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Development of Hardware Neural Network Controlled MEMS Micro Robot

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Abstract: This paper presents the MEMS (Micro Electro Mechanical Systems) micro robot which demonstrates the locomotion, controlled by the HNN (Hardware Neural Network). The size of the robot fabricated by the MEMS technology was 4×4×3.5 mm. The frame of the robot was made of silicon wafer, equipped with the rotational actuator and the link mechanism. The HNN controls the robot without using any software programs. In this robot, the HNN generated the locomotion pattern. The micro robot performed forward and backward locomotion, and also the locomotion switched by inputting the external trigger pulse. The locomotion speed was 19.5 mm/min.

１． Introduction

Recently, many studies have intensively been done on micro robots for many applications such as medical field, precise manipulations, and so on. Although the miniaturization of the robot has conventionally been progressed by mechanical machining and assembles, some difficulty has appeared in order to achieve further miniaturizations. Instead of conventional mechanical machining, MEMS technology has been studied for making the components of the micro robot [1].

Although, programmed control by a microprocessor has been the dominant system among the robot control, some advanced studies of neural network system has been paid attention for applying to robots, a lot of studies have reported both on software models and hardware model [2].

In this paper, micro robot of millimeter size has been proposed. The fabrication process is based on MEMS technology. Also, the control system is hardware type neural network system whose control pulse is generated by HNN. This paper presents the MEMS micro robot which demonstrates the locomotion, controlled by the HNN.

２． Mechanical architecture of MEMS micro robot

Fig.1 shows the schematic diagram of the fabricated MEMS micro robot. The structure and the locomotion resembled to the insect. Thus, the number of the legs of the micro robot were six. Inside the robot, a pair of the rotational actuator using the artificial muscle wires and link mechanism were generated the locomotion.

The rotational actuator was consisted of the two rotors, eight pieces of artificial muscle wires and a frame. The artificial wires were fixed to the frame. The artificial muscle wire extended at high temperature and shrunk at low temperature. In this study, the wire was heated by electrical current flowing, and cooled by stopping the flowing. The rotational movement of the each actuator was obtained by changing the flowing timing.

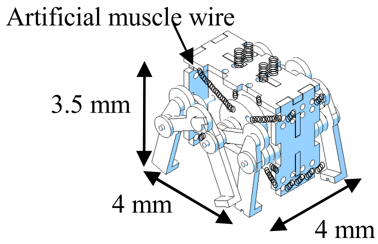

Fig.1 Design of the fabricated MEMS micro robot.

The link mechanism which is method of link the three legs by each three link bars. The center leg was connected to the rotational actuator without the link bar.

Fig.2 shows the schematic diagram of locomotion method. When heating the artificial muscle wire from EI_1 to EI_4 by rotation, the micro robot will move forward. On the other hand, when heating the artificial muscle wire from EI_4 to EI_1 by rotation, the robot will move backward. The locomotion pattern was 180 degree phase sift on each side to resemble the locomotion of insect.

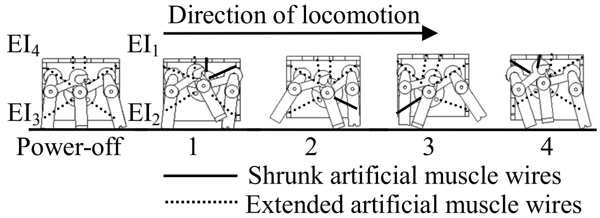

Fig.2 Schematic diagram of locomotion method.

３． Fabrication of micro robot using the MEMS technology

The parts of MEMS micro robot without the shaft and the artificial muscle wire was fabricated by MEMS technology.

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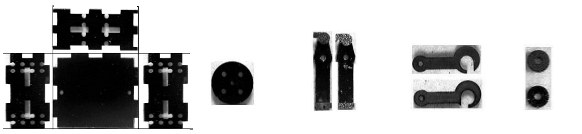
We use the 100, 200, 385, 500 μm thickness silicon wafer to construct the parts. The shapes of parts were machined by photolithography based ICP dry etching.

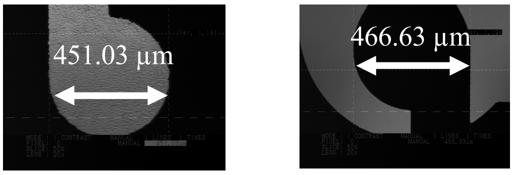
Fig.3 shows the parts of the MEMS micro robot, and Fig.4 shows the size of the favricated parts. The designed diameter of the Leg's axis was 450 μm. The designed diameter of the link bar's hole was 460 μm. The error rate of leg's axis was 0.23 %, and the error rate of link bar's hole was 1.38 %. Therefore, the connect point of link mechanism was made with an uncertainty of ± 2%. The link bars and the legs were fabricated in the gap between 15.6 μm.

Fig.5 shows the fabricated MEMS micro robot. The size of our MEMS micro robot was 4×4×3.5 mm. The wire on the micro robot was connected to the HNN.



(a)Flame (b)Rotor (c)Legs (d)Links (e)Speacer

Fig.3 Parts of the MEMS micro robot.



(a) Leg's axis (b) Link's hole

Fig.4 Size of the favricated parts.

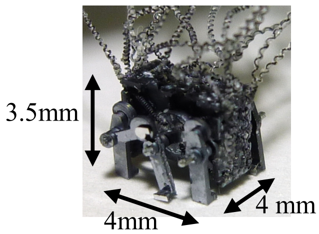


Fig.5 Fabricated MEMS micro robot.

４． Generation of the locomotion pattern using HNN

The control system of the robot is HNN. The purpose of using NN system is implement the excellent fanctions of living organisms. The NN generates the locomotion patterns by pulse waveform such as livig organisms using the coupled oscillators system. Fig.6 shows the schematic diagram of the HNN. The HNN consist of four coupled oscillators (EI_1, EI_2, EI_3, and EI_4). E and I represent an excitatory neuron model and an inhibitory neuron model, respectively. The solid circle indicates an inhibitory connection. We denote the coupled oscillator by EI.

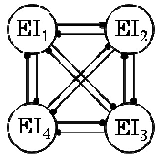
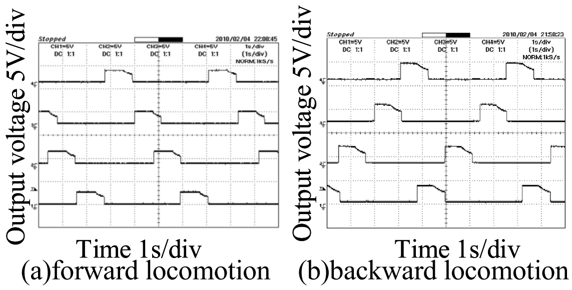


Fig.6 Schematic diagram of the HNN.

Fig.7 shows the exmanple of the generated locomotion pattern. As a result, our fabricated robot performed forward and backward locomotion, and also the locomotion switched by inputting the external trigger pulse. The locomotion speed was 19.5 mm/min and the step width was 1.3 mm.



(a)forward locomotion (b)backward locomotion

Fig.7 Exmanple of the generated locomotion pattern.

５． Conclusions

In this paper, we fabricated the 4×4×3.5 mm size micro robot by MEMS technology. The locomotion of micro robot was controlled by the HNN without using any software programs. As a result, the fabricated micro robot was performed forward and backward locomotion, and also the locomotion switched by inputting the external trigger pulse. The locomotion speed was 19.5 mm/min.

Acknowledgments

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