Development and Evaluation of Letter Reproduction System Using Cellular Neural Network and Oxide Semiconductor Synapses

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ABSTRACT

A letter reproduction system using a cellular neural network and oxide semiconductor synapses has been developed and evaluated using logic simulations and actual experiment. Oxide semiconductor devices are used for the synapse elements, whose deteriorating characteristic can be utilized as strength plasticity of synaptic connection based on modified Hebbian learning. In this presentation, first, the structure and operation of the letter reproduction system is explained. Next, it is evaluated using logic simulation, where the dependence of the correction accuracy of the letter reproduction on the conductance variation of the oxide semiconductor synapses is analyzed. Finally, the real operation is confirmed using an actual experiment. This study is a sole solution to actually realize three dimensional structural Artificial intelligence

KEYWORDS

Letter reproduction system, Cellular neural network, Oxide semiconductor Synapse

1 INTRODUCTION

Neural networks are promising systems with many advantages, such as self-organization, self-learning, parallel distributed computing, and fault tolerance, whose advantages are obtained by connecting an astronomical number of neuron elements with a much larger number of synapses elements [1-4]. However, because the conventional neural networks are complicated software executed on high-spec hardware, the machine size is very bulky, and power consumption is unbelievably huge. Consequently, neural networks named neuromorphic integrated system are reported [5-7]. For such system, it is necessary to simplify the processing elements and fabricate them at low cost. By employing oxide semiconductor synapses, we can fabricate abundant elements with printing process and stack in three-dimensional structure. In this study, a letter reproduction system using a cellular neural network and oxide semiconductor synapses has been developed and evaluated using logic simulations and actual experiment.

2 CELLULAR NEURAL NETWORK

A network architecture of the cellular neural network is shown in Fig. 1 [8,9]. Here, 25×25 neuron elements are aligned like an array matrix, orthogonally and diagonally connected only to neighboring neuron elements, and fabricated in an LSI chip. The synapse elements are fabricated using amorphous metal-oxide semiconductor devices deposited on the LSI chip. An operation principle of the cellular neural network is shown in Fig. 2. Here, 12×12 I/O neurons are assigned to every two neuron elements. When some letters are learned, high voltage (H) of Vdd is applied to the corresponding I/O neurons, and low voltage (L) of GND is applied to the other I/O neurons. All neuron elements dynamically become either fire or stable states.

3 OXIDE SEMICONDUCTOR SYNAPSE

Oxide semiconductor devices are used for the synapse elements [10]. Here, amorphous In-Ga-Zn-O (a-IGZO) films are used as the oxide semiconductor devices. Some electric currents flow through the synapses elements that are connected to the neuron elements with the different states, whose deteriorating characteristic can be utilized as strength plasticity of synaptic connection based on modified Hebbian learning. It is regrettably found that the characteristic deviation in the initial conductance exists, where the mean resistance is 3.75MΩ and resistance deviation is 1M Ω. The resistance distribution of the a-IGZO films is shown in Fig. 3.

4 SIMULATION RESULTS

The letter reproduction system is evaluated using logic simulation, where the dependence of the correction accuracy of the letter reproduction on the conductance variation of the oxide semiconductor synapses is analyzed. The network architecture of the cellular neural network is built in the logic simulation, and the deteriorating characteristic of the a-IGZO is modelled and installed in the logic simulation. The resistance distribution example inputted into the logic simulation is shown in Fig. 4, which is used as a Monte-Carlo simulation. The operation algorithm is as follows. First, in the learning stage, correct letters are inputted into the I/O neurons, and some electric currents flow through the synapses elements, whose deteriorating characteristic can be utilized as strength plasticity of synaptic connection based on modified Hebbian learning. Next, in the recognizing stage, one-pixel flapped pattern from the correct letters are put into the I/O neurons, and some revised patterns are produced from the letter reproduction system. The revised patterns are checked to be the same as the correct letters. The dependence of the correction accuracy on the resistance variation is shown in Fig. 5.

5 EXPERIMENT RESULTS

The cellular neural network and oxide semiconductor synapses are shown in Fig. 6. Here, as aforementioned, 25×25 neuron elements are aligned like an array matrix, orthogonally and diagonally connected only to neighboring neuron elements, and fabricated in an LSI chip. The synapse elements are fabricated using amorphous metal-oxide semiconductor devices deposited on the LSI chip. The operation algorithm is as follows. As aforementioned, first, in the learning stage, correct letters are put into the I/O neurons, and some electric currents flow through the synapses elements, whose deteriorating characteristic can be utilized as strength plasticity of synaptic connection based on modified Hebbian learning. Next, in the recognizing stage, one-pixel flapped pattern from the correct letters are put into the I/O neurons, and some revised patterns are produced from the letter reproduction system. The revised patterns are checked to be the same as the correct letters. The real operation confirmed using an actual experiment is shown in Fig. 7. It is found that the correct letters are truly reproduced for some cases.

