Enhancing Semiconductor Memristors with Halide Perovskites

Diego Curiel, Electrical Engineering
Mentor: Nicholas Rolston, Assistant Professor | Saivineeth Penukula, PhD student
School of Electrical, Computer and Energy Engineering

Introduction

Traditional semiconductor materials face challenges in balancing performance, stability, and cost. Halide perovskites offer a promising alternative due to their tunable electronic properties and low-cost, solution-based fabrication. These materials can be easily formed into thin films on transparent conductive substrates like indium tin oxide (ITO). This research explores the use of perovskite materials in memristor devices, electronic components that change resistance based on applied voltage and retain memory of previous states. By investigating different top electrode materials, this study aims to enhance the electrical switching behavior and stability of perovskite-based memristors for next-generation semiconductor applications

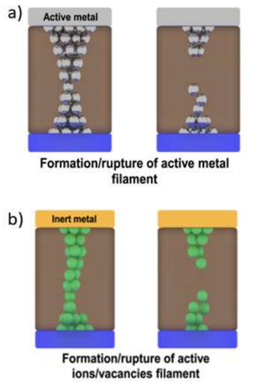

Figure 1: (a) Under an applied voltage, active metal atoms migrate through the perovskite layer to form a conductive filament. Reversing the voltage breaks the filament, switching the device between low and high resistance states. (b) movement of ions or vacancies within the perovskite is forming and rupturing conductive paths that control the device's resistance.

Procedures

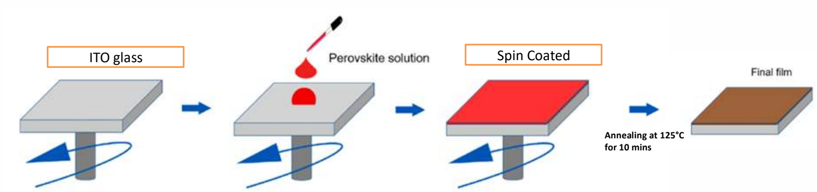

Figure 2: Demonstrates the process of applying the perovskite solution ($Cs_{0.2}FA_{0.8}PbI_3$) onto the ITO glass. With the exception of adding an extra layer of polymer PMMA (polymethyl methacrylate)

Results

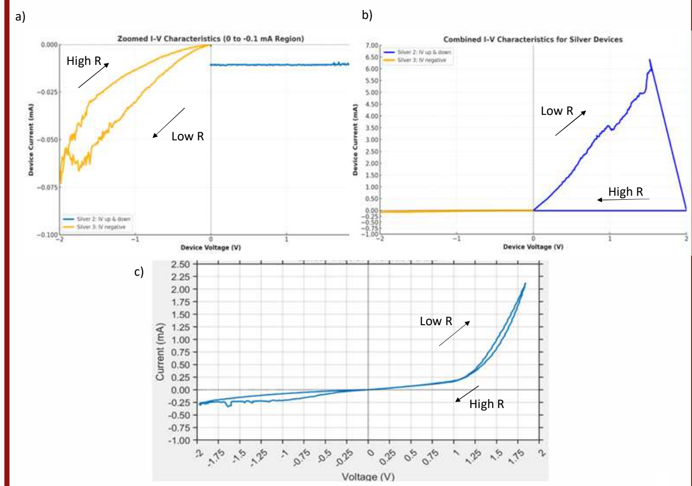

Figure 3: (a) Silver RS negative, (b) Silver RS positive, (c) Carbon positive and negative combined. R is defined as Resistance

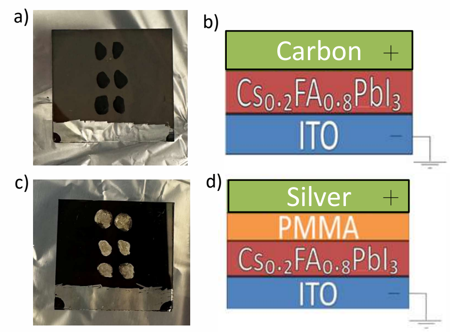

Figure 4: (a) Photograph of a carbon-based electrode on an indium tin oxide (ITO) film, where positive ions accumulated on the electrode and negative ions on the exposed ITO area. (b) Representation of 4a (c) Photograph of a silver-based electrode with a thin poly(methyl methacrylate) (PMMA) layer to enable charge transport and conduction of the active metal. (d) Representation of 4b.

Observations

Effects of Carbon Electrode

- A slight resistive switching was observed in the devices. The addition of the polymer introduced a negative effect on performance, whereas the electrode without the polymer layer exhibited better stability. Despite some disruption in both cases, the system demonstrated a clear reaction, indicating a complete and successful switching process.

Effects of Silver Electrode

- The device exhibited a clear resistive response due to the intrinsic properties of the active metal. It showed greater stability at the positive end and produced a reaction similar to the carbon-based electrode, though with slightly lower resistance.

Future Endeavors

- Evaluate repeated switching cycles to determine if the device functions effectively as a memristor.
- Test alternative electrode materials to improve switching consistency and stability.
- Apply refined voltage protocols to enhance film reliability and device performance

FURI

References and Acknowledgments

Tianwei Duan, Jiajia Zha, Ning Lin, Zhongrui Wang, Chaoliang Tan, Yuanyuan Zhou, The rise of metal halide perovskite memristors for edge computing, Device, Volume 1, Issue 6, 2023, 100221, ISSN 2666-9986, https://doi.org/10.1016/j.device.2023.100221.
Yan, K., Peng, M., Yu, X., Cai, X., Chen, S., Hu, H., Chen, B., Gao, X., Dong, B., & Zou, D. (2016, January 25). High-performance perovskite memristor based on methyl ammonium lead halides. Journal of Materials Chemistry C. https://pubs.rsc.org/en/content/articlelanding/2016/tc/c6tc00141f

I would like to sincerely acknowledge Professor Rolston and Saivineeth Penukula for their constant support and guidance. Their encouragement and the welcoming environment they fostered have greatly helped me in this project.

Ira A. Fulton Schools of Engineering
Arizona State University