Piezoelectric Transducer for Hearing Aid Using PZT Thin Film

Hidehiko Yasui, Minoru Kurosawa, Takeshi Morita, Takefumi Kanda, and Toshiro Higuchi

Department of Precision Machinery Engineering, Graduate School of Engineering, The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

Abstract: We fabricated a piezoelectric transducer using a PZT thin film deposited by a hydrothermal method in order to investigate the ability for earphone. The fabricated transducer had a bimorph construction and form a diaphragm for an earphone of hearing aid. The base material was a titanium foil from 5 to 20 μm thick. Both sides of the titanium, PZT thin films 10 μm thick was deposited. Diameter of the transducer was 6 mm. Using a 5 μm titanium base, we found the transducer was able to produce 61 dB (0 dB = 2 × 10⁻⁵ Pa) per 1.3 Vrms driving voltage below the fundamental resonance frequency.

INTRODUCTION

A hearing aid is important and simplest tool for people who have obstacle for hearing ability. In the future, human population will increase. It follows that the aged will increase. Accordingly, the number of people who have obstacle for hearing ability will also increase. Moreover, a hearing aid is useful for speech production of profoundly hearing-impaired children(1). The PZT material can produce sounds efficiently from electrical signal. The thin film technology is suitable for fabrication of small transducer which is worn in ear. Especially, a hydrothermal method has merits such as thick film fabrication and possibility of deposition on round surface. Therefore, we propose to fabricate a high performance earphone for hearing aid using the PZT thin film deposited by hydrothermal method.

STRUCTURE AND PRINCIPLE

The earphone is actuated by the PZT thin film deposited by the hydrothermal method(2). The deposit process is carried out in a solution of Pb²⁺, Zr⁴⁺ and Ti⁴⁺ containing KOH, in an autoclave. This process was composed of two repetitional reaction. In each reaction, the autoclave was kept at 140°C (first reaction) or 120°C (second reaction) for 24 hours. In these processes, 10 μm thick PZT thin film was deposited.

Diameter of the titanium base was 10 mm. The thicknesses of titanium were three kinds, 5, 10, 20 μm. Fabrication process of the transducer was two steps. First step was depositing PZT film by the hydrothermal process. Next step was vacuum deposition of driving electrodes. Gold was used for the electrodes. Each step is indicated in Fig. 1. With these processes, the transducers form bimorph type diaphragms.

The bimorph transducer was fixed at a circular edge by two silicone rubber O rings as illustrated in Fig. 2. The inner and outer diameters of the O ring were 5 and 7 mm. Silver paste was painted on the O ring in order to feed the signal. The electric signal is transduced to the mechanical vibration at the diaphragm. The sound pressure level is proportional to the dilatation of the closed space between the diaphragm and an eardrum.

![FIGURE 1. Tow steps of fabrication process: the titanium plate (left); after the first step, PZT film was deposited (center); then gold electrode is deposited (right)](image)

![FIGURE 2. The way to fix the diaphragm with two silicone rubber O rings](image)
EXPERIMENTS

To evaluate the transducer, we measured the vibration amplitude of the diaphragm and sound pressure. The vibration amplitude of the transducer at the center was measured using a laser Doppler vibrometer. For example, the amplitude-frequency characteristic of a 10 μm titanium base diaphragm is shown in Fig. 3. The driving voltage was 1.24 Vrms. The resonance frequency was 15.6 kHz. The peak at 11.4 kHz was not resonance, because diaphragm did not form vibration mode.

We used Ear Simulator Type 4157 (B&K) for the measurement of sound pressure. Using this instrument, we can test an earphone under the acoustic load conditions similar to inserting the earphone into an actual human ear. One example of the frequency response about a transducer of 10 μm titanium is shown in Fig. 4. The driving voltage was 1 Vrms. The resonance frequency was 3.3 kHz. Due to the characteristic of the Ear Simulator, the response had a peak near 13 kHz. The sound pressure level at 500 Hz increased in proportion to the driving voltage.

CONCLUSION

We investigated the possibility of the piezoelectric transducer for hearing aid using PZT thin film. The PZT thin film was deposited by the hydrothermal method. Using 5 μm titanium base, sound pressure level was about 60 dB per 1.3 Vrms with the ear simulator. However, required sound pressure level of an earphone is about 110 dB per 1.3 Vrms. We can fabricate various shaped transducer with the hydrothermal method. Therefore, the diaphragm shape should be optimized as well as PZT film quality to improve the performance of the transducer.

ACKNOWLEDGMENTS

The authors would like to thank Mr. H. Komura, Mr. T. Iwakura and Mr. T. Ohtani of Rion Co., Ltd., for their cooperation in valuable advices and technical support.

REFERENCES