Endurance Cycling of 3D Halide Perovskite Memristors Investigating Degradation Mechanisms and Electrode Dependence

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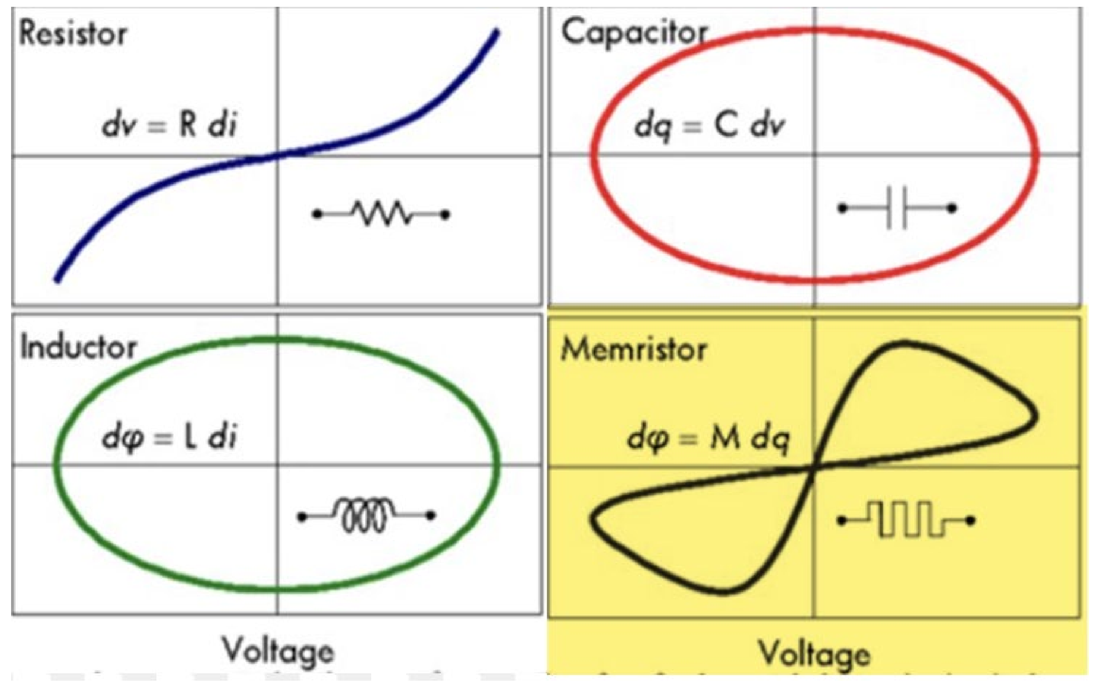
Introduction

Halide perovskites are promising low-cost, tunable alternatives to traditional semiconductors for memristors, electronic components that change resistance based on voltage history and retain their state after power-off, enabling non-volatile memory. My prior work demonstrated resistive switching in 3D perovskite films with silver (Ag) and carbon (C) top electrodes. However, cycling stability under repeated write-erase operations remains poorly understood. This project tracks switching voltages and resistance states across many cycles, comparing Ag vs. C electrodes to identify degradation and determine endurance limits

a)



b)

