Basic Research of Vibration Energy Harvesting Micro Device using Vinylidene Fluoride / Trifluoroethylene Copolymer Thin Film

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Abstract. Basic research of MEMS based micro devices for vibration energy harvesting using vinylidene fluoride / trifluoroethylene (VDF/TrFE) copolymer thin film was investigated. The VDF/TrFE copolymer thin film was formed by spin coating. Thickness of VDF/TrFE copolymer thin film was ranged from 375 nm to 2793 nm. Impedance of VDF/TrFE copolymer thin film was measured by LCR meter. Thin film in each thickness was fully poled by voltage based on C-V characteristics result. Generated power of the devices under applied vibration was observed by an oscilloscope. When the film thickness is 2793 nm, the generated power was about 0.815 µJ.

1. Introduction
Energy harvesting is innovative technology. It cropped minute energy from the environment of the circumference, and convert to electricity. Many companies and researchers focused on the field of energy harvesting. For example, Z. L. Wang at the Georgia Institute of Technology developed Radial-arrayed rotary electrification for high-performance triboelectric generator [1]. Piezoelectric polymers are one of the key technological materials for energy harvesting [2]. Especially, VDF/TrFE copolymer is one of the notable materials, because of their easy installation into mechanical sources and flexibility [3]. However, the performance and potentiality of the thin film for the energy harvesting device are still not clear. Thus, in this study, we investigated the performance of the power generation and demonstrated the practical usage of this piezoelectric polymer for energy harvesting.

2. Concept

2.1. Fabrication
Schematic image of the device fabrication is shown in figure 1. First, lower-electrode (Al) was fabricated on the polyimide substrate as shown in figure 1(a). Second, VDF/TrFE copolymer was fabricated by spin coating as shown in figure 1(b). VDF/TrFE copolymer film thickness was in a range of approximately 375 nm to 2793 nm. VDF/TrFE copolymer was coated several times to avoid the pinholes of the film. Third, upper-electrode (Al) was fabricated as shown in figure 1(c). Both electrodes were fabricated by dual ion beam sputtering method to decrease VDF/TrFE copolymer from melting by high temperature and damage of the surface of the polymer compared with RF sputtering method. The Al electrodes thickness was 230 nm.
2.2. Electric Measurement Results

Impedance of the VDF/TrFE copolymer film was measured by LCR meter as shown in figure 1(d). Frequency characteristics and $C-V$ characteristics of the VDF/TrFE copolymer thin film were shown in figure 2 and figure 3. Impedance measurements results were shown in figure 4. The impedance of the film increased in proportion to film thickness. Peak electric field showing the occurrence of polarization reversal was evaluated to be 40 MV/m as shown in figure 4.

**Figure 1.** Schematic images of device fabrication and photographs of the fabricated device

**Figure 2.** Frequency characteristics of the VDF/TrFE copolymer thin film

**Figure 3.** $C-V$ characteristics of the VDF/TrFE copolymer thin film

**Figure 4.** Film thickness vs $C-V$ peak voltage and impedance
3. Results and Discussion

The device in each thickness was fully poled by applying 60 MV/m based on the result of C-V characteristics. Then generated power of the device by vibration was observed by an oscilloscope (probe impedance: 10MΩ+15pF). Vibration was caused by bending the device as shown in figure 5. Figure 6 shows generated power vs bending degree when the film thickness was 2793 nm. Increment of generated power depends on the bending degree. Figure 7 shows generated voltage vs vibration time when vibration was caused by bending the device to 90 degrees, and figure 8 shows relationship between film thickness and generated voltage (peak to peak: $V_{p-p}$). When film thickness was increased, $V_{p-p}$ was reduced and vibration time was extended. For example, generated power was calculated by integration of time from generated voltage. Generated power was 0.815 µJ when the film thickness is 2793 nm at 10 MΩ load resistance.

![Figure 5. Experimental setup of device vibration](image)

![Figure 6. Generated power vs bending degree](image)

![Figure 7. Vibration time vs generated voltage](image)

![Figure 8. Film thickness vs generated voltage ($V_{p-p}$)](image)

Generated power of the device by the vibration was observed by adding load resistance. The load resistance was in a range of approximately 1 kΩ to 1 MΩ. Setup image of the device adding load resistance shows figure 9, and the generated power results were shown in figure 10. The result investigates the generated power increased in proportion to the load resistance. When film thickness is thin, the generated power decreased with a small load resistance. In order to increase generated power, lower impedance of VDF/TrFE copolymer film is required. However, impedance of the film was limited about 3.2 MΩ when the film thickness is 375 nm as shown in figure 4. Because of electrodes were shorted through pinholes, when film thickness was thinner than 375 nm.
4. Conclusions
This paper presents the micro device for vibration energy harvesting using VDF/TrFE copolymer thin film. The VDF/TrFE copolymer thin film was fabricated by spin coating. Thickness of VDF/TrFE copolymer thin film was ranged from 375 nm to 2793 nm. The impedance of the film increased in proportion to film thickness. Peak electric field showing the occurrence of polarization reversal was evaluated to be 40 MV/m. The device in each thickness was fully poled by applying 60 MV/m based on the result of C-V characteristics. When the film thickness is 2793 nm, generated power was 0.815 µJ. In this research, we didn’t measure or calculate $d_{31}$ or $d_{33}$. It should be measured near the future. When film thickness is thin, the generated power decreased with a small load resistance. In order to increase generated power stacked, we are going to fabricate the multi-layer structures of VDF/TrFE copolymer thin films.

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