Study on a Cuff Microelectrode using MEMS Technology

Shoji Takeuchi, Associate Professor, Institute of Industrial Science, The University of Tokyo

1. Introduction

This study aims at developing a cuff microelectrode capable of easily being fixed to nerve cords having micro-sized diameters. While nerve regeneration type and insertion type microelectrodes have been proposed, minimally invasive electrodes that do not cut or pierce the nerve are needed for measuring electric potentials during activity. Therefore, in this study, we incorporated a shape memory alloy (SMA) thin film microactuator in an electrode and attempted to attach the electrode to a nerve by electrically controlling the fixing operations. We proposed a 3D shape memory technique required at this time to develop a microcuff structure.

2. Fabricating Microelectrodes

A TiNi-based shape memory alloy was formed in a thin film to serve as the electrode structure. We fabricated a clipping mechanism (Fig. 1) that actively grips the nerve when driven by an electric current. Conventional TiNi thin films have lower responsiveness than other actuators due to the difficulty in raising their Martensite transformation temperatures because they are severely deformed at room temperature. By modifying the composition of the thin film and conditions of thermal treatment, we were able to raise the transformation temperatures to obtain a thin film that was Martensite at room temperature. Therefore, rather than allowing the clipping mechanism to be used repeatedly, we gave the mechanism unidirectionality, so that once clipped it could not be removed. This enabled us to manufacture a SMA thin film clipping mechanism that avoids the problem of responsiveness, normally a shortcoming in SMA actuators, has great elasticity at room temperature, and takes full advantage of its strength in high output.

3. Evaluating Electrode Properties

We recorded neural activity using the fabricated electrode. The 3D clipping mechanism was fixed to the ventral nerve cord of an insect without causing injury. It was also determined that heating had no effect on the nerve. Based on the measurements, no problems-and particularly no noise-were observed in the waveform of activity compared to those of normal electrodes (Fig. 2). Since the structure is highly elastic, the body tissue of the insect incurred no damage even when the mechanism collided with the tissue. It was also seen that neural activity could be measured while the insect was active, without the electrode coming loose.

4. Conclusion

The smaller the nerve to be treated, the more difficult it is to position the electrode near to or in contact with the nerve. It is impossible to record clear signals when an electrode has poor contact with the nerve. Electrodes using SMA thin films can easily perform this operation and remain fixed to the nerve even when the insect is active.

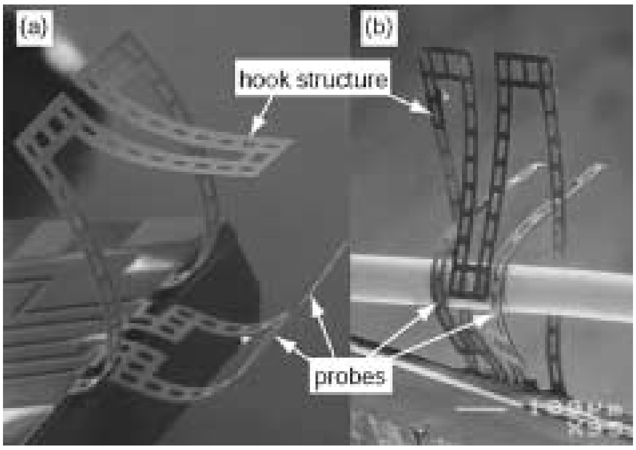

Fig. 1 (a) The fabricated SMA thin film microelectrode (b) the electrode clipped to a 100-μm wire

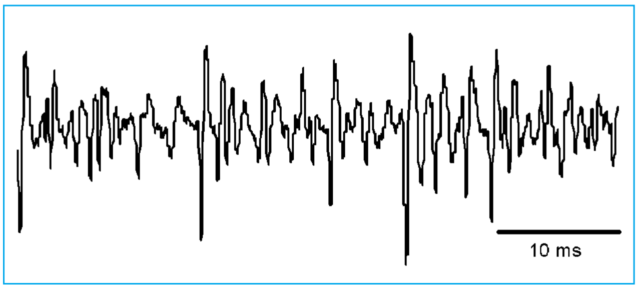

Fig. 2 Neural activity measured from the ventral nerve cord of an insect using the fabricated electrode

Study on Heart-Emulating Microactuators Using Self-Oscillating Gel

Ryo Yoshida, Associate Professor, Graduate School of Engineering, The University of Tokyo

1. Introduction

We developed a novel self-oscillating gel that, under fixed conditions, is capable of oscillating autonomously in a spontaneous rhythm like a heartbeat, as opposed to the conventional stimuli-responsive gels. Through a molecular design that converts chemical energy into mechanical energy by inducing the Belousov-Zhabotinsky reaction (BZ reaction) with a cyclic reaction circuit in the gel, also found in a chemical model of a metabolic response (TCA cycle), we demonstrated that the gel is made to periodically swell and deswell. This self-oscillating gel can conceivably enable the design of new materials capable of imitating biological functions, such as microactuators capable of autonomous periodic motion, self-beating (peristaltic) micropumps, molecular pacemakers, and information transfer elements. With the aim of developing new micromachines equipped with these functions, we established a technology for developing micro-size self-oscillating gel, analyzed the behavior of the oscillations, and conducted a basic study on constructing a material system.

2. Manufacturing microactuators (artificial cilia) through gel micromachining

We attempted two methods of micromachining self-oscillating gel. In the first method, shown in Fig. 1, we introduced a photocrosslinked section (phenyl azide group) into a polymer chain and micromachined the gel to a desired shape through photolithography using a photomask. The other method was performed according to a cutting-edge 3D micromachining technique (LIGA, moving mask X-ray lithography) using synchrotron radiation. In the latter method, we produced artificial cilia in the gel surface. The cilia comprised hundreds of protrusions of several ten to several hundred microns in size that were arranged in an array (Fig. 2). When effecting a chemical reaction wave in the gel, we observed periodic changes in the surface protrusions accompanying the wave propagation. This technique can conceivably be applied to a micro-transport system, for example, for transporting minute particles, cells, and the like added to the surface.

3. Conclusion

We designed and constructed a gel with a novel functionality for oscillating in a spontaneous rhythm like a heart muscle. This gel is of great interest for use as a microdevice element because of its ability to produce a rhythmical periodic motion and to transmit this rhythm as data. This may lead to the development of a novel material system having such functions as rhythmical motion, mass transport, and data conversion and transfer.

Fig. 1 Gel micromachining through photolithography

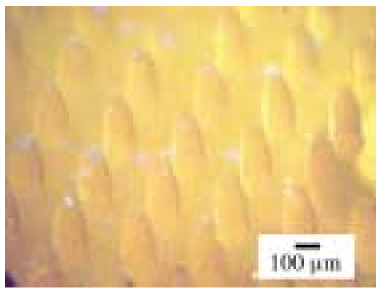

Fig. 2 Ciliary motion actuator formed of gel through LIGA