Fundamental Research on Polymer Material as Artificial Muscle

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Abstract

Presently, breakthrough industrial technology and scientific technology produce various instruments of downscale and weight saving. But the metal parts are widely used for magnetic motors. It is difficult to lighten the weight and to miniaturize the motor. Therefore, we need small, light actuators that can be built into motor. We focus attention on the polymer material artificial muscle that responds to electrical stimulation with a significant shape or size change.

In this research, the artificial muscle was produced by using the conductive grease and the polymer material. We used several kinds of polymer material films in our experiments to compare the performance of them. The displacement when the voltage is applied to electrode was measured. At last the result and conclusion are given.

Keyword: EAP, Artificial muscle, Acrylic form elastomer, Urethane gel

1. Introduction

The needs of miniaturization and weight saving of the machine are being increased more due to the development of the technology in recent years (For example, the small actuator for the miniature camera is mounted in the portable telephone). As we know, the biped robot which imitates a person's movement appears. But, it still seems that the movement of the robot is awkward. The reason is that person's muscle moves in a straight line, but the motion of the robot is by the rotation movement of servomotor, and this motion is thought as the main reason.

From these reasons, we paid attention to the soft actuator which is usually regarded as the artificial muscle. In this paper, we describe the results of the basic experiment and application about the dielectric elastomer EAP (Electro Active Polymer).

2. Dielectric elastomer EAP artificial muscle[1][2][5][6]

Dielectric elastomer EAP artificial muscle has the similar structure to the condenser that a dielectric is put with in the soft electrode as the Fig.1. A dielectric is film-shaped and very thin. The high voltage of about 4000V is impressed on that film. The big electric field occurs between the electrodes and electrodes attract each other. A dielectric film produces elastic deformation and expands in the horizontal direction by using elastomer of the acrylic form and the urethane gel.

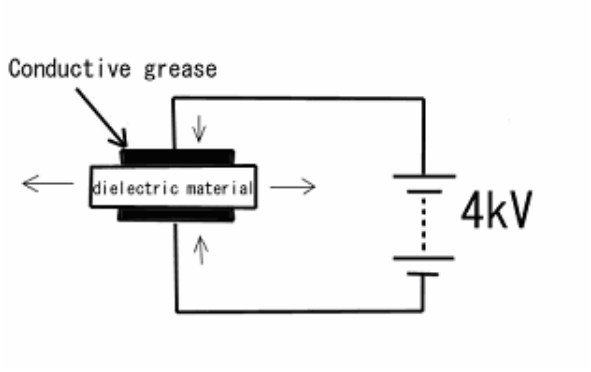

Fig.1 Structure of experiment

The displacement of compression between electrodes is very small. Therefore the dielectric elastomer EAP can be used as the actuator by applying the expanding force.

3. Fundamental experiment [1][2][3][5][6]

The stress that occurs between the electrodes is expressed by the equation (1).

$$P = \varepsilon_0 \varepsilon_r E^2 \qquad (1)$$

,where P: stress, ε_0 : permittivity in vacuum, ε_r : relative permittivity, E : electric field strength.

By the experiment, we confirm that the relationship between the displacement and the electric field strength corresponds to the equation(1). And we also examine that which materials are suitable for the soft actuator

The urethane gel and the acrylic form elastomer are used for the experiments. Each sample is fixed on the frame of an acrylic, which is shown in Fig.2. Fig.3 shows the structure of Fig.2. The reason to fix the film is to prevent the film from slackening. And it is also to prevent the electric discharge which happens easily for the experiment by high voltage.

Conductive grease was used for the electrode. And the diameter of the electrode is 15mm. The voltage of 4000V was applied to the electrode. The displacement was measured by the displacement measure instrument which uses the image processing .

And also the characteristics of the multi-layer of acrylic form elastomer are examined. Fig.4 shows the structure of multi-layer experiment. Since acrylic form elastomer is easy to be tested, it is selected to be used as the sample.

