Multiple resistive states in vanadium dioxide (VO_2) memristive devices

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Introduction

Traditional computers are based on the von Neumann architecture. During computing, the data is continuously shuttled back and forth between the physically separate processing and memory units, which leads to significant area/energy inefficiency and rate limitation. This is known as the von Neumann bottleneck[1].

Many attempts have been undertaken to step beyond the von Neumann bottleneck, such as the brain-inspired neuromorphic computer beyond CMOS devices using novel circuit elements. Among these, the memristor is the main functional unit.

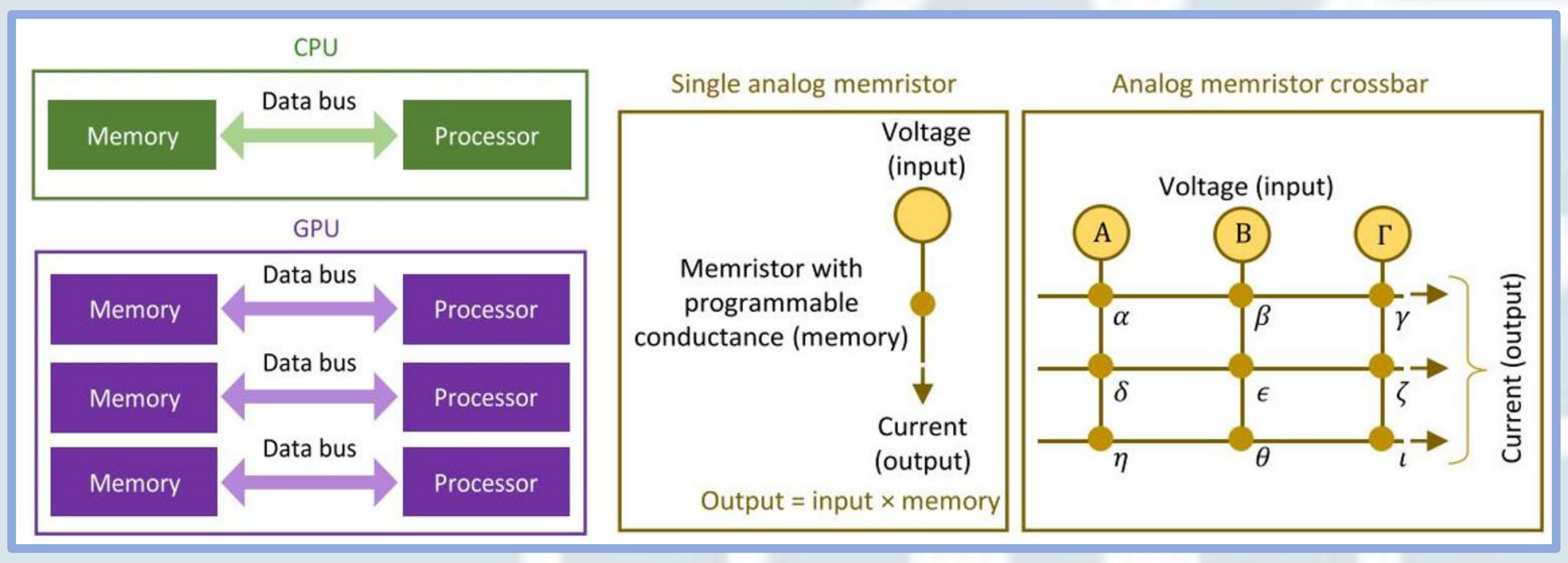


Fig. 1 The computing process in CPU, GPU and memristors.[2]

Memristors are also known as resistive switching devices. During computing, the intermediate results can be stored as conductance locally in each device. Organized into artificial neural networks (ANNs), the conductance can represent synaptic weights. Therefore, it will be helpful to have memristors with tunable weights for ANNs with training purposes.

