Study of Novel Micropolymer Actuator Powered by Enzymatic Reactions of Biomolecules

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1. Introduction

The central issue in how to achieve autonomous operation of micromachines in a living organism is how to supply the energy that drives the micromachines. In such an extremely small environment, there is no space to allocate for a battery or the like, nor is it possible to supply energy from an external source. In this study, chemical substances existing in the living organism were employed as polymer actuators by varying their concentrations. The idea is to produce mechanical energy from the chemical substance, a process very similar to the mechanism that living system use to produce energy.

2. Developing a Polymer Gel that Responds to Alcohol

Phospholipid bilayers forming biomembranes have a thickness of 50 nm. Though they are extremely thin, they have many functions. Polymers with a phospholipid polar group in the side chain, 2-methacrylooyloxyethyl phosphorylcholine (MPC) polymers, show excellent properties as a new biomaterial. Further, it was discovered to control the volume of the polymer reversibly through changes in concentration based on the peculiar solvation effect of a phospholipid polar group (Fig. 1). The polymer was repeatedly swelled and deswelled by increasing and decreasing the alcohol concentration (Fig. 2). This indicates that it is possible to manipulate the volume of a bio-responsive polymer gel by causing a reaction with components in an MPC polymer gel to selectively fix enzymes that generate alcohol.

3. Enzymatic Reactions Produced by Alcohol and the Swelling Function of Gel

It was attempted to generate movement in an MPC polymer gel by combining enzymatic reactions using alcohol compounds that exist in the body. Using an EMP cycle, it was generated ethanol with pyruvic acid decarboxylase and alcohol deyhdrogenase using pyruvic acid generated from glucose as the initial substance. It was confirmed that the MPC polymer gel deswelled in this system. Hence, we achieved a polymer actuator capable of supplying chemical energy using the energy source of glucose was achieved.

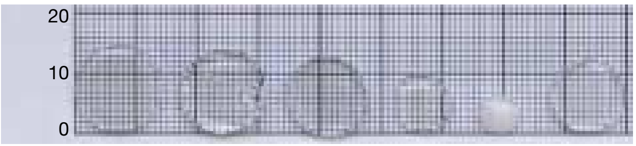

Fig. 1 Dependence of the volume of a cross-linked MPC polymer gel on alcohol composition Ethanol composition (from left): 0, 20, 40, 60, 80, and 100%

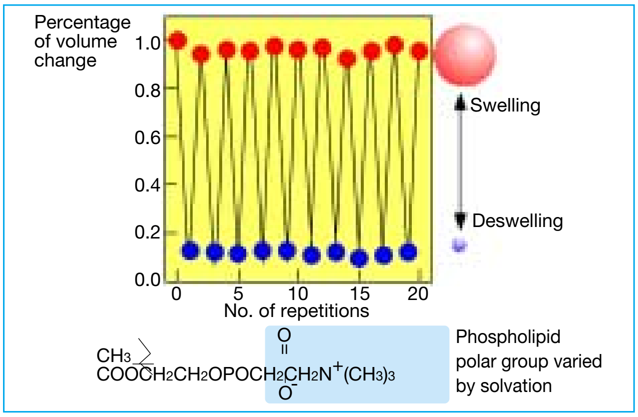

Fig. 2 Reversible volume changes of a cross-linked MPC polymer gel in an aqueous solution of pure water and 60% ethanol solution

Catheter Tip Position Sensing System Using MI Sensor

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1. Introduction

Minimally invasive examinations and treatments are performed by inserting a small instrument, such as an endoscope or catheter (a polymer tube having a diameter of about 0.3-3 mm) into the patient's body. While fluoroscopy is currently employed to determine the position of the catheter tip, this method provides only two-dimensional data, which makes for difficult determinations, and moreover produces inadequate image resolution. The capacity to determine the position and attitude (direction in which the tip is pointing) of the catheter tip three-dimensionally and in real time will benefit catheter navigation.

A practical tip position detecting system that employs micro-coils has already been developed. However, we are striving to develop a high-performance 3-axis micro-sensor that can be mounted on a catheter using micro-magnetic vector sensors. These sensors are based on a new principle of the magneto-impedance effect. The system detects exchange magnetic field emitted by an external coil and geomagnetism using three sensors mounted on the tip of the catheter, as shown in Fig. 1.

2. Developing a 3-axis MI Sensor System

In this sensor, a coil generating a bias magnetic field was wound around an amorphous wire having a diameter of 30μm. The sensor generates a voltage between the ends of the wire that varies according to the strength of the magnetic field. Three of the sensors were arranged orthogonally to one another in a 2-mm square column and achieved a positional resolution less than 1 mm and an angular resolution of about 1 degree at the point of position and attitude measurement. In order to combine the positions detected by the three sensors precisely, the sensors were mounted on a polymer which has an electrode patterns, as shown in Fig. 2.

To present 3-dimensional position and attitude data to the doctor, one could obtain and store three-dimensional blood vessel images in a computer prior to operation using contrast medium CT or the like and superimpose the three-dimensional position and attitude of the catheter tip onto the blood vessel images displayed on the screen. The current display system is configured of a three-dimensional blood vessel model image in a computer, as shown in Fig. 3. Measurement signals are input into the computer while calculations are performed to display superimposed position and attitude data in real time.

3. Conclusion

If we liken this sensor system to a car navigation system, the catheter tip corresponds to the car and the blood vessels to roads. By making this system practical, it is expected that minimally invasive therapy will become safer and more reliable, enabling us to perform examinations and treatment not possible before. Applying the system to an endoscope is also anticipated.

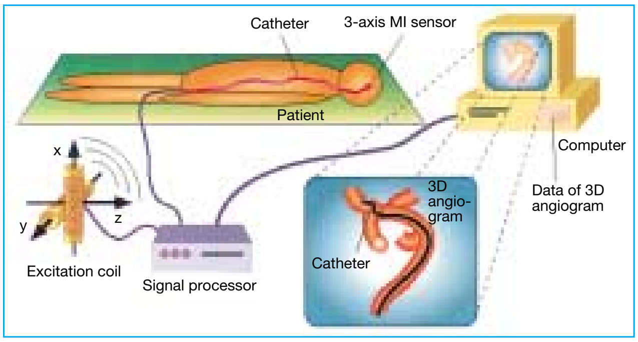

Fig. 1 A catheter tip position/attitude sensor system

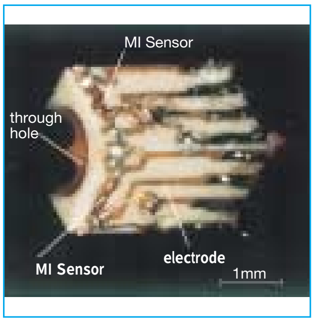

Fig. 2 3-axis micro-magnetic sensor

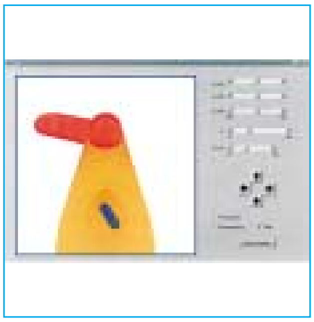

Fig. 3 Catheter tip position / attitude display system