Enhanced Optical Readout in Resistive Memory Through Plasmonic Amplification

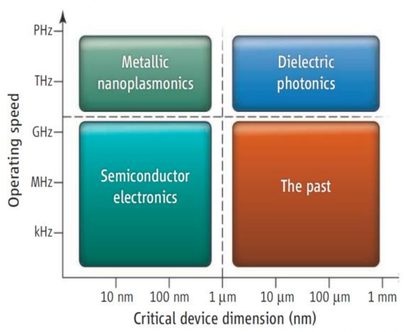
Lalit Singh[1], Rahul D. Mishra[1], Swati Rajput[1], Sourabh Jain[1], and Mukesh Kumar[1,2]

[1]Optoelectronic Nanodevice Research Laboratory, Electrical Engineering, Indian Institute of Technology Indore, India

[2]Centre of Advanced Electronics,

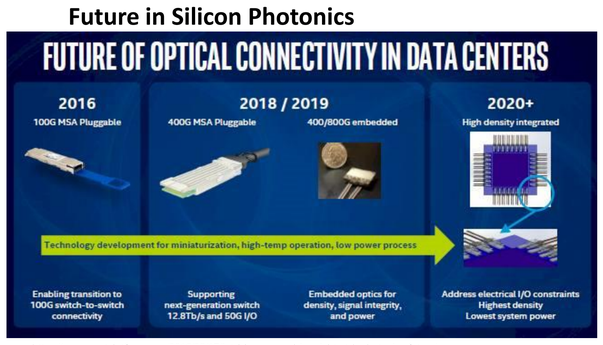
Abstract: An electrically writable resistive switch with optical readout capability is proposed with a high extinction ratio of 16 dB utilizing plasmonic amplification in InGaP. The proposed device operating at 1550 nm wavelength shows an optical gain of 2.4 dB. The optical readout is less error prone and has low energy consumption then it's electrical counterpart. The high index layer, bottom electrode material, provide dual benefits: low loss waveguiding of light and electrical rectification. The device can find applications in optical interconnects, optical modulation, memory and neuromorphic computations

Importance of nanophotonics



Science, 2010, 328, 440

Future in Silicon Photonics



https://www.nextplatform.com/2016/08/17/intel-leverages-chip-might-etch-photonics-future/

Requirement of Optical Processors

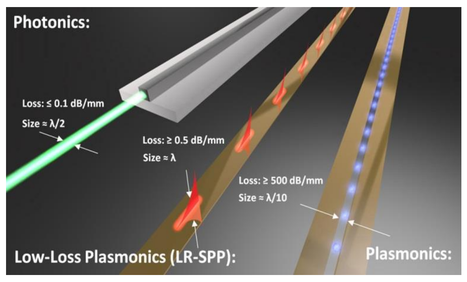
- Optical Interconnects
- Large-scale photonic integration
- Compact on-chip devices
- Nanophotonics

Compact Devices with Tuning

- Electrical control
- Tunable delay
- Low power tuning

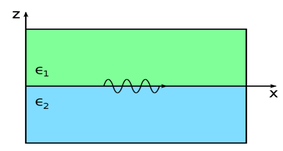
Control and Manipulation of light at nanoscale remains an important requirement

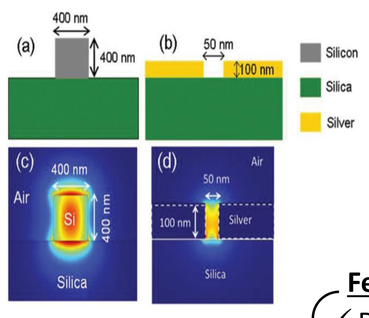
Plasmonics Waveguide



N. Kinset et. al. http://spie.org/newsroom/5462-a-platform-for-practical-plasmonics.

- Surface Plasmon Polaritons (SPP) are electromagnetic excitations
- Propagating at the interface between a dielectric and a conductor





M. Z. Alam, J. S. Aitchison and M. Mojahedi, Laser & Photonics Reviews, 8, 394-408, 2014.

Issues with Plasmonic Devices

- Short-life to serve as a basis for computer chips
- Large propagation loss & weak confinement
- Small Coupling efficiency

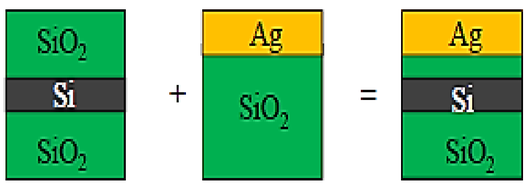
Major concern:

- Diffraction limited Device size
- Complex Tuning scheme

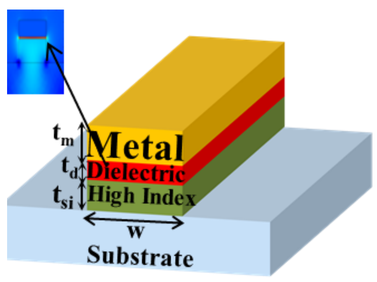
Features/Applications

- ✓ Devices for Optical Communications
- ✓ Tight Control on Optical properties
- ✓ Slow-light Devices
- ✓ Bio-chemical Sensors

Hybridization of photonic and plasmonic mode



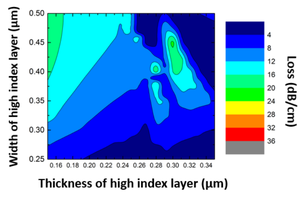
Oulton et al., 2008,Nature Photonics



- ❑ Optical mode + SPP mode => Hybrid plasmonic waveguide
- ❑ Dragging SPP mode deep into Dielectric/Semiconductor

Hybridization controlling elements

- ➢ Thickness and width of high index layer where leaky optical mode resides
- ➢ Thickness of dielectric layer
- ➢ Optimized thickness found out to be 10-nm for dielectric layer.

