Transmitter function of synapse-structure system using conducting polymer

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Abstract. Conducting polymers with neuron-like pattern has been polymerized by controlling polymerization conditions. These conducting polymers have been connected each other to prepare network. If the synapse function can be added to the network, artificial neural network is prepared by conducting polymer. In this paper, we consider the transmitter function using synapse-structure conducting polymer. It consists of three parts: primary circuit as presynaptic terminal, space as synaptic cleft and secondary circuit as postsynaptic structure. Dopant in conducting polymer works as neurotransmitter. Migration as well as diffusion is also considered for dopant ion to transit the space/cleft. When signals from the primary circuit came at the end of the primary circuit in electrolyte solution, the current in the secondary circuit increased because the released dopant ion transited the cleft and entered another conducting polymer. When two primary circuits was used, the current in the secondary circuit increased higher than one primary circuit. This means the synapse-structured conducting polymer system can be use as logical circuit.

1. Introduction
Conducting polymers with neuron-like pattern have been polymerized by controlling polymerization conditions. The neuron-like conducting polymer can be connected to prepare a network. The neuron-like or neural network device can be fabricated if three functions are added to the network of conducting polymer: (i) multilayer, (ii) threshold function, and (iii) controlled weight of network-path. Two methods have been suggested to fabricate the device neuron-like device: (1) Chemical and (2) electrical method. Furthermore, logical circuits (AND/OR circuits) have been fabricated by these networks. Meanwhile conducting polymers have been used in bioelectronics [1-].

Neural network in computer field, Perceptron, was investigated by considering neuron work, especially synapse function. Three functions ((i)-(iii)) described above are obtained by modeling synapse to make a system of brain. If the function at the synapse connection is realized by synapse structure; (a) presynaptic terminal, (b) synaptic cleft and (c) postsynaptic structure, threshold and weight characteristics can be easily realized.

In this paper, we consider the transmitter function using synapse-structure conducting polymer.

2. Synapse-structured using conducting polymer

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The synaptic junction consists of three parts. When signals arrive at the presynaptic terminal, neurotransmitters are released from presynaptic terminal to synaptic cleft and interact with receptor molecules in the postsynaptic membrane. They finally exert an effect on the membrane potential of the neuron.

The synapse structure using conducting polymer is also the same structure: primary conducting polymer as presynaptic terminal, secondary conducting polymer as postsynaptic structure and small gap as synaptic cleft. When the pulses arrive at the primary conducting polymer, dopant ions in the primary conducting polymer are released in the gap. The dopant ions released diffuse toward the secondary conducting polymer. The concentration of dopant ions increases near the secondary conducting polymer and the dopant ions penetrate the secondary conducting polymer. Then the conductivity of the secondary conducting polymer increases. Current in secondary circuit with the secondary conducting polymer increases.

3. Experimental

Figure 1 shows the experimental configuration. The primary circuit consisted of a pulse voltage source, conducting polymer with dopants and a counter electrode of Ni. The input is a series of 5 \([V]\) rectangle pulses whose width and period are 0.5 \([sec]\) and 1.0 \([sec]\) receptively. The secondary circuit consists of a source voltage and a film of conducting polymer undoped. The conducting polymer undoped was set between the input electrode, which is the conducting polymer doped, and the counter electrode. When the pulse voltage is applied, the ions penetrates the input-side of conducting polymer due to the potential slope, i.e. the ions drift into the input-side of conducting polymer. Thus the current in the secondary circuit increases.

4. Results and discussion

Figure 2 shows the secondary circuit current under three trials. The current increased after each trial of adding a series of pulsed. The dopant ions drifted from the input electrode of conducting polymer doped to the secondary conducting polymer undoped. The cross potential system assisted the transit of the dopant/transmitter. In the system the number of pulses control amount of dopant, which change the conductivity of the secondary conducting polymer. That should work as the weight and threshold of neural network.

To investigate the effect of the number of pulse effect on secondary conducting polymer, two Ni electrodes were used instead of conducting polymer electrodes and conducting polymer in secondary circuit was polypyrrole prepared by electrolyte of LiBF\(_4\) sodium \(p\)-toluene sulfonate. Figure 3 shows the experimental configuration with two primary circuits\((x1 \text{ and } x2)\). Figure 4 shows the addition of two input of \(x1\) and \(x2\). One input consisted of 15 pulses. When one input was on, the output of current was almost same. When double inputs were added\((x1 + x2)\), the output current was
higher than one input. It is hard to use this system for additional counter because of nonlinearity of conductivity but it works as AND logical circuit if the threshold is set at 0.073mA in this case.

5. Conclusion
The synapse-structured conducting polymer has been investigated for transmitter action of synapse. The structure using conducting polymer consisted of three parts; the primary circuit, the gap and the secondary circuit corresponding to presynaptic terminal, synaptic cleft and postsynaptic structure, respectively. The current through the secondary conducting polymer increased after each trial. The dopant ion worked as transmitter. The gradient of potential introduced has been used to accelerate the ions.

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