Project Title Goes Here

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TYPE II STRAINED LAYER SUPERLATTICE PLANAR DIODE FABRICATION VIA THERMAL DIFFUSION OF ZINC

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SENSORS DIRECTORATE OCTOBER 7, 2024

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Outline

- Introduction
- Type II Strained Layer Superlattice (SLS) Detectors
- Surface Leakage Current
- Sidewall Passivation and Planar Devices
- Planar Device Fabrication
- Characterization and Analysis
- Conclusion

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Introduction

Motivation:

Develop MWIR and LWIR FPAs utilizing Type II Strained Layer Superlattices (SLSs) and III-V semiconductors

Passive Sensing:

- ISR
- Persistent Surveillance (Air & Space)
- Threat Warning
- Infrared Search and Track (IRST)
- Tactical Reconnaissance
- Missile Warning
- Laser Warning

Commercial Applications:

- Residential insulation and water damage inspection
- Toxic gas detection
- Non-invasive imaging in medical industry

Right: *How Thermographic Inspections Work*. Energy.gov. https://www.energy.gov/energysaver/thermographic-inspections

Left: SSgt Raughton. *U.S. Air Force pilot inspects the IRST Pod attached to his F-15C Eagle*. January 26, 2022. USAF. https://www.af.mil/News/Photos/igphoto/2002937019/mediaid/5785264/

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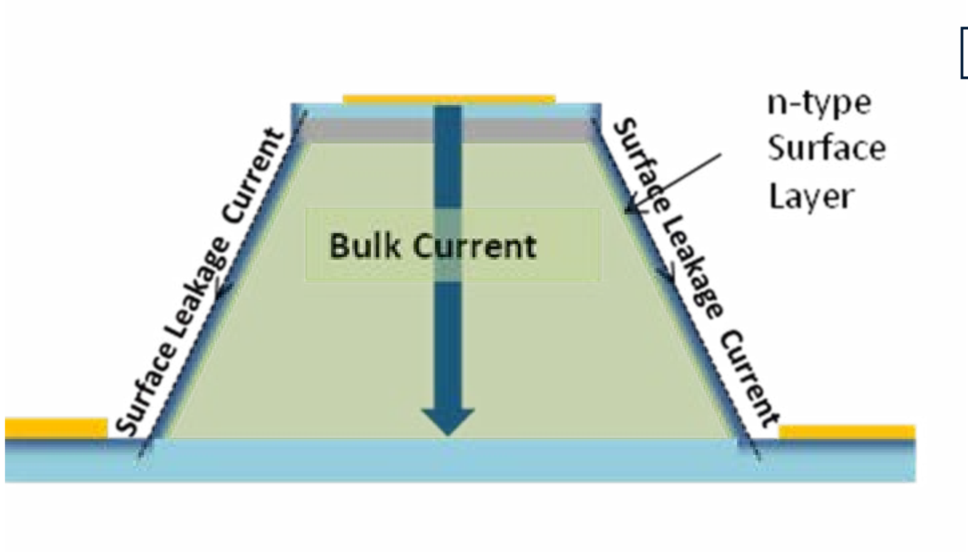
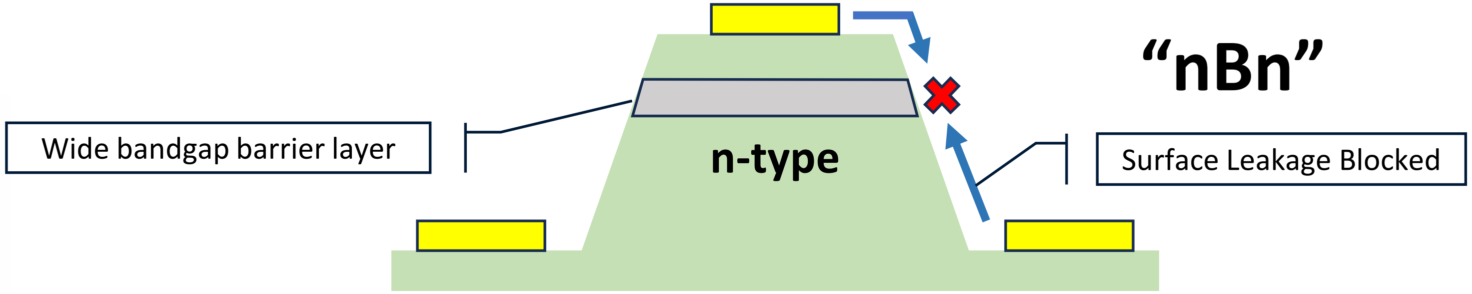
Surface Leakage Current

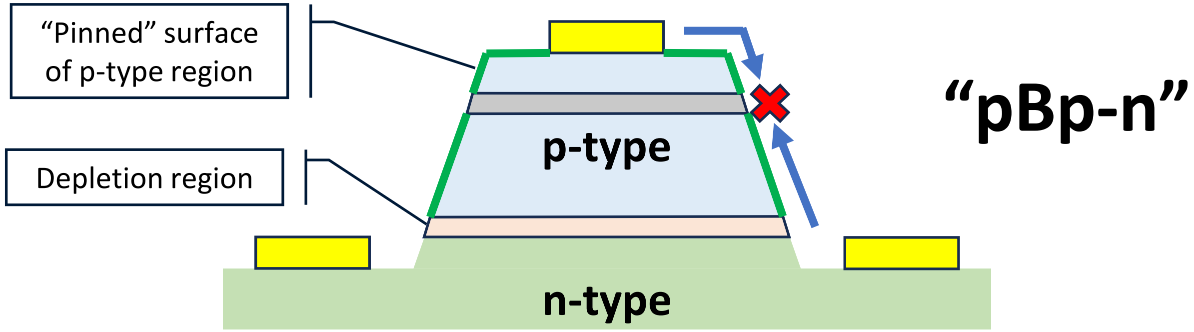




Unipolar barrier architectures using n-type layers (nBn) solve leakage current.