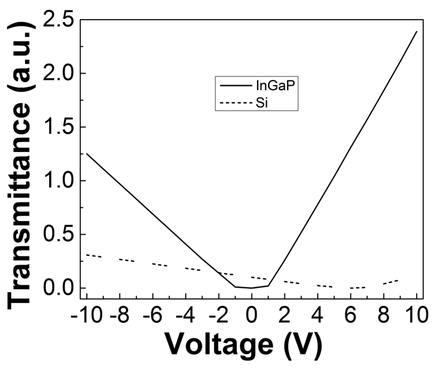


Findings

- ➢ Good Fabrication tolerance
- ➢ Smaller mode area ($\lambda^2/270$)
- ➢ Subwavelength dimensions
- ➢ Longer propagation

Loss Compensation using material again and Electron Injection

- ➢ Due to large metallic losses amplification is required
- ➢ To reduce losses
  - ✓ Pushing electrons away from metal surface
  - ✓ Increase number of electrons in dielectric layer
  - ✓ Increasing number of electrons near semiconductor dielectric interface
  - ✓ Using of gain material

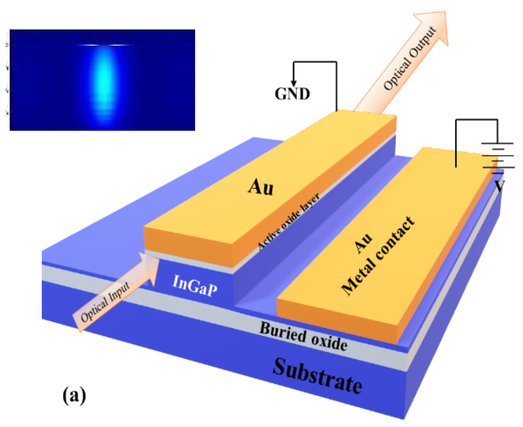


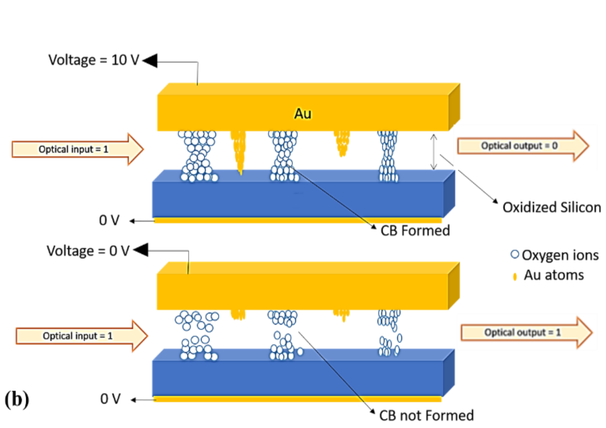
Material gain + electrons Injection = amplified SPP

Features & Applications:

- ❑ Phase modulation provides 670-µm of π shift
- ❑ Optical gain of 2.39 dB/cm of intensity
- ❑ With silicon gain is less than 0.5

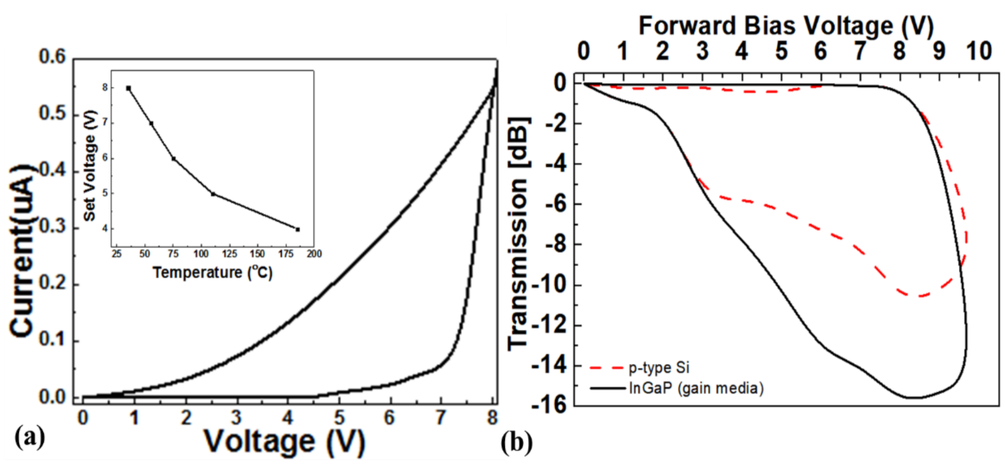
Optical Readout in Resistive Memory





Features

1. Optical readout of resistive switch
2. High endurance (comparing to other optical readout based devices)
3. Self rectifying (enables low leakage current high density fabrication)
4. Application in neuromorphic computation
5. 16 dB optical extinction ratio (6dB better then no amplification)
6. Low power consumption: 0.15pJ (over one readwrite cycle)
7. Frequency checked 2MHz
8. Two techniques for work: Valency change effect + Electrochemical Metallisation



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Summary

- ➢ Confinement at real nano-scales
- ➢ Optical readout of resistive memory
- ➢ SPP amplification is possible with material gain and population inversion
- ➢ Application in on chip optical modulation at nanoscale

Acknowledgment:

The author acknowledge the financial support by DST Nano Mission DST/NM/NT/1009/2017(G) and Council of Scientific and Industrial Research CSIR(22/814/19/EMR-II).