Influence of the Oxygen Content in IGZO on the Pattern Recognition Rate in Pd/IGZO/p+-Si Memristors

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The indium-gallium-zinc-oxide (IGZO) is a potential material for low-cost wearable healthcare/IoT circuits and systems due to its compatibility with a low-temperature process along with a fair mobility on flexible and/or stretchable substrate [1]. Furthermore, the IGZO memristor is a promising device as the building block for the wearable neuromorphic computing system, the analog memory operation of which is based on the oxygen ion/vacancy-based redox reaction [2]. On the other hand, for a high pattern recognition rate in neuromorphic system, the potentiation and depression curve of the memristor should be designed to be as linear with the number of pulses as possible [1]. However, considering the RC delay and threshold conditions of the integration and fire (I&F) circuit, not only the linearity of the potentiation and depression curve but also the signal magnitude is important to design and optimize the memristor [2]. Moreover, the efficient and precise simulation framework linking the fabrication process and the pattern recognition rate is indispensable for the process-device-circuit co-design of neuromorphic systems. In this work, the influence of oxygen content in IGZO on the pattern recognition rate in Pd/IGZO/p^+-Si memristors is investigated and simulated with the emphasis on the linearity of potentiation and depression curves and the magnitude of memristor current. The oxygen content of IGZO was controlled by adjusting the oxygen flow rate (OFR) during the sputter-deposition of IGZO.

The larger OFR is, the smaller amount of oxygen vacancies in IGZO is. It makes the IGZO's fermi level lower and the current smaller (Fig. 1(a)). The change of memristor current according to OFR can also affect the potentiation/depression characteristics. A large amount of oxygen prevents abrupt change in conductance when the synaptic weight is electrically updated. Thus, the higher oxygen content in IGZO is, the potentiation and depression curves become more linear to the number of pulses (Fig. 1(b)). In order to calculate the pattern recognition rate, the measured synaptic behavior is modeled and also incorporated into the simulation frame work. Furthermore, the convolutional neural network (CNN)-based weight update simulation is performed by using 60,000 MNIST handwritten digit databases. If the I&F circuit shown in Fig. 1(c) is not taken into account, the larger OFR, the better recognition rate due to better linearity, however considering the I&F circuit, the tendency is oppositely converted (Fig. 1(d)). Our result is potentially useful for the process-device-circuit co-design of the IGZO memristor-based neuromorphic systems.

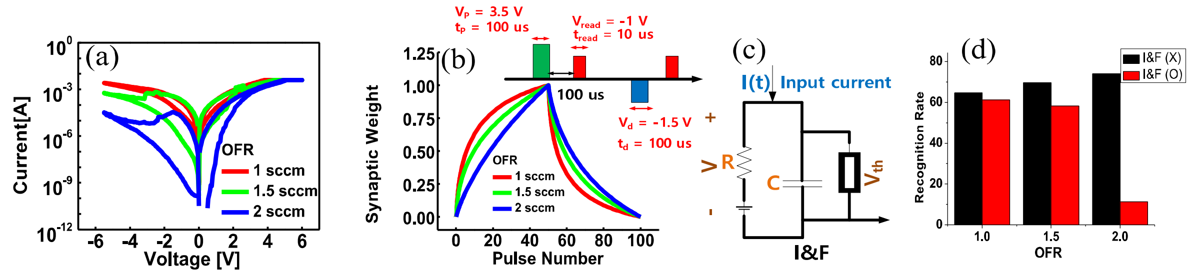

Fig. 1. (a) Measured OFR-dependent I-V characteristic and (b) the potentiation/depression normalized synaptic weight of Pd/IGZO/p^+-Si memristor. (c) Schematic of I&F circuit and (d) the simulated recognition rate with or without I&F circuit.

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