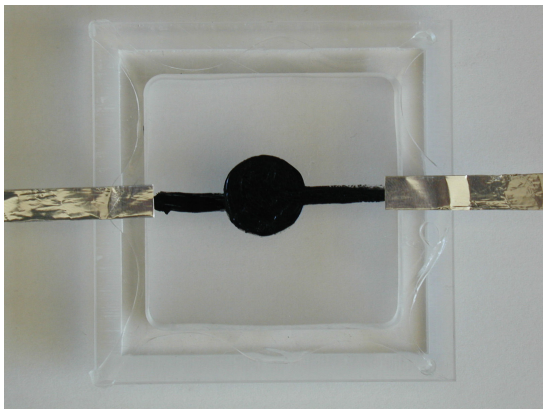

Fig.2. Photograph of experimental sample

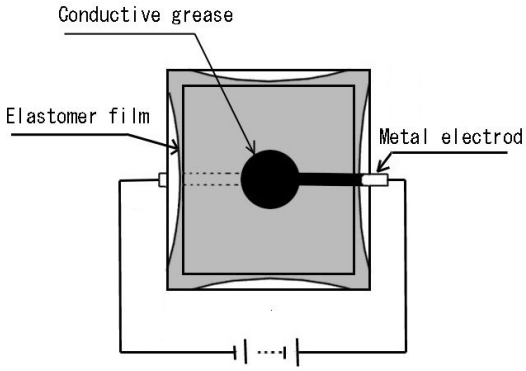

Fig.3. Structure of experimental sample

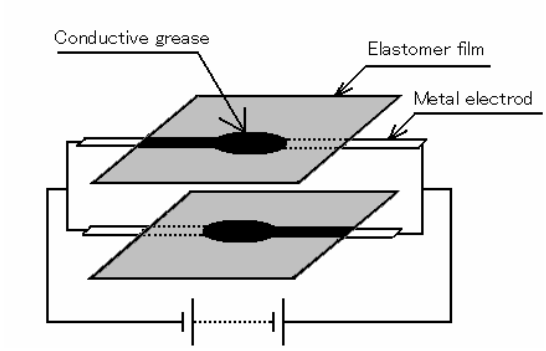

Fig.4. Structure of multi-layer experimental sample

4. Experimental result and consideration

4.1 Comparison urethane gel between acrylic form

Fig.5 shows the result of the comparative experiment between urethane gel between acrylic form. It shows that the displacement describe a parabola according to the increasing of the electric filed strength. The relationship between them coincides with the equation (1).

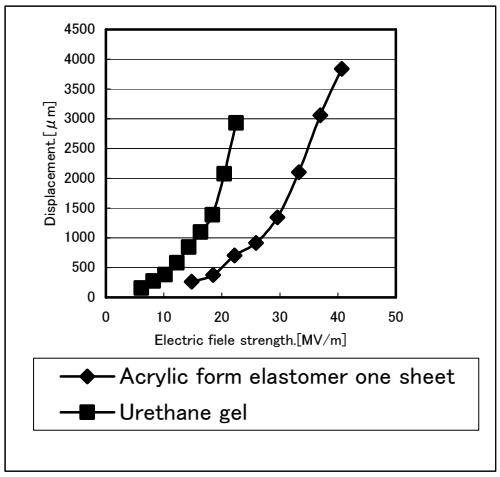

Fig.5 Relationship between electric field strength and displacement (One sheet)

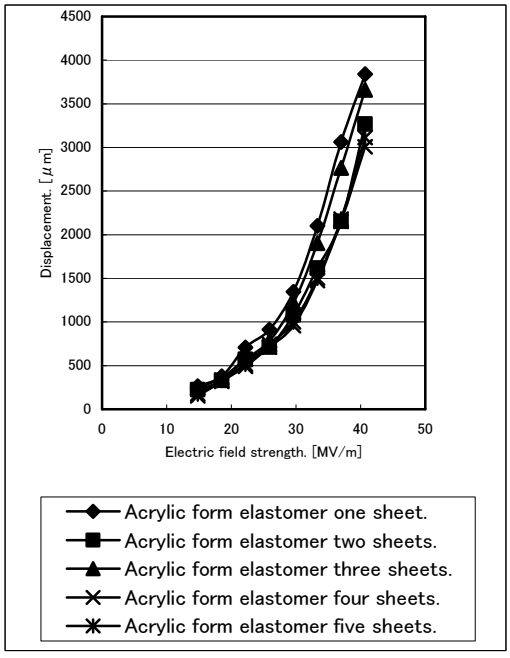

Fig6. Relationship between electric field strength and displacement (multi-layer)