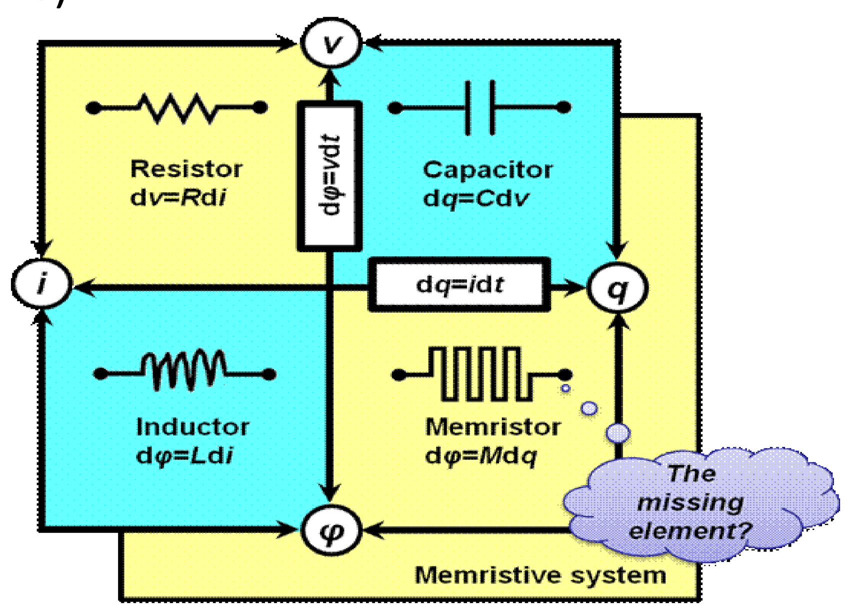


Figure 1(a) The four fundamental circuit elements. (b) Describes the memristor ($d\phi = M \cdot dq$) is the missing fourth element, relating magnetic flux to charge, enabling history-dependent resistance.

Results

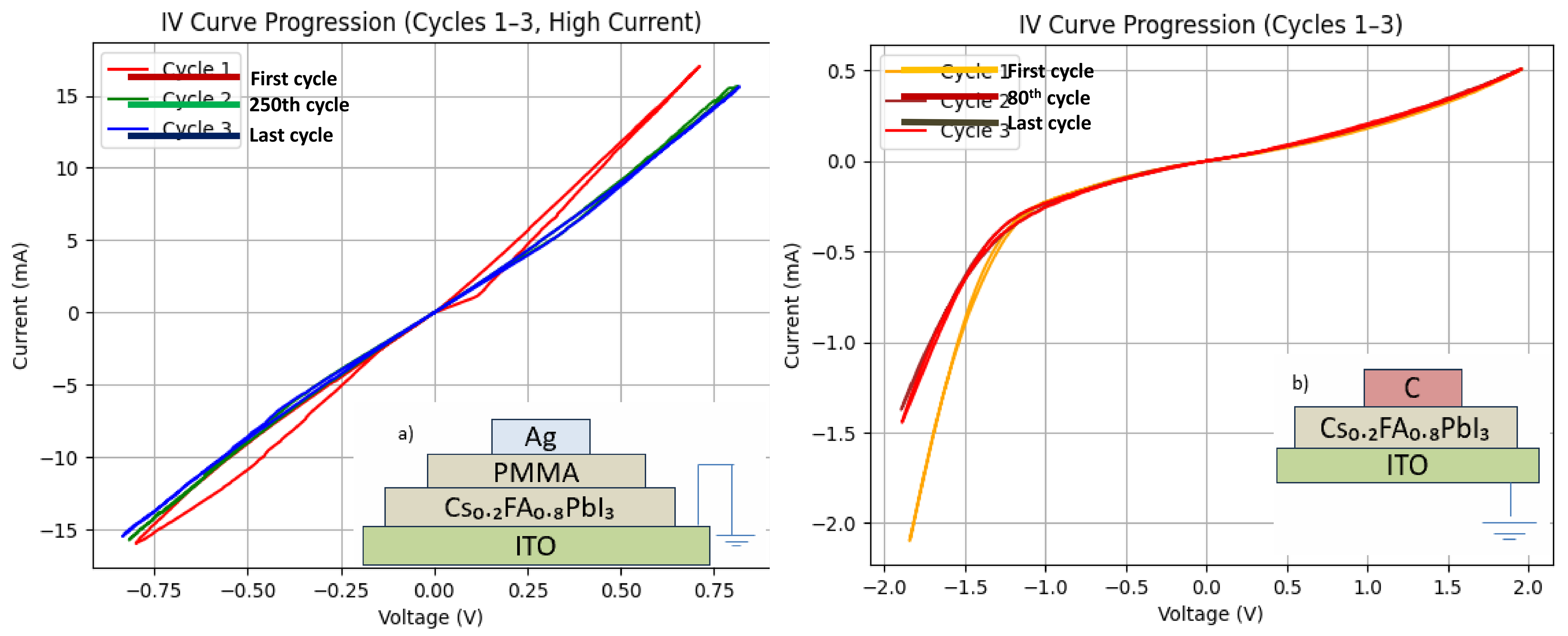


Figure 2(a) represents the thin-film device with a silver electrode and a poly(methyl methacrylate) layer, as well as the resistive switching behavior of silver. Figure 2(b) shows the carbon-based device with an ITO electrode and the resistive switching behavior of carbon. In both configurations, a positive bias is applied to the electrode and a negative bias to the ITO.

