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High-Performance Optically Readable Nanophotonic Resistive Switch

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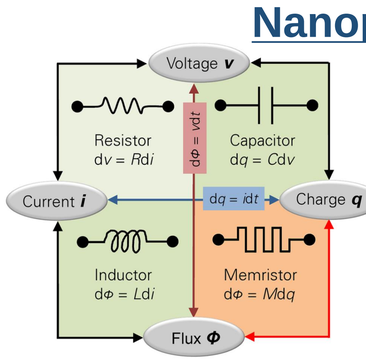
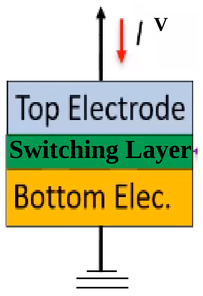
Abstract: We present a double-slot nanophotonic structure for optically accessible resistive switching at a wavelength of 1550 nm. This silicon-based device distinguishes states by detecting two distinct optical intensity levels, achieved through the formation and annihilation of Ag filaments within the SiO_2 region via applied voltage. The engineered device geometry enhances the impact of p-Si on Ag filaments, enabling effective opto-conductive filament interaction. Additionally, the proposed optical switch exhibits broadband propagation from 1500 nm to 1600 nm. Our device offers high cycling endurance, low operating voltage, and an ultrahigh extinction ratio of 35 dB, demonstrating potential for data storage, optical interconnects, neuromorphic computing, and high-density photonic circuits.

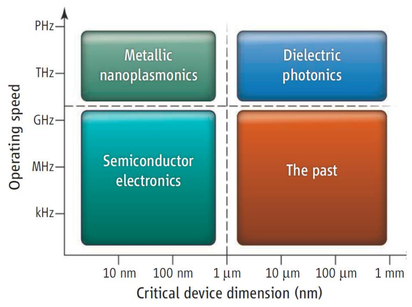
Nanophotonic Resistive Switching



Forth missing passive element

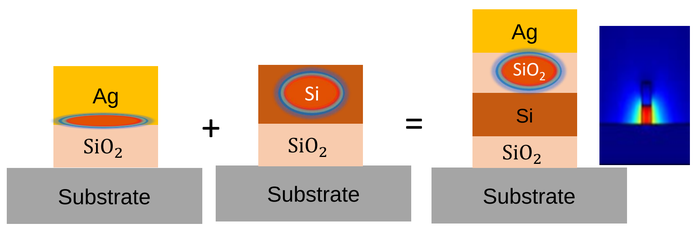


MIM based Resistive Switch



Importance of Plasmonics

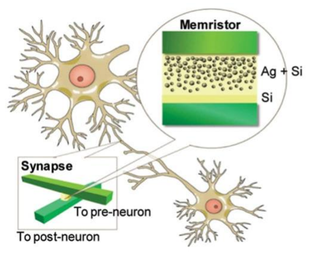
Source: M. L. Brongersma et. al., Science, 328(5977), 2010.



Plasmonic Waveguide | Dielectric Waveguide | Hybrid Plasmonic Waveguide

Hybridization of Plasmonic and Dielectric Modes

Source: *R. F. Oulton et al., Nature Photonics 2008.*

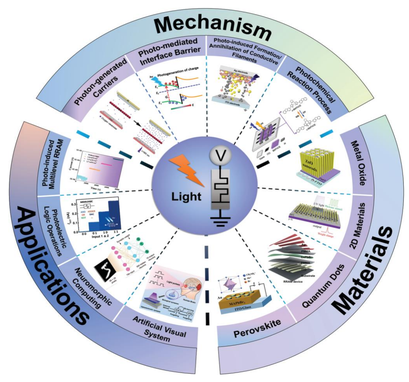


Memristors as Artificial Synapses in Neuromorphic Systems

Ref. W. Wang, et.al., Adv. Sci. 2022.

Benefits of Nanophotonic Resistive Switching

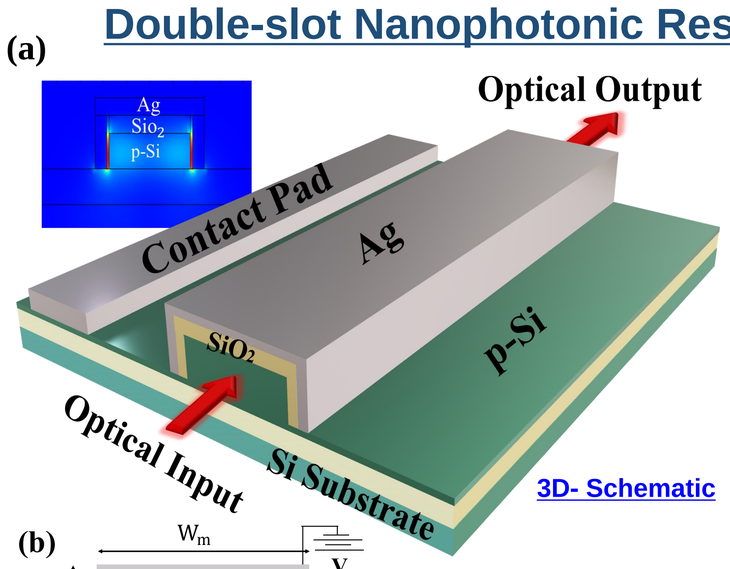
- ❖Forth missing passive element
- ❖Memristive: Memory + Register
- ❖Huge data handling capability
- ❖Wide bandwidth
- ❖Improved EM interference immunity
- ❖Seamless Integration with Photonic Circuits
- ❖Ideal for High-Speed Applications



