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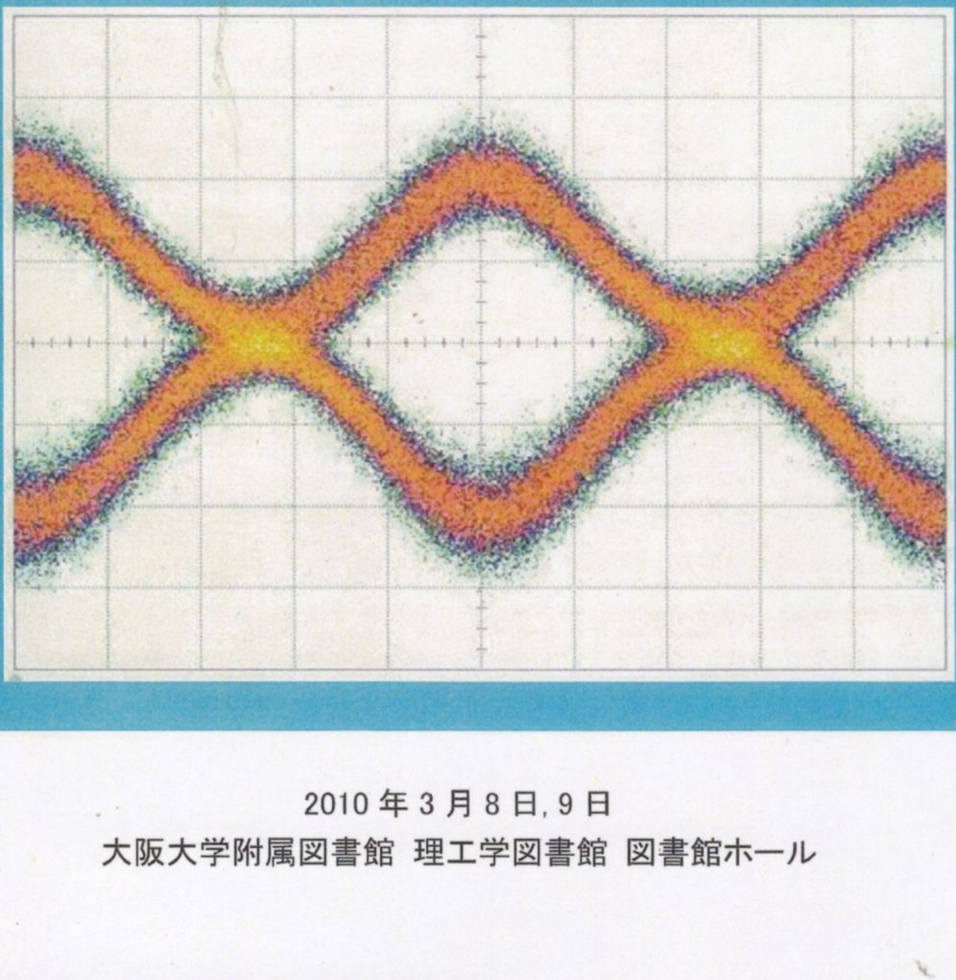
# 第5回非線形テクノサイエンス講演会

## NONLINEAR TECHNO-SCIENCE



2010 年 3 月 8 日, 9 日
大阪大学附属図書館 理工学図書館 図書館ホール

共催 工学研究科 電気電子情報工学専攻
工学研究科 機械工学専攻
基礎工学研究科 未来研究ラボシステム「非線形ダイナミクス」
光科学センター

## 「第5回非線形テクノサイエンス講演会」実行委員会

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# 第5回非線形テクノサイエンス講演会 プログラム

2010 年 3 月 8 日, 9 日(大阪大学附属図書館 理工学図書館 図書館ホール)

**3 月 8 日(月)**

9:30 挨拶

9:40−11:00 (座長:川野聡恭)

1A-1 Measurement of Electrically Evoked Auditory Brainstem Response Using Bionic Auditory Membrane for Cochlear Implants 新宅博文, 稲岡孝敏, 中本洋平, 林昌秀, 加賀谷洋一, 中川隆之, 伊藤壽一, 川野聡恭(基)

1A-2 電場を印加したナノ流路における電気浸透流と長鎖DNAの流動特性
上原聡司, 新宅博文, 川野聡恭(基)

1A-3 A Study on Vibration Dynamics of Bionic Auditory Membrane for Artificial Cochlea
Harto Tanujaya, Hirofumi Shintaku, Satoyuki Kawano(基)

