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Memristor Based on TiO_x/Al_2O_3 Bilayer as Flexible Artificial Synapse for Neuromorphic Electronics

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Introduction In recent years, the memristor has become a new type of component that simulates nerve synapses. Although memristor devices manufactured on rigid substrates generally demonstrate reliable storage performance, the adaptability of memristor to large strains is still severely restricted during bending or stretching [15]. To obtain flexible and outstanding synapse characteristic memristor devices, the $Pt/TiOx/Al_2O_3/Pt/ITO$ flexible memristor is designed in this work to implement biological synaptic function in the brain-inspired computing systems.

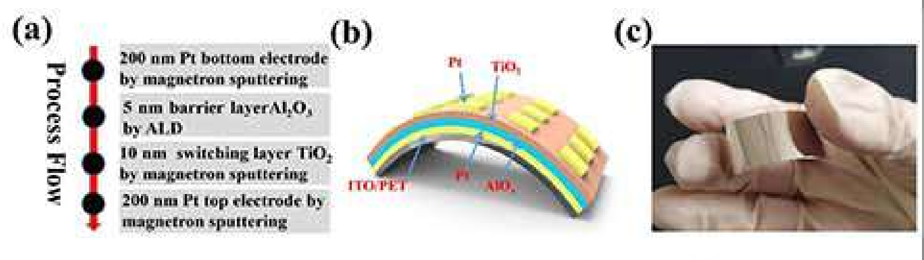

Fig. 1. (a) Device 1 fabrication processes. (b) and (c) Are schematic structure and photograph of the Device 1 flexible memristor, respectively.

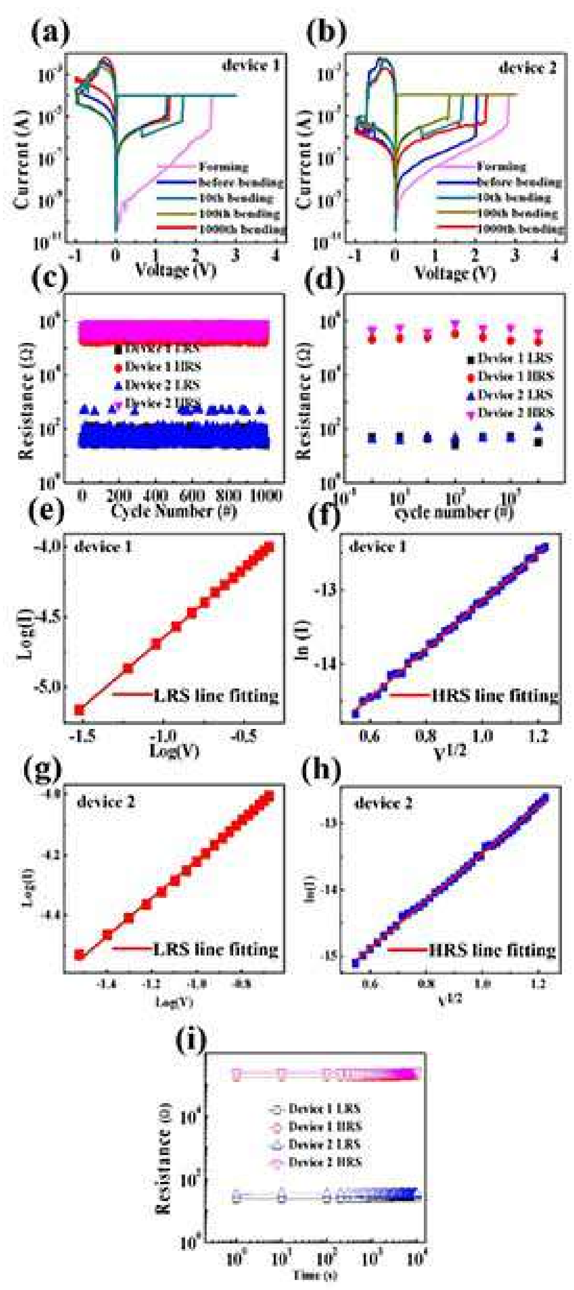

Fig. 2. Typical *I–V* curves of (a) Device 1 and (b) Device 2, before and after 10, 100, 1000 bending, respectively. (c) and (d) Endurance test results of Device 1 and Device 2, respectively. (e) and (f) Double-logarithmic LRS and HRS *I–V* curves of the Device 1. (g) and (h) Double-logarithmic LRS and HRS *I–V* curves of the Device 2. (i) Retention test of the LRS and HRS of Device 1 and Device 2, respectively.

