparisons are made for obtaining the basic knowledge and the design data.

## 2. Method

### 2.1. Mechanical model

The designing concept of the developed device is mimicking the shape of the basilar membrane in biological cochleae to realize the frequency selectivity as shown in Fig.1. Based on the previous work by von Békésy, it is possible that the cochlea can be modeled as a unrolled geometry to analyze the basic characteristics, in spite of the rolled shape of biological cochlea [1,2]. Therefore, the device is designed as a straight manner.

The device consists of an artificial basilar membrane made of a piezoelectric material and a fluid channel under the membrane. To realize the frequency selectivity, the shape of the membrane is designed to be trapezoidal. As a model of scala tympani, the fluid channel is designed. The membrane could be assumed as a thin plate and the oscillatory dynamics of the artificial basilar membrane can be predicted using a thin plate bending model with the plane stress conditions [3].

The artificial basilar membrane is made of polyvinylidenedifluoride (PVDF) (KUREHA, JAPAN) with the thickness of 40  $\mu\text{m}$ . The Young's modulus and the density of PVDF are 4 GPa and 1790  $\text{kg/m}^3$ , respectively. The trapezoidal shape is designed as the length of 30 mm along x direction with the varying width from 2.0 to 4.0 mm. The artificial basilar membrane is placed on the fluid channel during the both experiment. Design of the fluid channel is 17 and 4 mm in width and depth, respectively.

The 24 electrodes are fabricated on the upper surface of the artificial basilar membrane. These electrodes are used to measure the electric signal generated by the piezoelectric effect of PVDF.

### 2.2. Experiment

For both experiments, the acoustic waves are produced by a speaker (FOSTEX, JAPAN) with the magnitude of 75 dB SPL and applied through the atmosphere to the upper side of the artificial basilar membrane. The vibrating amplitude is measured using laser Doppler vibrometer (LDV). In the second experiment, the fluid channel is filled with silicone oil with the viscosity and density of  $1.75 \times 10^{-3}$  Pa s and 873  $\text{kg/m}^3$ , respectively. The frequency of acoustic waves is controlled from 1 to 20 kHz which are in the range of human auditory.

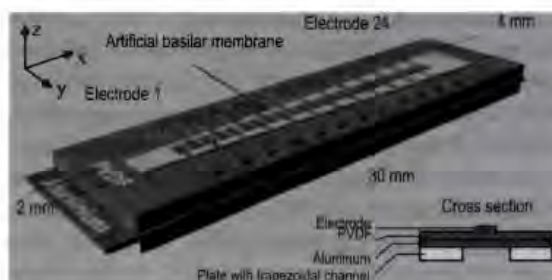


Fig. 1. Cochlear model



### 3. Results and Discussion

Figure 2 shows the vibrating amplitudes of the artificial basilar membrane in the air at  $f =$  (a) 6, (b) 9, and (c) 12.8 kHz. The location of the maximum amplitude changes to the smaller  $x$  with increasing the frequency. This indicates that the resonant frequency increases as the width of the artificial basilar membrane decreases.

Figure 3 shows the vibrating amplitudes of the artificial basilar membrane in the liquid at  $f =$  (a) 1.7, (b) 2.9, and (c) 4 kHz. These vibrating amplitudes have the same trend with measurement in the air in Fig. 2, where the location of the maximum amplitude changes to the smaller  $x$  as the frequency increases. The differences between them are found in the resonant frequencies and the vibrating amplitudes. Results in the air have higher resonant frequency and larger vibrating amplitude than those in the liquid. These differences are considered as the result of the fluid-structure interaction. These phenomena of the frequency dependence have similarities with those of the biological basilar membranes.

Figure 4 shows the vibrating amplitude of the artificial basilar membrane in the air and liquid at various frequencies. Figure 4 (a) ~ (c) show results in the air at  $x =$  (a) 27, (b) 16, and (c) 5 mm and Fig. 4 (d) ~ (f) show these in the liquid at  $x =$  (d) 26, (e) 20, and (f) 4 mm. The frequencies at the peaks are considered as the resonant frequency at the local area of the artificial basilar membrane. These resonant frequencies are decreased with increasing the width along  $x$  direction.

Figure 5 shows the resonant frequencies in the air and liquid at various  $x$ . The resonant frequencies in the air are higher than that in the liquid. This graph shows that the range of the local resonant frequency in the air and liquid are from 4.4 to 14.4 kHz and 1.7 to 4 kHz, respectively.

### 4. Conclusion

Artificial cochlea can realize the frequency selectivity at the range of 4.4 to 14.4 kHz in the air and 1.7 to 4 kHz in the silicone oil. In this experiment, design of the artificial cochlea is relatively large for implantation into the cochlea, but this problem can be solved by the use of the microfabrication technology.

### Acknowledgements

Harto Tanujaya acknowledges the support of Ministry of National Education Republic of Indonesia and COE Program Osaka University. Special thanks are due to Dr. Yoichi Kagaya for his help when fabricate the prototype in the first experiment.

