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PZT/PZT Piezoelectric Device for Biological Signal Measurements

生体信号観測用 PZT/PZT 圧電デバイスの開発

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1. Introduction

In recent years, home health monitoring for early detection of health problems has been a hot topic and health nonitoring chair with sensors could be a useful tool because it is stressfree. However, the signal to noise ratio (SNR) requirement of sensors is very demanded. Typical biological signal measurement, polyvinylidene difluoride (PVDF) sensors are used, even though SNR of PVDF is not high enough due to ringing effect. Development of new sensors for biological signal measurement has been desired.

Flexible sol-gel composite film sensor was developed for high temperature non-destructive testing applications.[1)] Sol-gel composite was made from the mixture of ferroelectric powders and dielectric sol-gel solution and flexibility was accomplished due to the porosity existed in the piezoelectric film. Sol-gel composite piezoelectric film sensor has high SNR and high sensitivity for movement so that it was expected that it was possible to measure biological signal. In the previous study, $Pb(Zr,Ti)O_3$ (PZT)/PZT piezoelectric film sensors, which were made by PZT powders and PZT sol-gel solution, succeeded in pulse wave measurement from the wrist.[2)] However, it is difficult to ask the drivers to wear the wirstband with sensors. In addition, piezoelectric films in the past study were made by manual spray coating and it was difficult to achieve repeatability and mass productivity.

In this study, PZT/PZT piezoelectric film sensors were made by automatic spray coating method. Also biological signal was measured by sensors embedded in the chair. Measurements by Electrocardiogram (ECG) and respiration sensor were also carried out simultaneously for comparison purpose.

2. Sample fabrication

PZT/PZT sol-gel composite sensors were made by sol-gel spray technique. First, PZT powders and PZT sol-gel solution were prepared. PZT sol-gel solutions was self-manufactured. PZT powders was chosen because of raw material availability, high sensitivity, and poling facility[3)].The mixture of PZT powders and PZT sol-gel solution was ball milled. Then, the mixture was sprayed onto a stainless substrate by an automatic spray coating machine. The thickness of stainless substrate were 60μm. This substrate was chosen due to appropriate hardness and high temperature durability. After spray coating, Drying at 80°C on a hot plate, 150°C in an oven and firing at 650°C in a furnace was processed for 5 min each. Those spray coating process and thermal process were repeated until film thickness reached 90μm. After film fabrication, poling was operated by corona discharge at room temperature. The distance between the tip of the discharge and the piezoelectric film on the substrate was about 1.5cm. Piezoelectric constant d_{33} was 68.5pC/N. After these processes, thin aluminum top electrodes were manufactured by evaporation. Finally, electrical connections were assembled to serve as biological sensor. Optical image of PZT/PZT piezoelectric film sensor onto stainless substrate is shown in **Fig. 1**.

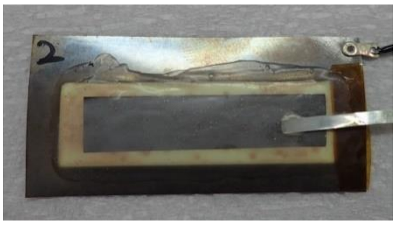

Fig. 1 Optical image of PZT/PZT piezoelectric film sensor.

3. Biological signal measurement

Biological signal was measured by sitting on a chair with PZT/PZT piezoelectric film sensors and PVDF sensors. ECG by the sensors attached to subclavian and abdomen and respiration by abdominal circumference respiration sensor were meaussred cimuleteneously for comparison pourpose. 10Hz low pass filter was used for PZT/PZT and PVDF sensors. The piezoelectric sensor layout is shown in **Fig. 2**. Two PZT/PZT piezoelectric film sensors were taped onto the middle of wodden chair side by side near one of the PVDF sensors. This location was chosen because it has high possibility to monitor biological signal caused by the pulse wabe and respiration efficiently from the past studies.