Procedure and Description

a) b)

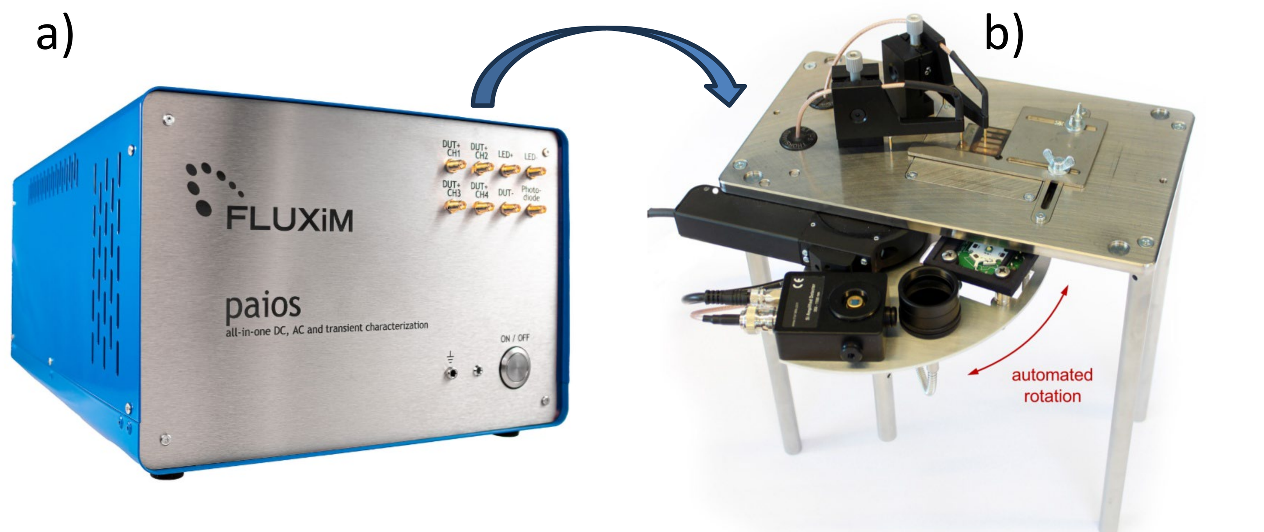


Figure 3 (a) FLUXiM PAIOS connected to the sample on (b) via OUT+ (to electrode) and OUT– (to GND) pins for voltage application and endurance cycling. (b) Automated stage with dark box for controlled light illumination.

Description

The PAIOS system was connected to the sample via OUT+ (top electrode) and OUT– (GND). A complete voltage cycle was programmed: 0 → +2 V → 0 → −2 V → 0. Each full cycle took 1 minute and 34 seconds. This cycle was repeated 500 times, totaling approximately 14 hours of continuous cycling. The setup was left running overnight, and switching voltages and resistance states were recorded to observe electrode-dependent degradation.

Observations

The sweeps did not run for the same number of cycles. The carbon device was cut off at approximately 150 cycles, while the silver device completed the full 500 cycles, however, the reason for the early cutoff in the carbon device is unknown. The silver electrode device shows higher current initially, likely due to metallic filament formation, but begins to degrade over subsequent cycles, with reduced current and less stable behavior. In contrast, the carbon device appears more consistent in curve shape across sweeps, though it still exhibits some degradation over time, with an approximate 0.7 mA drop in current. Since these samples were carried over from the previous semester, both devices show signs of aging, with the degradation being more pronounced in the silver device.

Figure 4 (a) Carbon shows minimal to no degradation

Figure 4 (b) Silver shows degradation

What's next?

Temperature Dependent Measurements

- Study device behavior across a range of temperatures to better understand ion migration, filament formation, and thermal degradation mechanisms.

Expand Electrode Material

- Investigate alternative top electrodes (Au, Cu, and hybrid-based) to understand further how electrode reliability influences switching and endurance.

High-Cycle Endurance Analysis

- Perform extended cycling (10^3–10^5 cycles) to evaluate long-term reliability, track a gradual shift in parameter, and establish a failure threshold for different electrode materials.

References and Acknowledgments

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