From Fig.5, it is clarified that even a small voltage can affect the displacement of urethane gel when compared with acrylic form. And the maximum displacement of urethane gel can be obtained by the 20 MV/m of electric field strength, that is half of the voltage for the same displacement of acrylic form. But the response rate of urethane gel is slower than that of acrylic form.

4.2 Effect of the multi-layer of acrylic form

Next, for confirming the effect of the multi-layered acrylic form, the acrylic forms of from one layer to five layers are tested and the results of the multi-layer of acrylic form are shown in Fig.6. Each multi-layer of acrylic forms results in the similar curve.

High voltage is necessary to change dielectric elastomer EAP, and the thinner the film of EAP becomes, the lower the voltage to apply is. However, the thinner the film becomes, the more the strength of the film reduces.

On the other hand, the multi-layer of acrylic form can increase the strength by the same voltage of the single layer. Furthermore, it has the possibility that the compression displacement in the vertical direction to the electrodes can be used for the application of the multi-layer EAP.

The compression displacement in the vertical direction will be large when we increase the number of the multi-layer and the multi-layer EAP will be able to apply as an actuator.

5. An application example as an actuator

We propose an actuator for the pump to circulate the air as an application example. The main parts of the actuator can consist of the dielectric elastomer EAP and the spring, Therefore the actuator can be miniaturized and lightened the weight. The structure of the proposed application example is shown in the Fig.7.

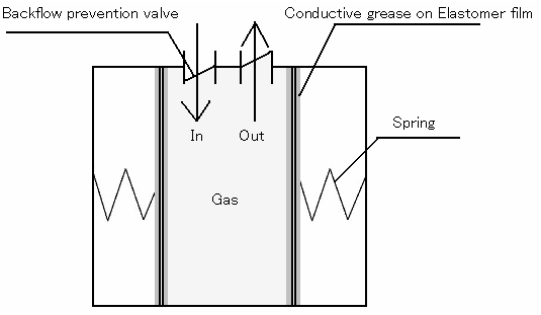

Fig.7 Structure of application example as actuator

At the initial condition, the springs press down the elastomer film to the central axis. And a film stretches by increasing a high voltage and at the same time the springs extend to the direction of the central axis. When the applied voltage becomes low, the spring regains the initial position. By repeating this cycle, the gas inside the pump is circulated. This simple mechanism can break down the problem which is the weak point of present pulse pattern pump that is difficult to miniaturize. And it also may be able to be applied to the artificial heart if the fluid circulate is strengthened by using the strong spring. However, because the high voltage power supply is used, it is necessary to take care about the electrical discharge.

6. Conclusions

In this paper, we described the soft actuator that is called dielectric elastomar EAP artificial muscle in the introduction. The fundamental experiment of artificial muscle was done, and the application of artificial muscle was proposed. The various other applications are suggested by a lot of researchers[3][4]. Therefore, the artificial muscle is improved every day.

If the artificial muscle which respond instantly to the very weak electric stimulus from the human body can be developed, a big revolution will be brought to the artificial limb technology.

Big evolution was also made for the biped walking robot in recent years by easily imitating a person's movement. But, the vibration that occurs by the rotation movement of motors causes a big trouble when controlling many motors of the biped robot.

The soft actuator which can make a straight line-like movement by only given voltage without vibration attract the attention of the researchers of robotics. Because it is possible to be used to the various fields as mentioned above, a soft actuator can be thought as the new technology for the research and application of various filed.

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