1A-4 電極/電解質積層界面におけるプロトン流動のモデル
土井謙太郎, 細沢裕彰, 橋爪裕基, 川野聡恭(基)

11:00−11:15 (休憩)

11:15−12:15 (座長:村上匡且)

1A-5 チャネル内相互作用が RZ 光パルスの位相に与える影響 丸田章博, 冨岡省吾(工)

1A-6 超高強度レーザーと様々な電子密度ターゲットにおける高速電子生成に関する研究
陰岩直哉, 羽原英明, 田中和夫(工)

1A-7 超高強度レーザーと物質との相互作用 -クーロン爆発とその応用- 村上匡且(レ)

12:15−13:15 (昼休み)

13:15−14:15 【基調講演】 (座長:田中和夫)

1B-1 太陽プラズマにおける爆発的増光現象の物理 柴田一成(京都大学)

14:15−14:30 (休憩)

14:30−15:30 (座長:中澤康浩)

1B-2 フラストレート三角・カゴメ格子磁性体での磁性 中澤康浩, 山下智史(理)

1B-3 Phase Field 法を用いた金属中の水素と欠陥の相互時間発展解析
森英喜, 君塚肇, 尾方成信(基)

1B-4 鉄中水素拡散における非線形ダイナミクス
君塚肇, 森英喜, 尾方成信(基)

15:30－16:50　　(座長:丸田章博)

1B-5　生物ネットワークの統計力学:「複雑に相互作用するたくさんの違うモノ」をどう理解するか？　時田恵一郎(サ, 理, 生)

1B-6　脊髄誘発磁場分析における磁場源の考察　佐藤真(基)

1B-7　Mathematical modelings for tumor invasion and numerical simulations (腫瘍形成モデリングと数値シミュレーション)　Mahemuti Rouzimaimaiti, Takashi Suzuki(基)

1B-8　形状記憶性をもつ熱弾性体に関する Pawlow モデル　田崎創平(基)

17:00－　　**懇親会** (銀杏会館 2 階　銀杏クラブ)

## 3月9日(火)

9:30－11:10　　(座長:井上義朗)

2A-1　撹拌槽内の3次元層流混合機構　井上義朗(基)

2A-2　回転翼撹拌槽内における孤立混合領域の可視化と構造解析　橋本俊輔, 石川雄基, 中田義和, 伊藤寛之, 井上義朗(基)

2A-3　イオン液体中における 9,9'-ビアントリルの電荷分離反応との溶媒和ダイナミクス　長澤裕, 大石章人, 伊藤剛志, 安田雅一, 村松正康, 石橋千英, 伊都将司, 宮坂博(基)

2A-4　Ab initio 分子軌道法に基づく励起子表示と量子マスター方程式法による動的第一超分極率の時空間解析法　岸亮平, 藤井宏旭, 南拓也, 高橋英明, 中野雅由(基)

2A-5　結晶表面に形成した微細パターンの表面拡散による形態変化　須藤孝一(産)

11:10－11:25 (休憩)

11:25－12:25 【特別講演】　　(座長:杉本信正)

2A-6　Statistical appreach to bifurcations in subcritical high-dimensional dynamical systems　Paul Manneville (Ecole Polytechnique)

12:25－13:30 (昼休み)

13:30－15:30　　(座長:梶島岳夫)

2B-1　平面クエット系における乱流－層流吸引域境界上の周期軌道の不安定多様体と乱流遷移　河原源太, 松村篤(基)

2B-2　下壁面熱流束振動により生じる正方容器内熱対流場の共鳴現象　石田秀士, 吉村英朗, 河原源太(基)

2B-3　半無限円柱ジェットの対流・絶対不安定性と崩壊過程　吉永隆夫, 辻川寛(基)

2B-4　両端が閉じた管の中の非線形熱音響タコニス振動のシミュレーション　稲垣剛司, 杉本信正(基)

# A Study on Vibration Dynamics of Bionic Auditory Membrane for Artificial Cochlea

Harto Tanujaya, Hirofumi Shintaku, and Satoyuki Kawano

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**ABSTRACT**

The cochlea in the inner ear is an important organ for hearing. In this work, we develop a novel artificial cochlea using P(VDF-TrFE) to realize the fully implantable system for sensorineural hearing loss by microfabrication and thin films technologies. The device consists of a piezoelectric membrane made of P(VDF-TrFE) fabricated on a silicon substrate and discrete electrodes on the surface. The membrane converts mechanical deformation induced by acoustic waves to electric signals due to the piezoelectric effect. The geometry of the membrane is designed to realize the frequency selectivity at the range of 500 ~ 5,000 Hz. The experiment is carried out to investigate the vibrating characteristics of the membrane. To model the cochlear duct, the device is mounted on a substrate with a fluid channel filled with silicone oil. The results show that the resonant frequency is changed along the position due to the varying local mechanical boundary condition governed by the geometrical configuration. Furthermore, based on the relationship between position and the resonant frequency, it is found that the device can realize the frequency selectivity at the range of 1.45 ~ 10.65 kHz.