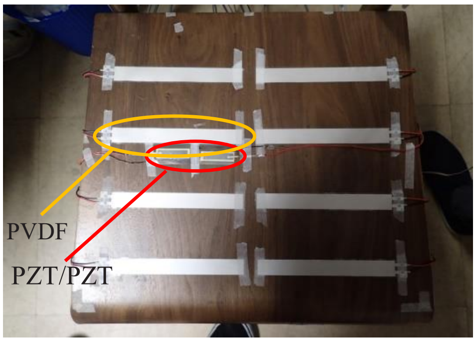

Fig. 2 The layout of PZT/PZT piezoerectric film sensors and PVDF sensors

The typical measurement results by ECG, one of the PZT/PZT piezoelectric film sensor, and PVDF are shown in **Figs. 3-5**, respectively. From Figs.3-5, peak intervals of PZT/PZT piezoelectric film sensor and PVDF sensors were similar with the peak interval from ECG (R-R interval). However, the PZT/PZT piezoelectric film sensor showed more clear peaks than PVDF. In addition, by PZT/PZT film sensor, broad peaks caused by respiration were also confirmed. It is noticed that no signifant difference was confirmed between measurement results obtained by 2 PTT/PZT film sensors. Therefore, PZT/PZT sensors were superior to PVDF sensors as biological signal measurement applications.

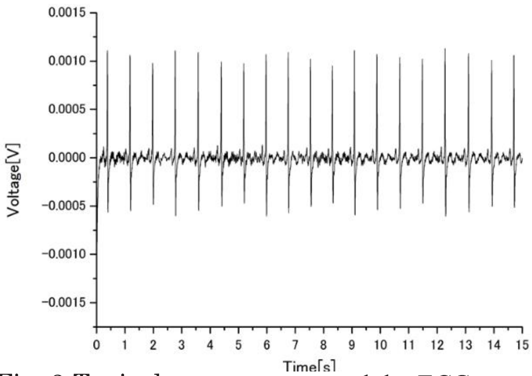

Fig. 3 Typical measurement result by ECG

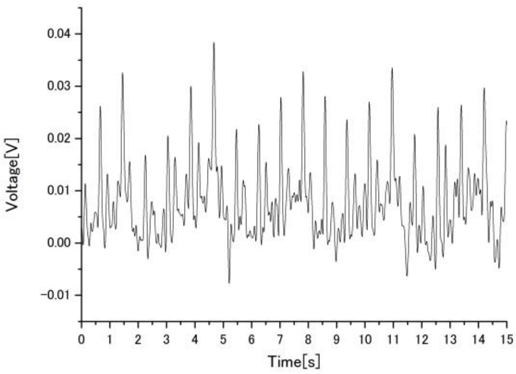

Fig. 4 Typical measurement result by PZT/PZT piezoelectric film sensor

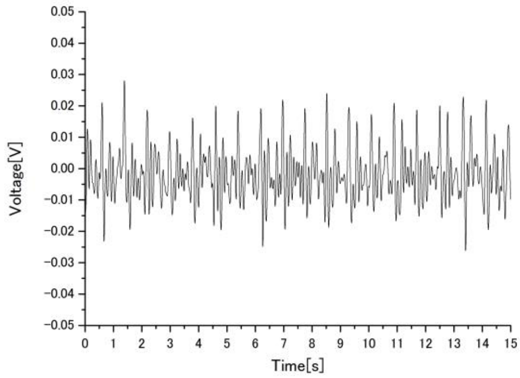

Fig. 5 Typical measurement result by PVDF sensor

In order to evaluate sensor performance as pulse wave meaurement quantitatively, the error rate was calculated as following equation;

$$\text{Error rate} = \frac{1}{n}\sum_{i=1}^{n}\left|1 - \frac{I_{C_i}}{I_{C_i}'}\right| \times 100$$

where I_{ci} is the i-th R-R interval from ECG and I_{ci}' is the i-th peak interval of the signals by the PZT/PZT piezoelectric film sensor and PVDF sensor, respectively. Error rate of PZT/PZT compared with ECG was 1.3% without signal processing, which was lower than that of PVDF sensor, 3.7%.

4. Conclusion

90µm thick PZT/PZT piezoelectric film was fabricated on a 60µm thick stainless substrate by an automatic spray coating machine for biologicl signal measurement. The piezoelectric constant d_{33} was 68.5pC/N. Biological signal was measured by sitting on a chair with PZT/PZT piezoelectric film sensors and PVDF sensor. PZT/PZT piezoelectric film sensors were able to measure clearer peaks caused by pulse wave and respiration than PVDF sensor. Error rate compared with ECG was 1.3%, which was lower than that of PVDF sensor. From this study, PZT/PZT piezoelectric film sensor can monitor the biological signal better than PVDF due to higher SNR.

References

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