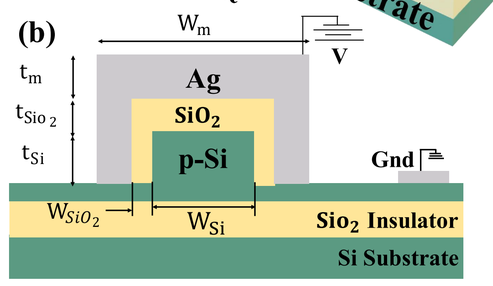
Mechanisms, Materials, and Applications of the Photonic Memristive

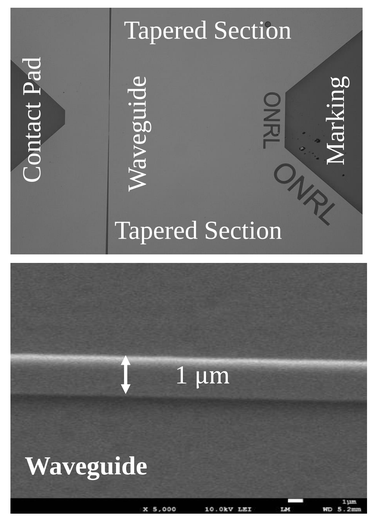
Ref. W. Wang, et.al., Adv. Sci. 2022.

Double-slot Nanophotonic Resistive Switch



3D- Schematic

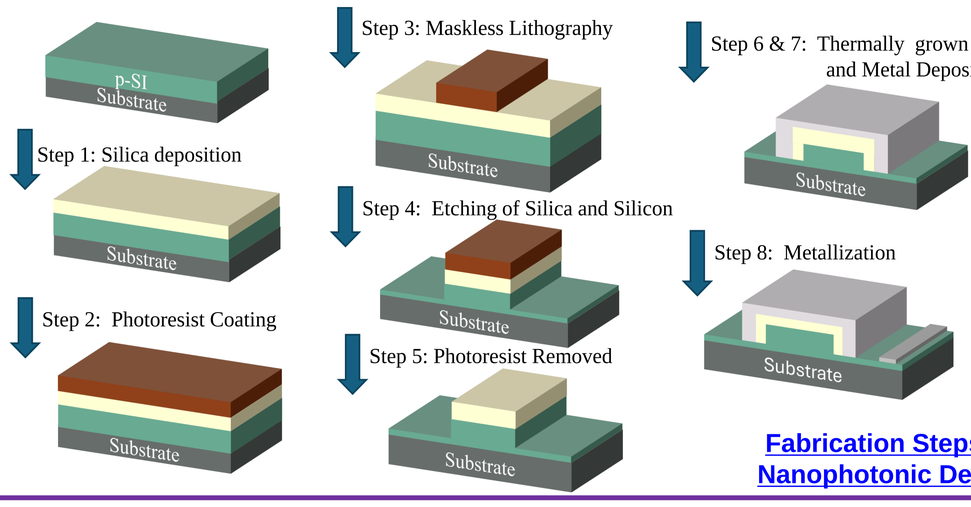




Microscopic & SEM Images

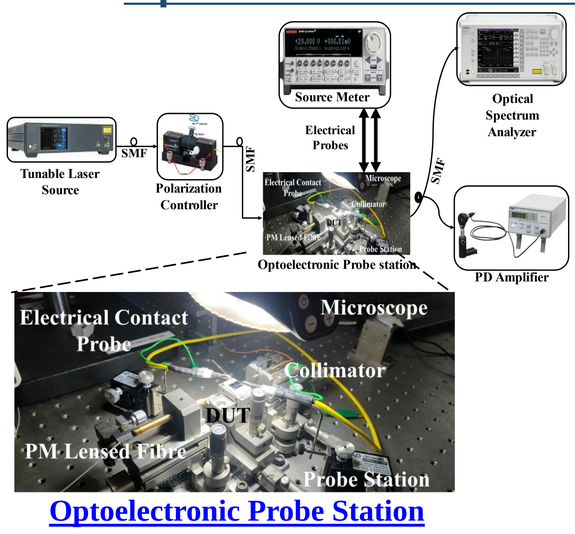
Uniqueness

- ❖Introduction of the vertical double slots
- ❖High extension ratio and endurance achieved
- ❖CMOS-compatible fabrication