Keywords: Artificial cochlea, Frequency selectivity, P (VDF-TrFE), Vibration, Fluid-structure interaction

## 1. Introduction

Hearing is very important for human to communicate with others. In particular, children who have problem with their hearing get into trouble in their growth and the quality of life. In normal hearing, sound waves are converted into vibrations of basilar membrane (BM) in the inner ear. The hair cells on BM convert the sound wave into electric signals which are transferred to the brain via auditory nerve [1][2]. At present, there are several prostheses, i.e. cochlear implant, to help human who have hearing impairment that caused by malfunction of the hair cells in the cochlea. These cochlear implants consist of two parts; implantable stimulating electrodes (receiver and electrodes) and an extracorporeal device (batteries, processor and microphone). In our research we develop a fully implantable and self contained artificial cochlea using the piezoelectric membrane made of P(VDF-TrFE). The basic vibrating characteristics of the membrane are analyzed by applying sinusoidal acoustic waves to the device.

## 2. Method

Figure 1 shows the artificial cochlea developed in this work. The artificial cochlea consists of a trapezoidal and piezoelectric membrane and 24 discrete electrodes on it. The membrane, which is named as an artificial basilar membrane, is vibrated by applying acoustic wave. The vibration is converted into the electric signal due to the piezoelectric effect. Because the width of the membrane is varied along the longitudinal direction, the local resonant frequency of the membrane changes as the position. As the result, a certain electrode has a specific frequency, where it gives the relatively large electric signal. Thus, the frequency of the acoustic wave can be detected based on the position of the resonance and the magnitude of the electric signals. To detect the

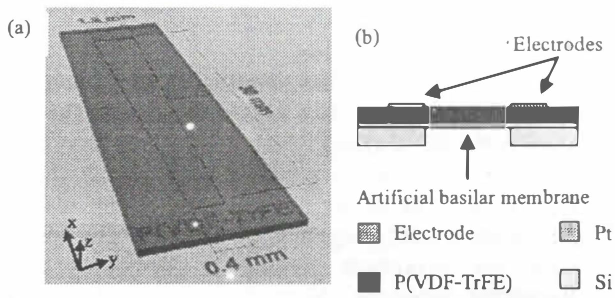


Fig. 1 Schematic of artificial cochlea (a) three dimensional view and (b) cross sectional view

frequency of acoustic wave range from 500 to 5,000 Hz by the device, the width of the membrane is linearly changed from 0.4 to 1.2 mm along $x$, whereas the length is designed to be 30 mm. The artificial cochlea is fabricated based on MEMS (Microelectromechanical Systems) and thin film technologies. The fabrication is started from the deposition of Pt film with the thickness of 460 nm on Si substrate. The piezoelectric material of P(VDF-TrFE) is formed on the Pt electrode with the thickness of 3.5 μm. The discrete electrodes are fabricated on the surface. To make the membrane flexible, the Si substrate is etched from the backside using Deep-RIE (Reactive Ion Etching).

The vibrating characteristics of the membrane are measured with mounting the device on a substrate with a fluid channel. The fluid channel is a model of cochlea duct and is filled with silicone oil of a model of lymph liquid. The sinusoidal acoustic wave at 75 dBSPL is applied to the artificial cochlea. Distance between speaker and artificial cochlea is 150 mm with tilt angle of 60 deg. The frequency is controlled from $f$ = 1.0 to 15 kHz, where the range is in the human hearing. The vibrating amplitude is measured using Laser Doppler Vibrometer (LDV).

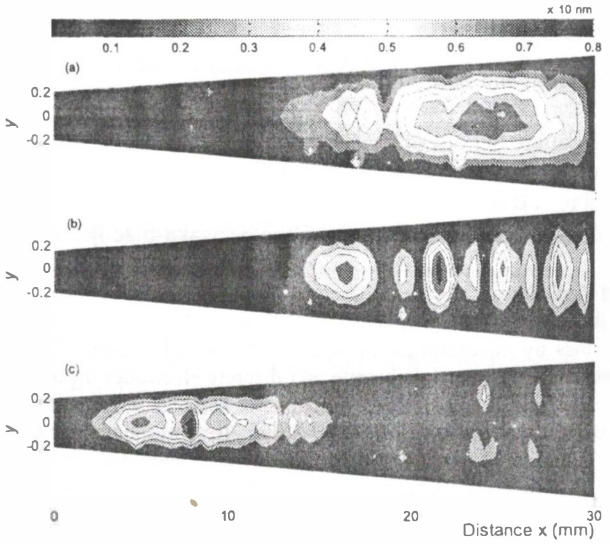


Fig. 2 Contour maps of the vibrating amplitude of artificial basilar membrane at $f$ = (a) 1.45, (b) 3.95, (c) 10.6 kHz.

