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Effect of substrate dimensions on PZT/PZT piezoelectric microphone

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1. Introduction

COVID-19 has been classified as a class 5 infectious disease, and mask are still being used in medical institutions. However, the decrease in sound pressure level caused by wearing masks hinders smooth communication during conversation[1]. Therefore, we developed a wearable microphone using (Pb(Zr,TiO_3:PZT/PZT) piezoelectric film (hereafter referred to as PZT/PZT) that is not affected by the decrease in sound pressure level due to mask-wearing because the microphone is used by fixing to the mask frame and pharynx.

2. Simulation using the finite element method

2.1 Sample of Developed microphone

In this study, we use the finite element method system called "Femtet" provided by Murata Software to determine the resonance frequencies. First, we calculated the resonance frequencies of the developed microphone. The developed microphone, as shown in **Fig. 1**, consists of a vibrating plate (SUS304) measuring 6.5 × 23 × 0.08 mm, a piezoelectric film (PZT/PZT using the sol-gel composite method) measuring 4.5×15×0.08 mm, and upper electrode (silver paste) measuring 2.5×12×0.01 mm. For the simulations, the material constants of the vibrating plate and upper electrodes were directly used from Femtet. However, in previous study, the PZT/PZT that is made by sol-gel composite method was found to be 5.8 kg/m^3[3], as it is lower than that of conventional PZT, so we changed the material constants of the density. Additionally, we assumed that the piezoelectric film would be fixed to the mask frame (**Fig. 2**), and thus, both ends of the vibrating plate were fixed. The result of the simulations under these conditions are shown in **Fig. 3**. Resonance frequency of developed microphone is 47 kHz, it is evident that the developecad microphone has resonance frequencies that are not properly design for human voice.

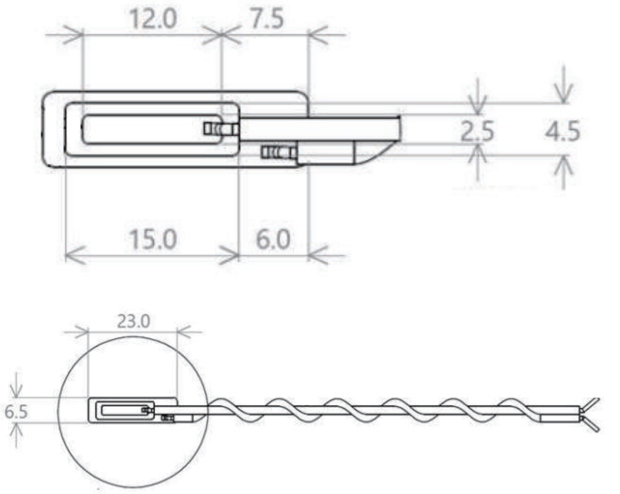

Fig. 1 Dimensions of the developed microphone

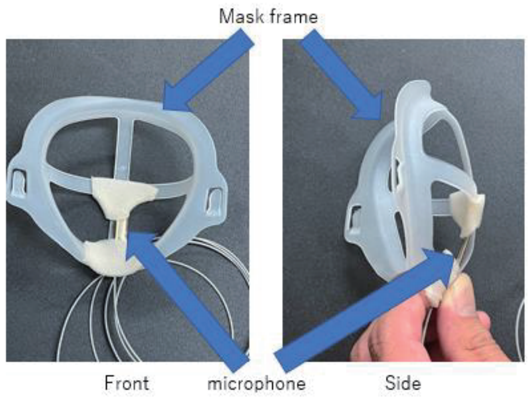

Fig. 2 Microphone fixed to mask frame

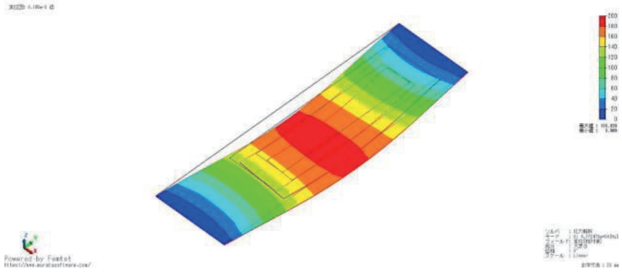

Fig. 3 The simulation result of developed microphone

2.2 VCV articulation perception experiments

We conducted VCV articulation perception experiments using the developed microphone. As a result of the experiments, the developed microphone showed significant attenuation in the second and third formant frequencies compared to typical lapel microphone, as illustrated in **Fig. 1.** We think that the cause of this attenuation is the improper design of the microphone's resonance frequencies, leading us to conclude that size optimization of the microphone is necessary. Therefore, the purpose of this study is to perform simulations for the size optimization of the

PZT/PZT piezoelectric microphone.