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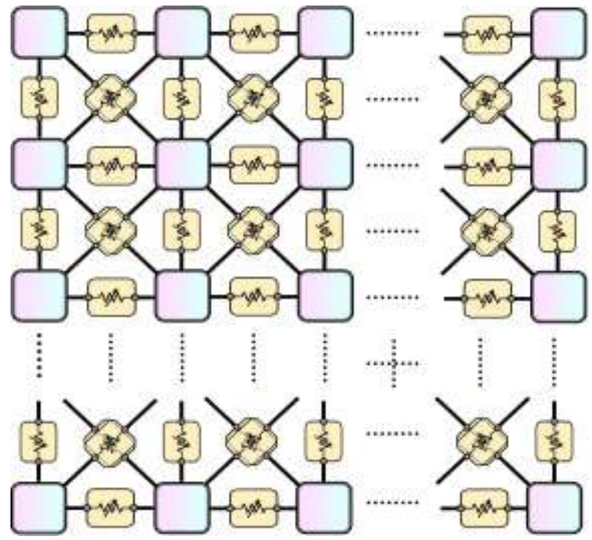

Figure 1: Network architecture of the cellular neural network.

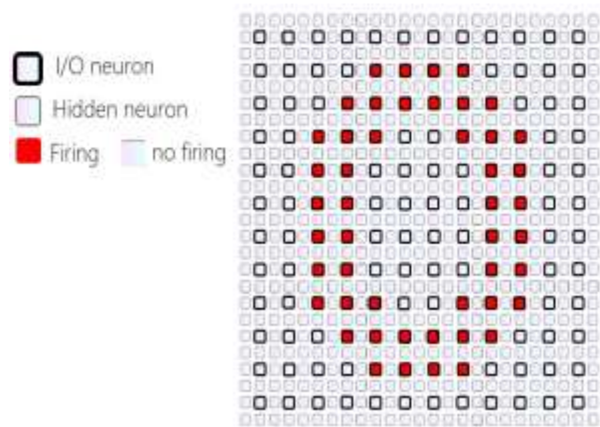

Figure 2: Operation principle of the cellular neural network.

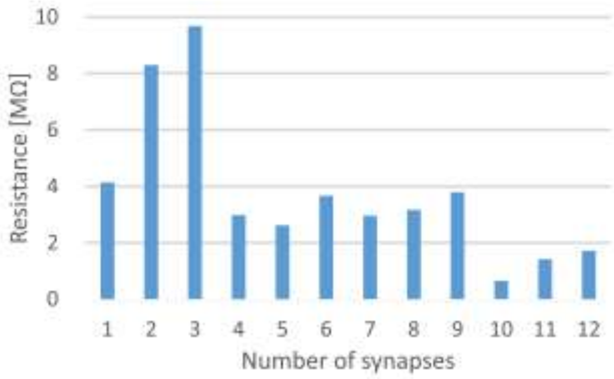

Figure 3: Resistance distribution of the a-IGZO films.

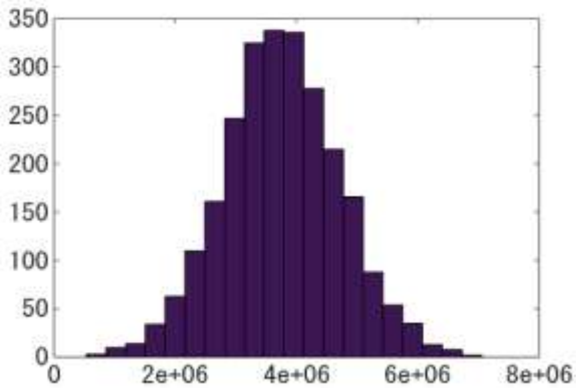

Figure 4: Resistance distribution example inputted into the logic simulation.

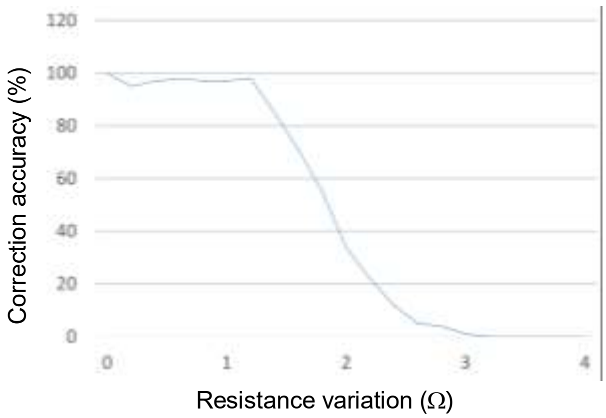

Figure 5: Dependence of the correction accuracy on the resistance variation.

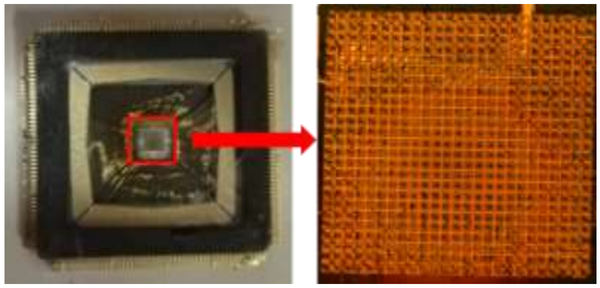

Figure 6: Cellular neural network and oxide semiconductor synapses.

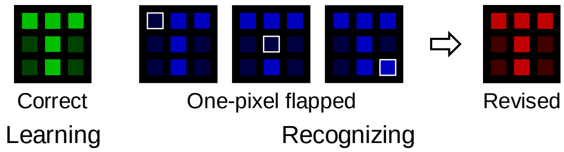

Figure 7: Real operation confirmed using an actual experiment.