### References

- [1] von Békésy G, *Experiments in Hearing*. McGraw-Hill, New York, 1960.
- [2] Wever EG, Lawrence M. *Physiological Acoustics*. Princeton, New Jersey, 1954.

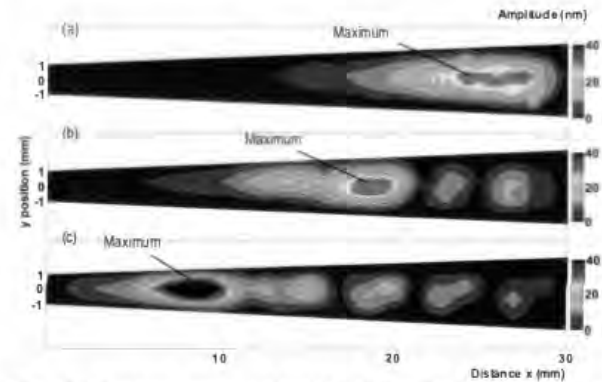


Fig. 2. Contour maps of artificial basilar membrane in air at  $f =$  (a) 6, (b) 9, and (c) 12.8 kHz

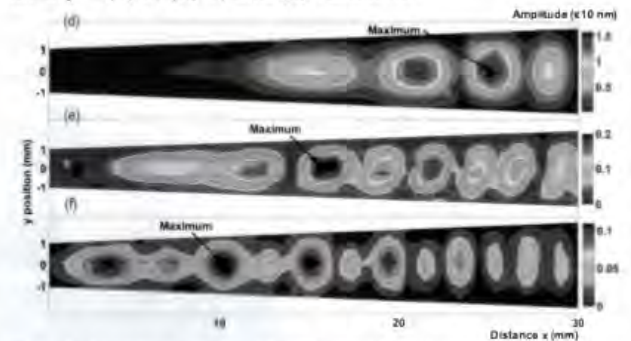


Fig. 3. Contour maps of artificial basilar membrane in silicone oil at  $f =$  (a) 1.7, (b) 2.9, and (c) 4 kHz

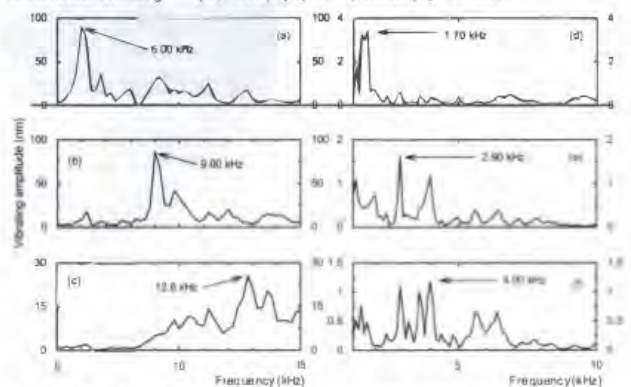


Fig. 4. Vibrating amplitude of artificial basilar membrane in air at  $x =$  (a) 27, (b) 16, and (c) 5 mm, and in silicone oil at  $x =$  (d) 26, (e) 20, and (f) 4 mm

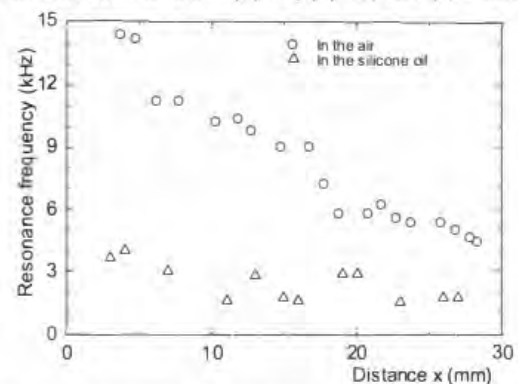


Fig. 5. Resonant frequency of artificial basilar membrane in air and silicone oil at various  $x$

# 3rd East Asian Pacific Student Workshop

---

## ORIGINALITY REPORT

---

3%

SIMILARITY INDEX

2%

INTERNET SOURCES

2%

PUBLICATIONS

2%

STUDENT PAPERS

---

## PRIMARY SOURCES

---

1

[www.science.gov](http://www.science.gov)

Internet Source

1%

---

2

Mehrara, M., M. J. Nategh, and H. M. Naeeni.  
"Analytical solution to the elastic bending of long  
and rectangular thin plate resting on rubber  
foundation", Proceedings of the Institution of  
Mechanical Engineers Part C Journal of  
Mechanical Engineering Science, 2012.

Publication

1%

---

3

[133.1.54.170](http://133.1.54.170)

Internet Source

1%

---

4

[Submitted to University College London](#)

Student Paper

1%

---

Exclude quotes On

Exclude matches < 1%

Exclude bibliography On