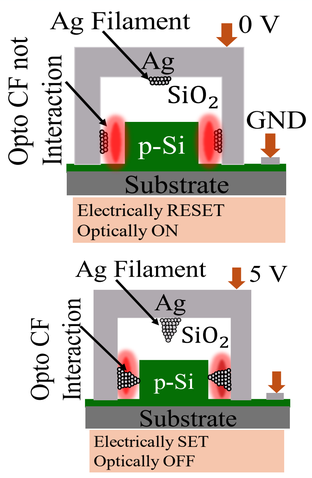


Fabrication Steps of Nanophotonic Device

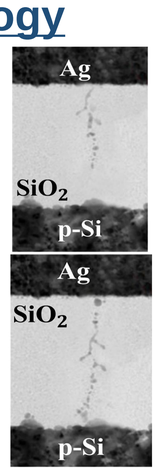
Optoelectronic Measurements & Methodology



Optoelectronic Probe Station



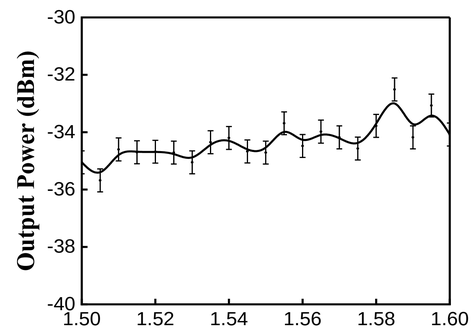
CFs Rapture and Formation

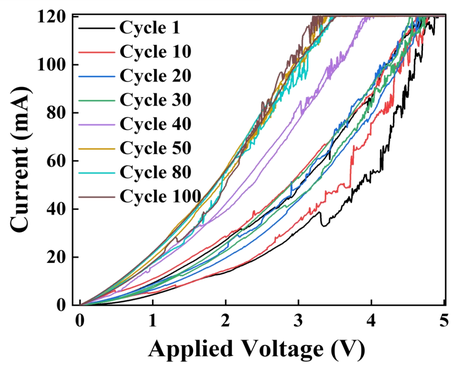


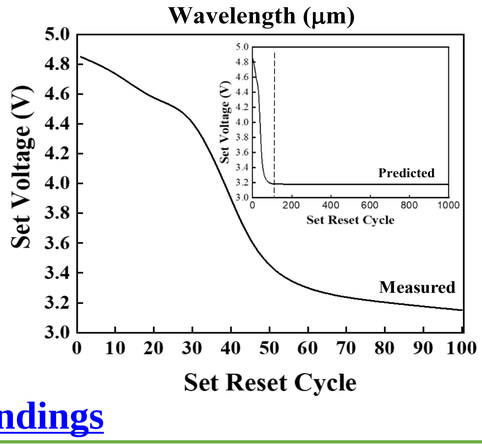
In situ: Metal Filament Morphology

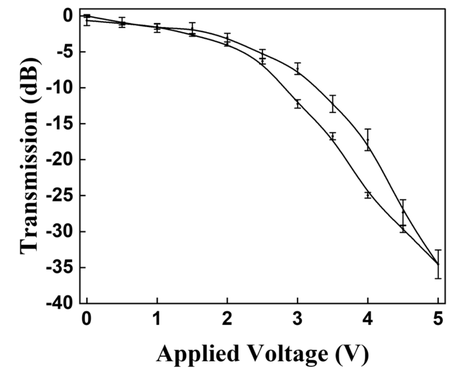
Ref. D Ielmini, Semicond. Sci. Technol., vol. 31, 2016.

Experimentally Measured Results









Comparison of Proposed Work

Parameter	ER (dB)	Operating Voltage	Device Length (μm)
Ref. [3]	10	1 to 10	1000
Ref. [4]	0.4	-3 to 9	-
Ref. [5]	12/6	-2 to 2	10/5
Ref. [6]	20	-2 to 4	20
Proposed Work	**35**	**0 to 5**	**20**

Summary

- ✓ Optical readable nanophotonic resistive switch
- ✓ Vertical hybridization of the fundamental mode of a p-Si waveguide with the SPP in double-slot
- ✓ Exhibits broadband propagation
- ✓ High extension ratio at subwavelength scale
- ✓ High Endurance, low power consumption
- ✓ Compatible to CMOS fabrication technology
- ✓ Applicable in emerging technologies: **Advanced digital memory, neuromorphic computing, In memory computing, and programmable photonic circuits.**

Findings

- ❖ Exhibits broadband propagation over 1500 nm to 1600 nm
- ❖ High endurance over ~1000 Set/ Reset Cycles
- ❖ Enhanced extension ratio of 32 dB

➢ S. Kumar et al., "**Multilevel Nanophotonic Resistive Switching in Ag-ITO-SiO_2 on Silicon** ", **Journal of Lightwave Technology** , Oct. 2024, DOI: 10.1109/JLT.2024.3474775.

➢ Technology upgraded to **Reconfigurable Multiwavelength Nanophotonic Circuit** & submitted to **Advanced Optical Materials**, Nov. 2024. *(Under Review)*

Acknowledgment

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