Materials & Methods

Vanadium Dioxide (VO_2)

- Sharp and hysteretic temperature-dependent insulator-to-metal transition (IMT)
- Several orders of magnitude resistivity change
- Stable intermedium resistive states

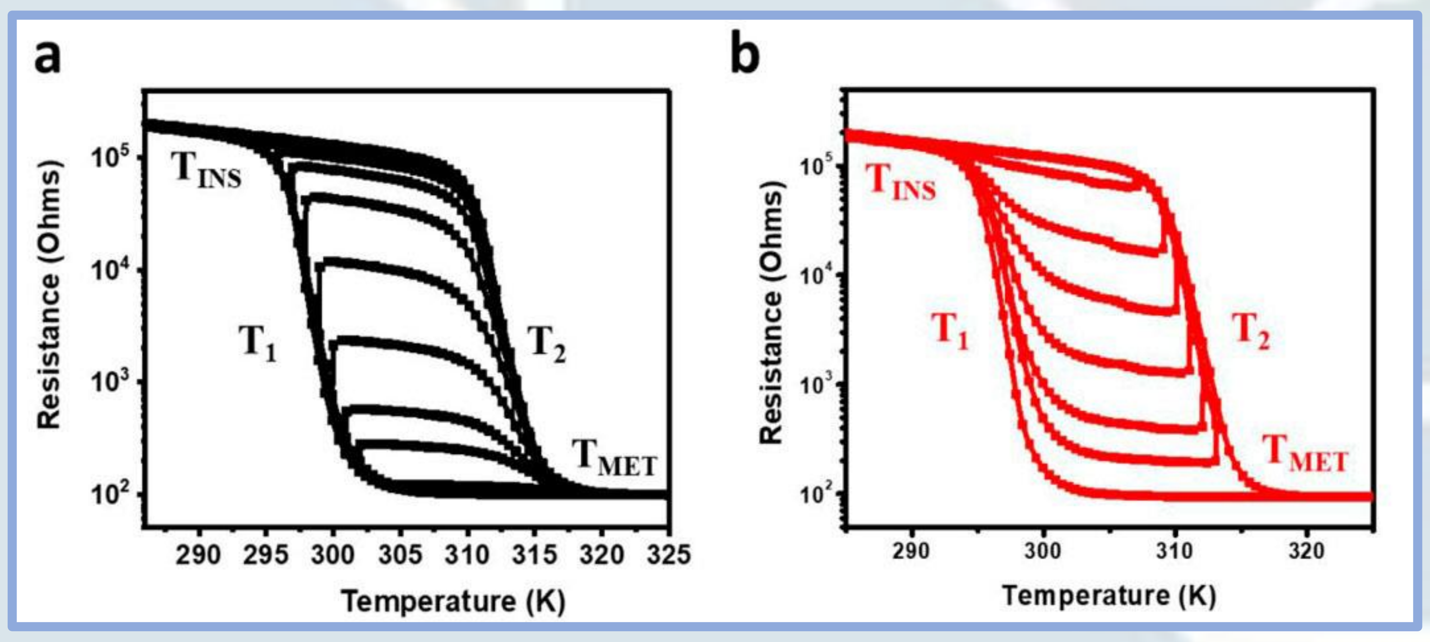


Fig. 2 Temperature-dependent resistivity of VO_2 film.[3]

Pulsed Laser Deposition (PLD)

- Target: V_2O_3 tablet
- Laser energy density of ~1.3 J/cm^2
- Repetition rate of 10 Hz
- Deposition temperature: 400 ºC

