Highly Reliable Bi_2O_2Se Dendritic Neuron for Spatial-Temporal Signal Processing

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Artificial intelligence (AI) has shown remarkable performance in various tasks by mimicking biological neurons and synapses with simplified models; however, a lack of neuron functionalities can lead the energy inefficiency and performance degradation while handling complex tasks. Biological neurons process input signals nonlinearly to handle unstructured data, with the branches of neurons called dendrites. In this study, we demonstrate a compact artificial dendritic neuron using bismuth oxyselenide (Bi_2O_2Se)-based memristors. Bi_2O_2Se was grown on metal-patterned substrates via a low-temperature selenization process at 350 °C, which was confirmed through XRD and Raman analysis. The fabricated device achieved excellent endurance characteristics of over 10^6 and an on/off ratio of over 10^6. In addition, the layered structure of Bi_2O_2Se, limiting the metal injection, results in dynamic memristor by the formation of unstable conductive filaments. The dynamic characteristic of the Bi2O2Se dendritic neuron is modelled by the pulse measurement. We confirmed that Bi_2O_2Se dendritic neurons can process spatial temporal signals and construct reservoir networks and dendritic neural networks based on the Bi_2O_2Se dendritic neurons. The designed neural network achieved a recognition rate of 95% in MNIST digit recognition and 85% in the street view house numbers (SVHN) dataset. The proposed research is expected to pave the way toward the hardware implementations of neural networks beyond simplified neuron models.

Figures

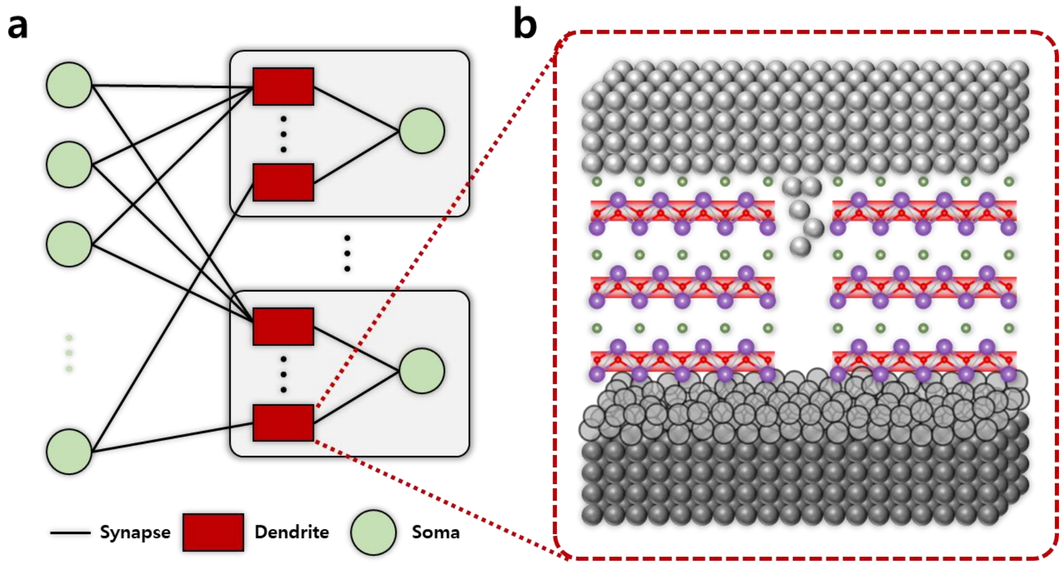

Figure 1: (a) Schematic illustration of the dendritic neural network. (b) Device schematic of the Bi_2O_2Se memristive dendritic neuron.