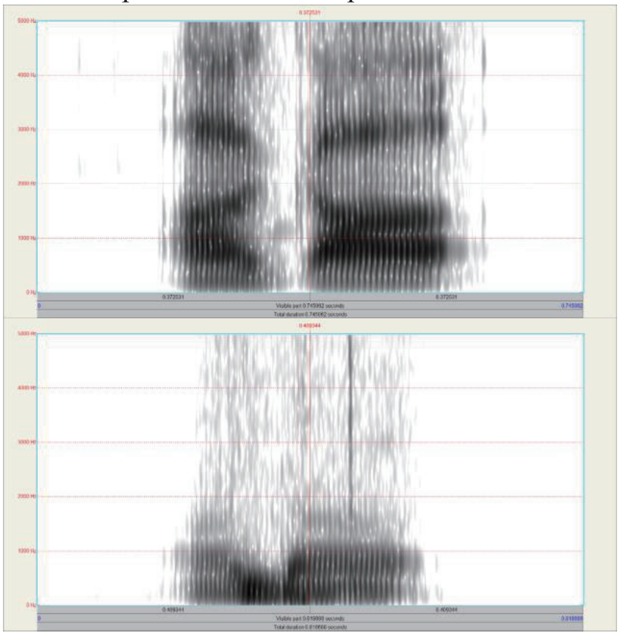

Fig. 4 The spectrogram of the VCV audio data (upper: pin mic, lower: developed mic)

2.3 Consideration for optimization

Table I is the simulation results of resonance frequency for varying the size of the microphone, and * in **Table I** mean that piezoelectric film and upper electrode are in the center of the vibrating plate. First of all, we considered changing the width of the microphone. The resonance frequency could be reduced by changing the width of the microphone, and narrowing it was particularly effective. Next, we considered lengthening the length of the microphone. By lengthening the microphone, the ideal resonance frequency could be designed, but as shown in **Fig. 5**, the maximum displacement was away from the piezoelectric film. It was also found that Narrow* has smaller resonance frequency than Narrow, and that the arrangement of the piezoelectric film and upper electrode also affects the design of the resonance frequency. Based on these, we designed a microphone size (Idea*) with ideal resonance frequency. **Fig. 6** shows the simulation results of Idea*.

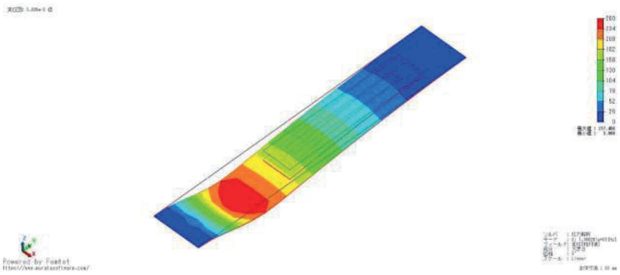

Fig. 5 The simulation result of Long microphone

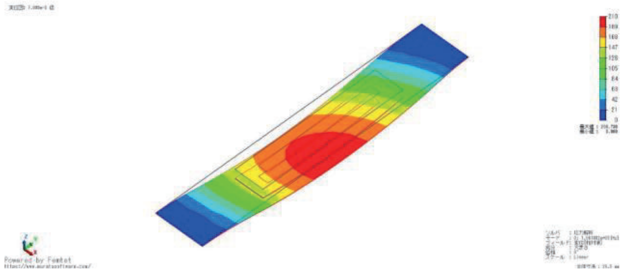

Fig. 6 The simulation result of Idea* microphone

Table I The resonance frequency of various size microphone

Microphone (size of vibrating plate)	Resonance frequency [kHz]
Developed (6.5×23× 0.05)	47
Narrow (5× 23 × 0.05)	35
Narrow*	81
Wide (12×23×0.05)	11
Long (5× 30 × 0.05)	1.5
Ideal*(5×28.5× 0.05)	1.5

3. Conclusion

In this study, we aimed to optimized the size of the PZT/PZT piezoelectric microphone through finite element method simulations. The simulation results revealed that the resonance frequencies of the developed microphone were not well designed within the frequency range of the sound. Furthermore, by varying the size, we were able to design microphone with the desired resonance frequency. In the future, we plan to fabricate a microphone with the size obtained from the simulations and conduct performance verification.

References

1) M. Kitajima, M. Kaetsu, Y. Ino, JJANS **11**, 48 (2012) [in Japanese]

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