### 3. Results and discussion

Figure 2 shows the amplitude distribution at (a) 1.45, (b) 3.95 and (c) 10.6 kHz, respectively. The results show different vibrating behavior at each frequency. The amplitude increases at a certain local place, where the resonance is occurring. The places of the maximum amplitude at each frequency are different. The position $x$ with the maximum amplitudes decreases as the frequency increases. Note that the local maximum amplitudes are considered as the results of the standing waves in $x$ direction.

Figure 3 shows the frequency dependence of the vibrating amplitude at $x$ = (a) 28.5, (b) 13.9 and (c) 5.8 mm, respectively. The amplitudes at different places show clear peaks at different frequencies. The frequency at the peak is considered as the resonant frequency at the local area of the membrane. The value seems higher at smaller $x$, i.e. the narrower area. This is corresponding to the results in Fig. 2. This feature is owing to the local mechanical boundary condition which is determined by the shape of the membrane. That is, the wavelength of the acoustic wave is affected by the width of the membrane.

Figure 4 shows the resonant frequency at various position $x$. The resonant frequency is ranged from 1.45 to 10.65 kHz and decrease as $x$. Compared with the theoretically predicted values of the frequency of 0.5~5 kHz, the measured ones are higher. The further discussion on the underestimation in the frequency should be carried out by increasing the number of the experiments.

### 4. Concluding remarks

Frequency selectivity of the artificial basilar membrane is confirmed at the range of 1.45 ~ 10.65 kHz. The resonant frequency increases as the width of the membrane decreases. The theoretically predicted value of the frequency is lower than the experimental measurement.


### Acknowledgement

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### References


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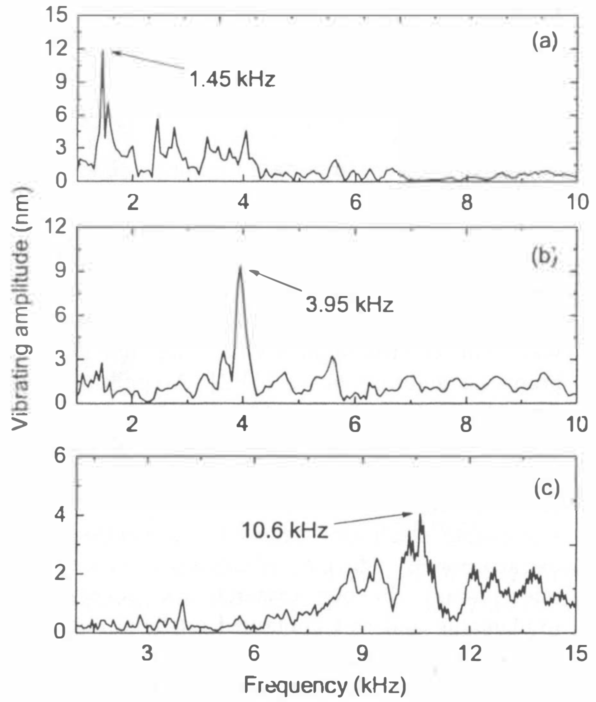


Fig. 3 Frequency dependence of vibrating amplitude of the artificial basilar membrane at $x$ = (a)28.5, (b)13.9, (c)5.8 mm.

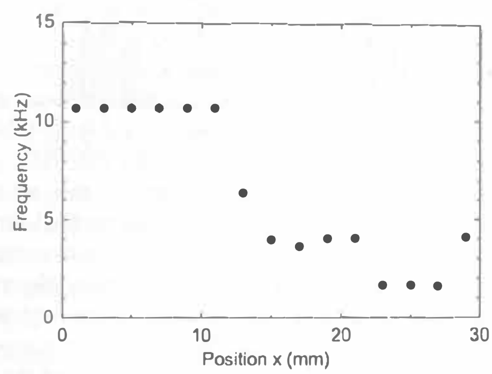


Fig.4 Relationship between position $x$ and resonant frequency.