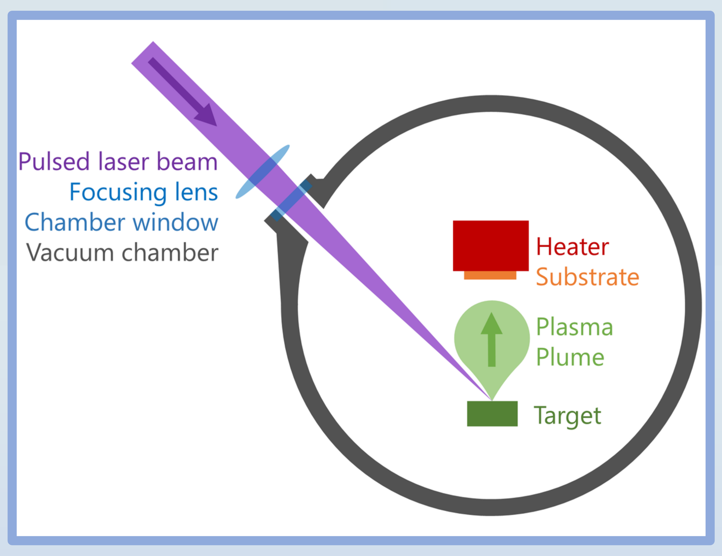
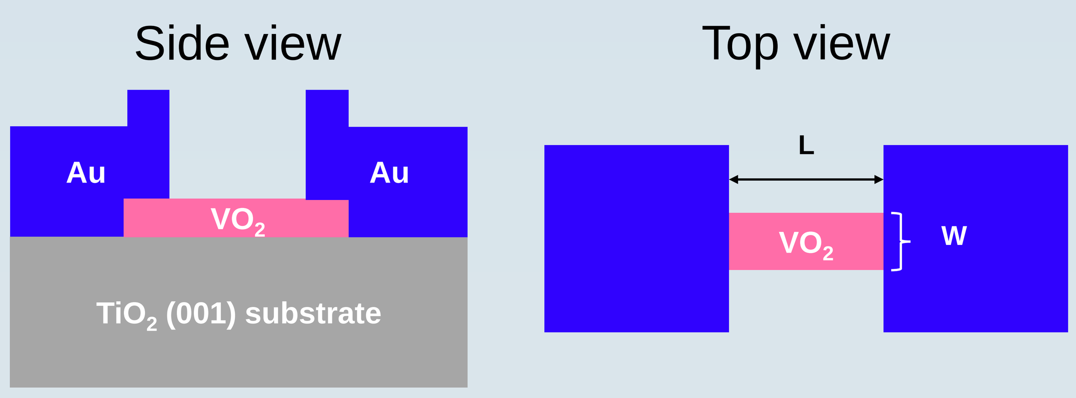


Fig. 3 Schematic of PLD.

Results & Conclusions



Thickness: 10 nm

L: 20 μm; 15 μm; 10 μm

W: 5 μm; 10 μm

- Repeatable unipolar switching behavior has been observed.
- More power is required to switch for the first cycle.
- Second switch occurs during RESET with high compliance current.
- By adjusting the compliance and voltage bias, the resistive states can be tuned and stabilized at desired value.

