Switching Dynamic Modulation of Ag-Ag_2S Nanoparticle Networks for Hardware-Based Reservoir Computing

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Reservoir computing (RC) is an alternative framework of recurrent neural networks that enable temporal information processing with greatly reduced learning complexity. The RC-based device has been successfully realized to gain high speed and power-efficient computing. However, how to optimize the reservoir state in the device is still a big challenge. To solve computational tasks, the device requires high dimensionality, nonlinearity, short-term memory (or fading memory), and separation property[1]. Recently, atomic switch networks are a promising candidate to perform RC devices, which the interconnection of the random networks could offer increased interconnectivity of the nodes in the reservoir. The Ag-Ag_2S-based atomic switch has been proposed to mimic the human brain's synaptic behavior, which could be considered for the RC device [2]. In this work, we focus on the short-term memory features to ensure that the reservoir state depends on the present and recent-past inputs, but the influence of past input is faded out. The hardware-based RC is implemented using Ag-Ag_2S nanoparticle (NP) networks. The Ag-Ag_2S NPs are synthesized via a Brust-Schiffrin method. The Pt electrodes with 40 nm of thickness are deposited on a SiO_2/Si substrate, and the reservoir device is formed by drop-casting the NPs on the gap of electrodes. During DC-voltage sweeps, the device exhibits a resistive switching behavior, as shown in **Fig.1**. The high current state and the low current state can lead to growth and shrinkage of the conductive filament in the device, suggesting interconnectivity of the NPs in the reservoir device. We use input voltage pulse and vary the %duty parameter to investigate the short-term memory feature, as shown in **Fig.2**. Under pulse train, the current increase with increasing the pulse number at 50%duty, called learning behavior. The 75%duty pulse train lead to decreasing of the current, indicating forgetting behavior. This result suggests that the short-term memory feature can be obtained. In summary, switching dynamic states in the device could be modulated by adjusting pulse parameters, providing high performance for computation application.

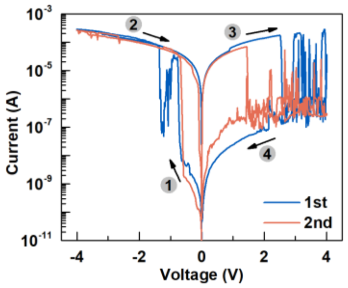

Fig.1 I-V characteristic of the device applied voltage from 0V to -5V, -5V to 0V, 0V to 5V, and 5V to 0V continuously.

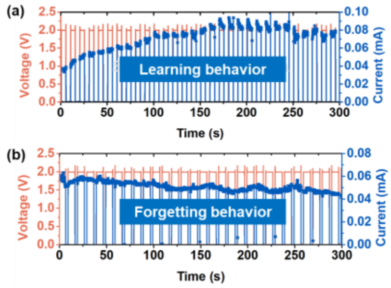

Fig.2 Current responses after applying 2 V pulse with 50%duty (a), and 75%duty (b).

Refs. [1] G. Tanaka, *et al. Neural Netw.* **115**, 100-123 (2019). [2] Hadiyawarman *et al. Jpn. J. Appl. Phys.* **60**, SCCF02 (2021).