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Development of pressure sensor using P(VDF-TrFE) thin film

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Abstract

Recently, Unmanned Aerial Vehicles (UAVs) have been developed which can fly by using remote control and automatic operation technology and can also take pictures. The number of users are increasing rapidly for hobbies and businesses. However, when these UAVs are flapped by the wind, they may lose stability and fall, or lose control. As a solution to this problem, the development of a dragonfly micro projectile which imitates the shape and flight method of the wing of a dragonfly, which is capable of various movements such as rapid acceleration, rapid turning, and hovering, has been advanced. However, the dragonfly micro projectile is currently under development, as it cannot fly continuously because its posture becomes unstable after takeoff and it falls. For this reason, it is necessary to control the posture of the dragonfly micro projectile in order to maintain its posture during the flight. Therefore, in this study, a pressure sensor mounted on the wing surface has been developed for the purpose of controlling the posture of a dragonfly micro projectile. As a material of the pressure sensitive part of the sensor, the use of the piezoelectric polymer compound in which the creation of the flexible sensor is possible by the thin film processing using the spin coat method was proposed. In this research, P (VDF-TrFE), which exhibits particularly strong piezoelectricity has been used. The response of the sensor was confirmed by measuring the electromotive force of 2.5mV when pressure of 0.01kPa is applied to the fabricated 100nm nanosheet sensor using a bulge tester.

Biomimetics, Pressure Sensor, P(VDF-TrFE), nano-sheet, Spin Coating

1. Introduction

In recent years, unmanned aircrafts capable of flying and photography by remote control and automatic piloting have been developed, and users who are interested in using this technology for hobbies and businesses are rapidly increasing [1]. However, there is a possibility that these UAVs may become uncontrollable or unstable on being flapped by the wind [2]. If the above-mentioned issue can be solved, it will be possible to perform various exercises such as sudden acceleration, sudden turning, hovering, etc [3]. The development of ultra-small projectiles that imitate the shape and flying method of dragonfly wing has been advanced [4]. Figure 1 shows a model of a dragonfly type ultra-small projectile.

However, the dragonfly type ultra-small flying object becomes unstable in posture after takeoff and falls, so continuous flight is impossible. Therefore, it is necessary to keep posture well controlled while flying [3]. So, in this study, to control the posture, installing a pressure sensor on the wing surface of a dragonfly type aircraft is suggested. We carried out measurement of the pressure distribution on the wing surface and made the flapping motion according to the necessary conditions obtained from the pressure distribution. In the previous study [4], a lead zirconate titanate (PZT) pressure sensor was developed for the pressure sensitive part assumed to be mounted on the actual dragonfly wing. However, the developed pressure sensor is large with respect to the wing and it is difficult to attach it to the wing because its size and weight impede the flight. Therefore, it is necessary to develop a pressure sensor for measuring the microscopic pressure distribution without hindering fluttering even if a pressure sensor is mounted. Therefore, in this report, we propose a pressure sensor using P (VDF - TrFE) (Vinylidene fluoride trifluoride ethylene). P (VDF - TrFE) [5] which is capable of creating a flexible sensor as a material of a pressure sensor mounted on a micro projectile and exhibits particularly high piezoelectricity among polymer compounds is applied to a nanosheet. We use the created P(VDF-TrFE) nanosheet for the pressure sensitive part of the sensor and Ag for the electrode to create the sensor. Finally, we measure the sensor created by the bulge method and check the electromotive force when pressure is applied to the nanosheet type pressure sensor with different film thickness.

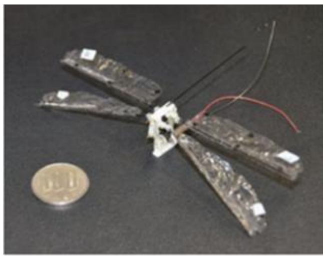

Figure 1. Dragonfly-type microminiature flight vehicle [3]

2. Pressure Sensor Fabrication

2.1. Nanosheet preparation

In this section, we will create a nanosheet-type pressure sensor. The shape of the pressure sensor is 20 mm x 20 mm square. PDMS with excellent flexibility was used for the mounting surface of the pressure sensor. First, a lower electrode Ag is deposited on a PDMS substrate using an ECR sputtering method capable of forming a high-purity film. Next, a P (VDF-TrFE) nanosheet as a pressure-sensitive material is deposited on the lower electrode Ag by spin coating. The concentration of P (VDF-TrFE) and the film thickness for each concentration are shown in Table 1. After the film formation, the P (VDF-TrFE) nanosheets were heat-treated using a dry oven in order to promote the crystal structure of the P (VDF-TrFE) nanosheets. The heat treatment condition at this time is 130 ° C. for 1 hour. Finally, Ag is formed as an upper electrode on P (VDF-TrFE) under the same conditions as the lower electrode by the ECR sputtering method.

Table 1 Spin coating Condition

	P(VDF-TrFE)
Condcentration [mg/ml]	80,40,20
Film thickness [nm]	924,189,91

2.2. Polarization treatment

Polarization processing of the created nanosheet type pressure sensor was performed. In carrying out the polarization treatment, a high voltage power supply was connected to the Cu block as the upper electrode and the Cu plate as the lower electrode, and the polarization treatment was performed under the condition of an applied electric field of 450 [V / μm][6] for 10 minutes.