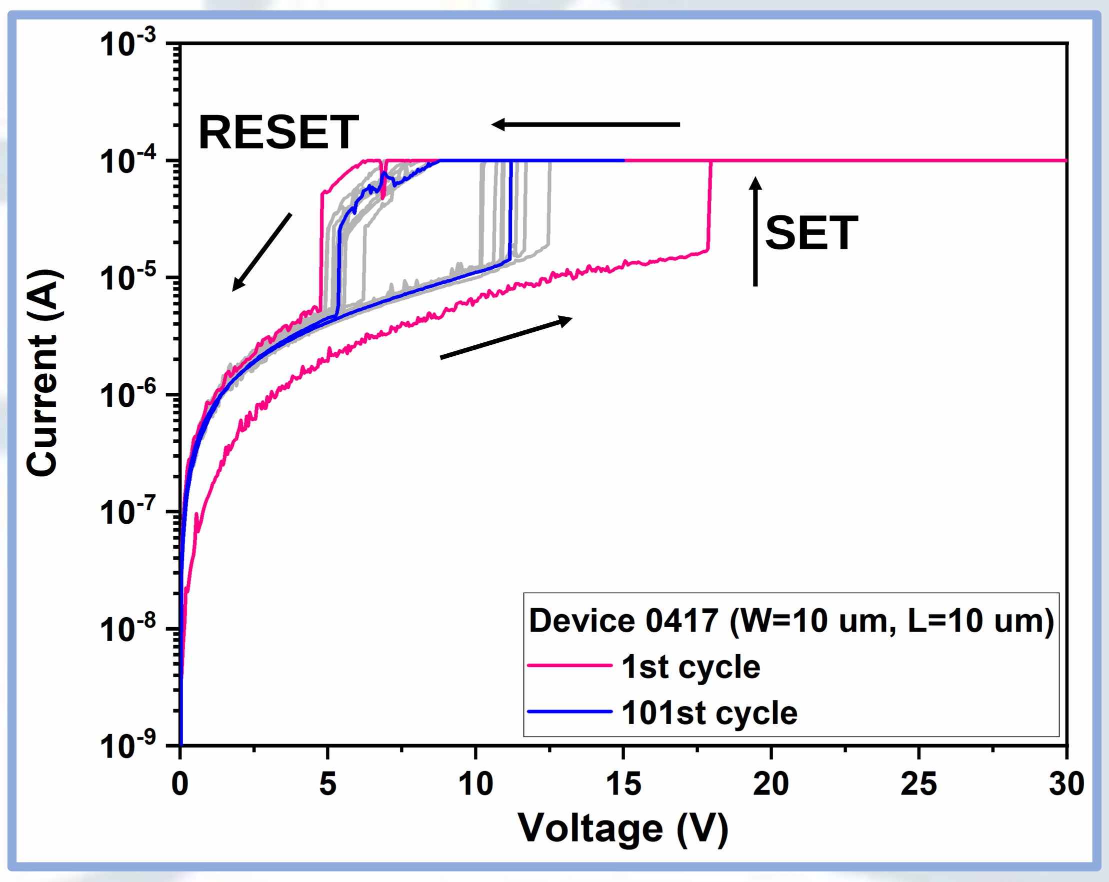


Fig. 4 Voltage linear sweep for 101 cycles.

