AMBIPOLAR OXIDE THIN-FILM TRANSISTOR-BASED ARTIFICIAL SYNAPSES

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Many intelligent behaviors, such as learning and perception, are affected by external environmental stimuli in the human nervous system. Therefore, one of the significant challenges is to develop an artificial synapse device with reconfigurable excitatory and inhibitory responses for artificial intelligence systems with human-like perceptual capability.

Here, we developed a gate-tunable synaptic device using ambipolar oxide thin-film transistors (TFTs)and successfully demonstrated dynamic reconfigurable excitatory and inhibitory synaptic responses in a single device, which can emulate the fundamental synaptic responses for developing diverse functionalities of the biological nervous system. Figure 1 shows the schematics of the operation of ambipolar oxide thin-film transistors for gate-tunable synaptic device controlling dynamically reconfigurable excitatory and inhibitory synaptic responses. Since the balanced ambipolarity is significant, moreover, a boron-incorporated SnO (SnO:B) oxide semiconductor channel was newly developed to improve the ambipolarity. The ambipolar SnO:B-TFT could be fabricated with good reproductivity at the low process temperature of 250 ^{o}C and exhibited good TFT performances such as nearly zero switching voltage, the saturation mobility of ~1.3 $cm^2V^{-1}s^{-1}$, *s*-value of ~1.1 $Vdecade^{-1}$, and on/off-current ratio of ~8×10^3 for *p*-channel mode, while ~0.14 $cm^2V^{-1}s^{-1}$, ~2.2 $Vdecade^{-1}$and ~1×10^3 for *n*-channel modes, respectively. The ambipolar device imitated potentiation/depression behaviors in both excitatory and inhibitory synaptic responses using *p*- and *n*- channel transport, respectively, by tuning a gate bias. The low-power consumption of < 20 and <2 nJ per pulse for the excitatory and inhibitory operation was also achieved. The presented device operated in an ambient atmosphere and confirmed good operation reliability over 5,000 pulses and long-term air environmental stability. Moreover, the dual-mode operation also tunes the frequency-dependent synaptic plasticity to frequency-independent plasticity, enabling versatile applications. Compared to previously reported devices using 2D materials, the presented oxide semiconductor device offers several advantages such as better conductance update property, low power consumption, and easy fabrication process using conventional film growth method with good reproductivity.

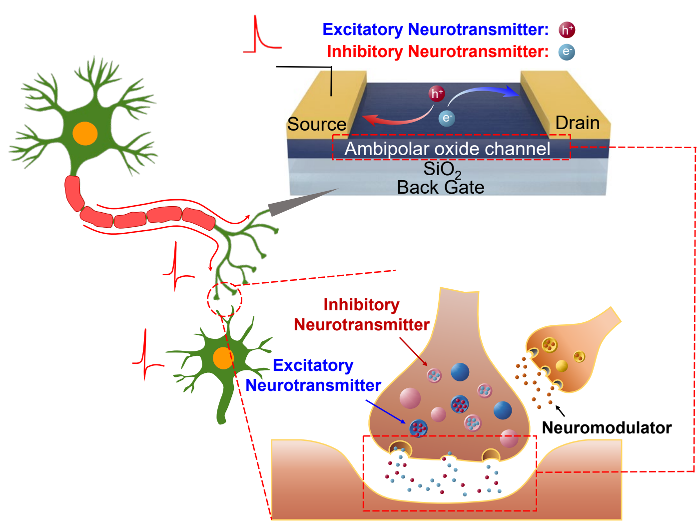

Figure 1 A gate-tunable synaptic device controlling dynamically reconfigurable excitatory and inhibitory synaptic responses was developed using ambipolar oxide thin-film transistors with a boron-incorporated SnO (SnO:B) channel.