3. Results & Discussion

Pressure was applied to the created nanosheet type pressure sensor using a bulge tester and the output voltage was measured using a nanovoltmeter. Part of the P(VDF-TrFE) nanosheet which is the pressure sensing part of the sensor mentioned in section 2 was removed by C_3H_6O (Acetone) to expose a part of the lower electrode, and Ag paste Copper wire was attached. After that, a nanovoltmeter was connected. Pressure was applied using a bulge tester and the electromotive force at that time was confirmed using a nanovoltmeter. The results are shown in Figure 2. As a result of applying pressure to the nanosheet type pressure sensor with different film thickness of the pressure sensing part, it was confirmed that the output voltage increases proportionally with any film thickness as the pressure increases. In addition, it was confirmed that the output voltage decreased as the film thickness of the pressure sensitive part increased.

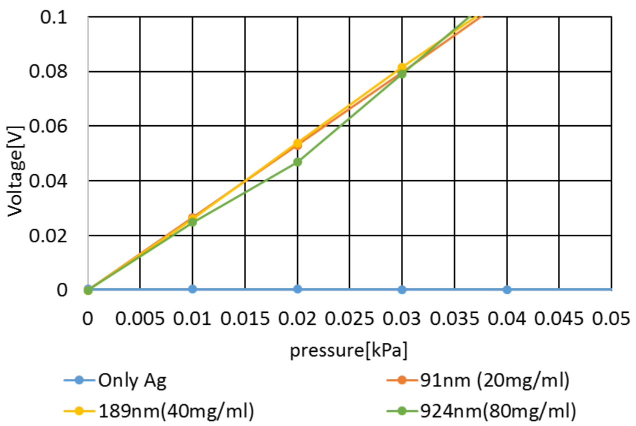

Figure 2. Piezoelectric Effect

In this section, the pressure sensor created in this study is evaluated when mounted on a dragonfly wing, using Beaufort scale [7] for wind force. The wind pressure for each level was determined by the following equation:

$$\text{Wind Pressure}[kg/m^2] = 0.05[kg/m^3] \times (\text{Wind Velocity}[m/s])^2 \text{ [8]}$$

When this equation was used, the minimum wind speed for each level was substituted for the wind speed. Wind pressure and a wing area of 704.7mm^2[9] are used to guide pressure on the wings of the dragonfly. Finally, [kgf/m^2] was converted to kPa, and the pressure after mounting the pressure sensor on the wing of dragonfly was obtained. The results obtained are shown in Table 2. In the Beaufort scale table, wind stages 3, 4, and 5 are named as gentle breeze, moderate breeze, and fresh breeze, respectively. In the gentle breeze, leaves and small twigs show the state of continuous movement. Moderate breeze indicates the state in which twigs move. Finally, fresh breeze is a wave on the surface of ponds and ponds[7].From the above results, it was confirmed that the electromotive force could be measured even against the minute pressure by the wind stages 3, 4 and 5 when the pressure sensor made in this study was mounted on the wing of dragonfly.

Table 2 Wings Pressure

Wind power	**Wind speed [m/s]**	**Wind pressure [kgf/m^2]**	**kPa**
Gentle Breeze	3.4	0.58	0.004
Moderate Breeze	5.5	1.51	0.01
Fresh Breeze	8	3.2	0.022

4. Conclusion

After the creation of nanosheet-type pressure sensors using P (VDF-TrFE), the following findings were obtained.
When pressure was applied to a nanosheet-type pressure sensor using P (VDF-TrFE), it was confirmed that the applied pressure and the output voltage increased proportionally for all film thickness.
The equivalent electromotive force was confirmed at any film thickness when pressure was applied to the nanosheet-type pressure sensor using P (VDF-TrFE).
When the pressure sensor was mounted on a dragonfly wing, it was confirmed that the electromotive force could be measured by the distortion of the wing and that the wing could be controlled.

References

[1] MLIT, Unmanned aerial vehicle (Drone, radio controlled machine etc.) guidelines for safe flight, (2008).
[2] Nobuaki WADA, Graduation thesis summary, (2016)
[3] Hisayoshi NAKA, Hiromu HASHIMOTO, Experimental visualization of three-dimensional flow using flapping model mimicking free-flight of dragonfly by tomography, Proceedings of the Japan Society of Mechanical Engineers, (2015)
[4] Kazuki MITOBE, Investigation of pressure measurement of the wing surface and development of thin film pressure sensor during gliding of dragonfly, master's thesis, (2016)
[5] Yoshirou TAZITU, From basic to applied polymeric piezoelectric materials and inorganic piezoelectric ceramics, CMC Publishing
[6] SolvayS.A.,Solvay, asking more from chemistry, （2018）
[7] Meteorological Agency, Meteorological Observation Guidebook
[8] Miyakojima Meteorological Observatory, Disaster Prevention, (2017)
[9] "Structural analysis of the wings of the damselfly and the damselfly" by Kenji MACHIDA , (2008)