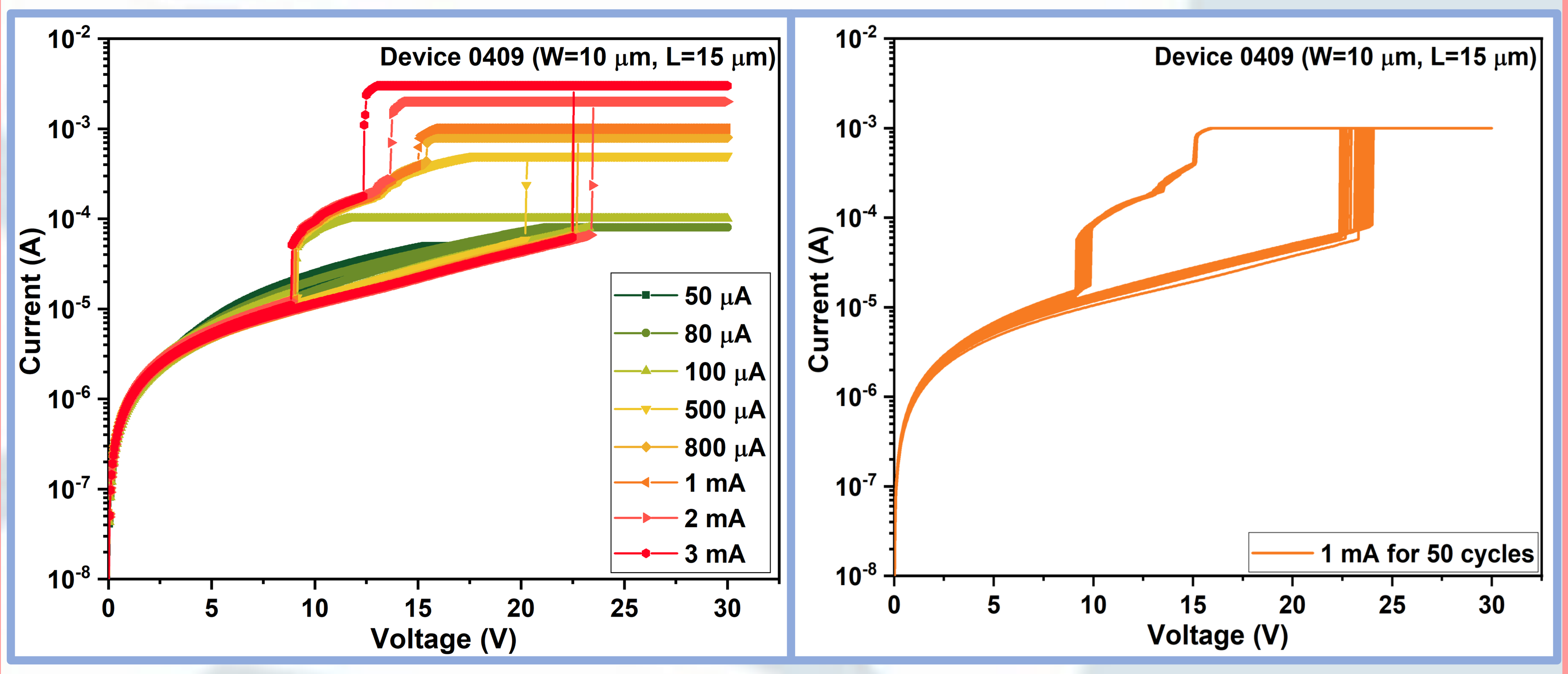


Fig. 5 Left Voltage linear sweep with different compliances.
Right Voltage linear sweep with compliance at 1 mA for 50 cycles.

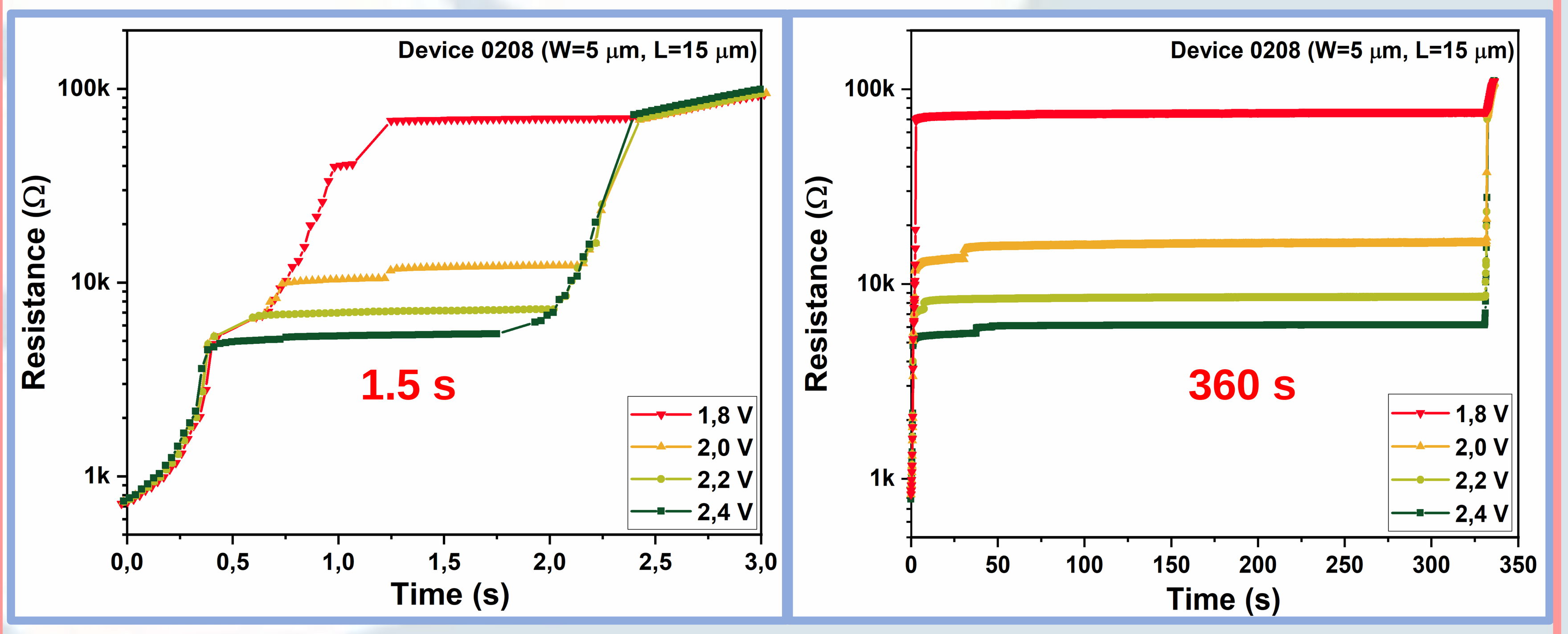


Fig. 6 Stable resistive states under different voltage bias.

References

[1] A. X. Gray et al, Phys. Rev. Lett. **2016**, 116, 116403.

[2] J. D. Kendall, Appl. Phys. Rev. **2020**, 7, 011305.

[3] A. Rana et al. Sci. Rep. **2020**, 10, 3293.