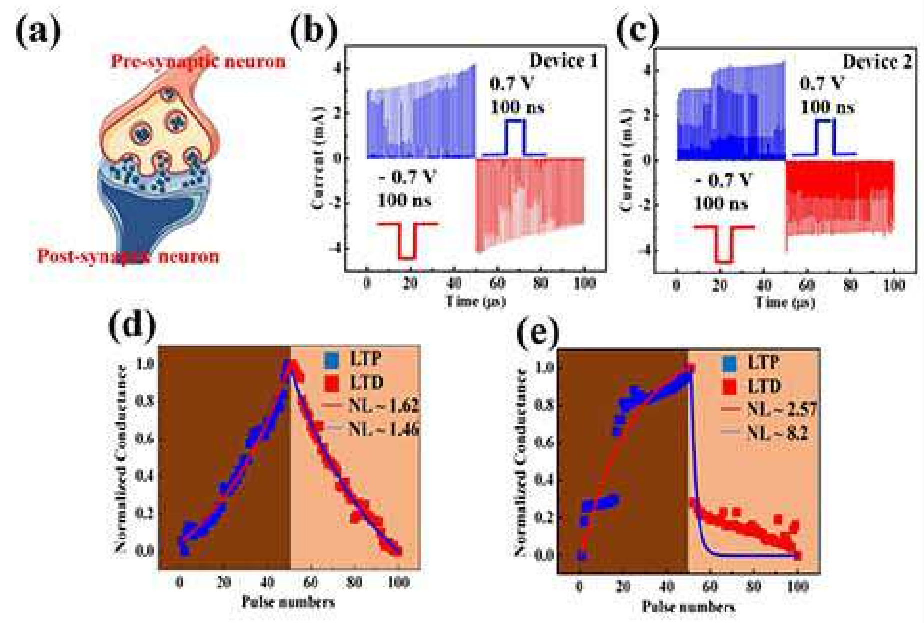

Fig. 3. (a) Schematic of synapse. (b) and (c) Current output under 50 repeated positive pulse (0.7 V/100 ns, interval times is 1 μs) and 50 repeated negative pulse (−0.7 V/100 ns, interval times is 1 μs) of Device 1 and 2, respectively. (d) and (e) Reproducible conductance (synaptic weight) modulation under 50 repeated positive (potentiation) pulses and 50 repeated negative (depression) pulses of Device 1 and 2, respectively.

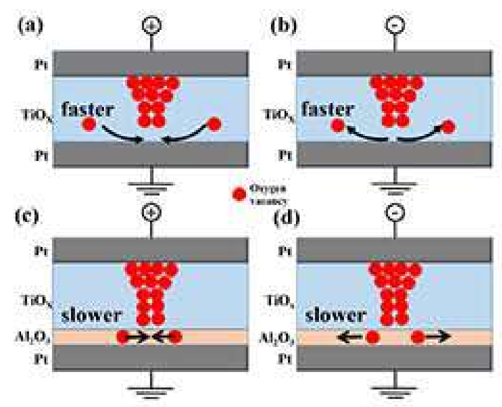

Fig. 4. Schematic illustration of set and reset process in (a) and (b) Device 2 and (c) and (d) Device 1, respectively.

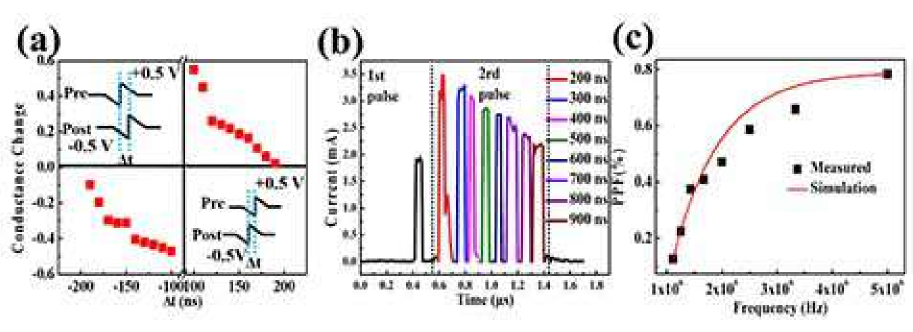

Fig. 5. (a) Asymmetric Hebbian STDP rule obtained in Device 1. (b) PPF effect obtained in Device 1 by applying two paired pulses (0.8 V, 100 ns) at eight different intervals. (c) PPF ratio as a function of pulse interval.

Conclusions In summary, the $Pt/TiO_x/Al_2O_3/Pt/ITO$ was prepared to study its artificial synaptic behaviors. Excellent mechanical property was confirmed with 1000 times bending. 100 times ON/OFF ratio is realized. The LTP and LTD nonlinearity in the $Pt/TiO_x/Al_2O_3/Pt/ITO$ were decreased from 2.57 to 1.46 and 8.2 to 1.62, respectively, compared to the $Pt/TiO_x/Pt/ITO$ without Al_2O_3 diffusion barrier layer. The synaptic functions STDP and PPF were successfully mimicked. This flexible memristor has shown great potential in the next generation of wearable electronic products and artificial neural network applications.

References [1] C.X. Wu, Adv. Mater., vol. 29, no. 10, p. 1602890, 2017.

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