Leakage Current in pn diodes:

- **Caused by:** surface Fermi-level 'pin'-ing of the p-type region in detectors
- **Results in:** electrons along the surface moving freely between the contacts, creating a shunt



pBp-n detectors solve this problem, but have higher Dark Current and effectiveness of the barrier is limited in reduced mesa sizes.

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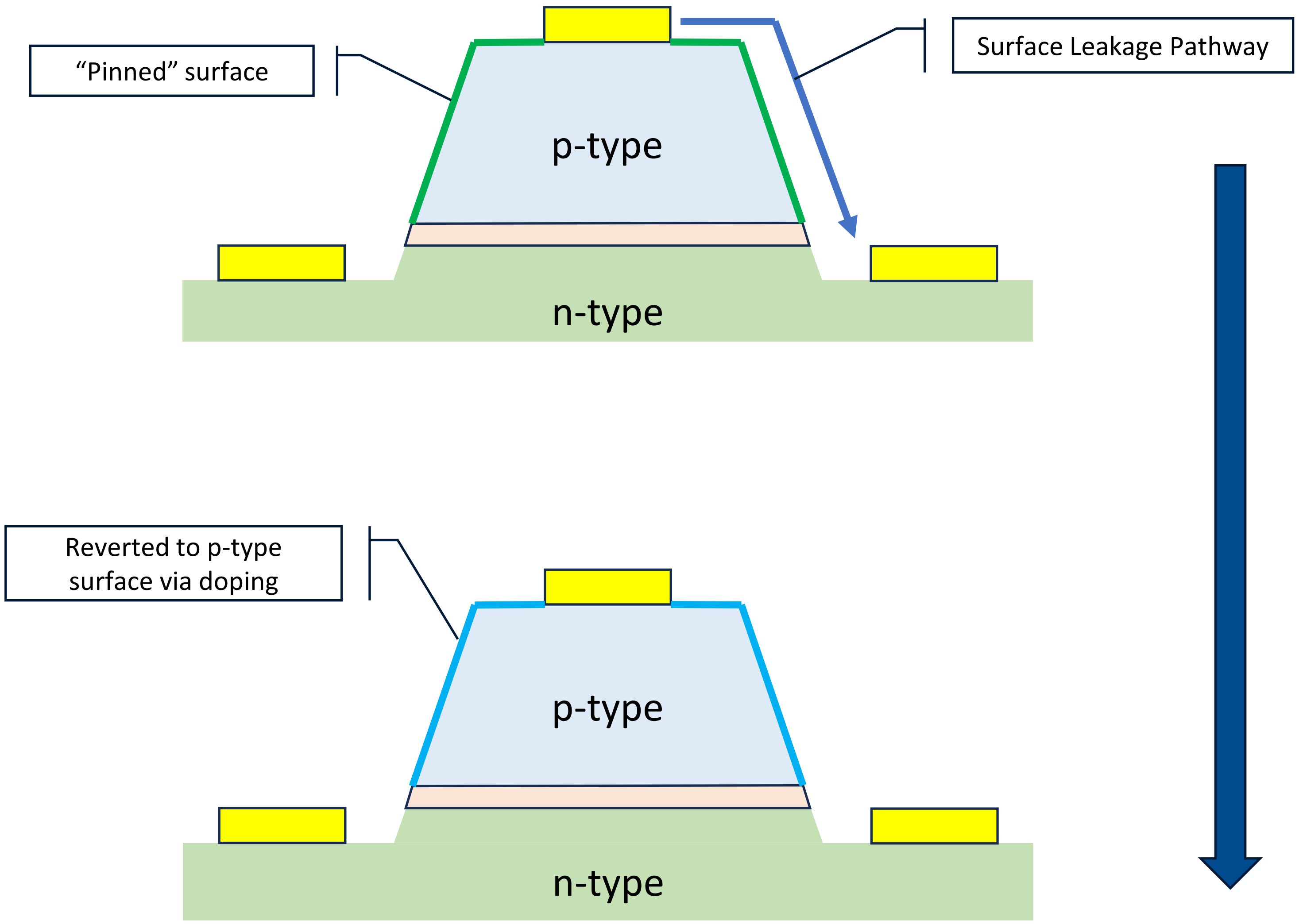
Project Goal

- **Final goal:** to passivate the “pinned” surface via p-type doping
- **Doping Process:** thermal diffusion of zinc
- **First step:** prove that zinc can dope the n-type SLS (including the “pinned” surface) p-type via thermal diffusion
- **Initial goal:** create simplified planar homojunctions with thermally diffused zinc in n-type SLS



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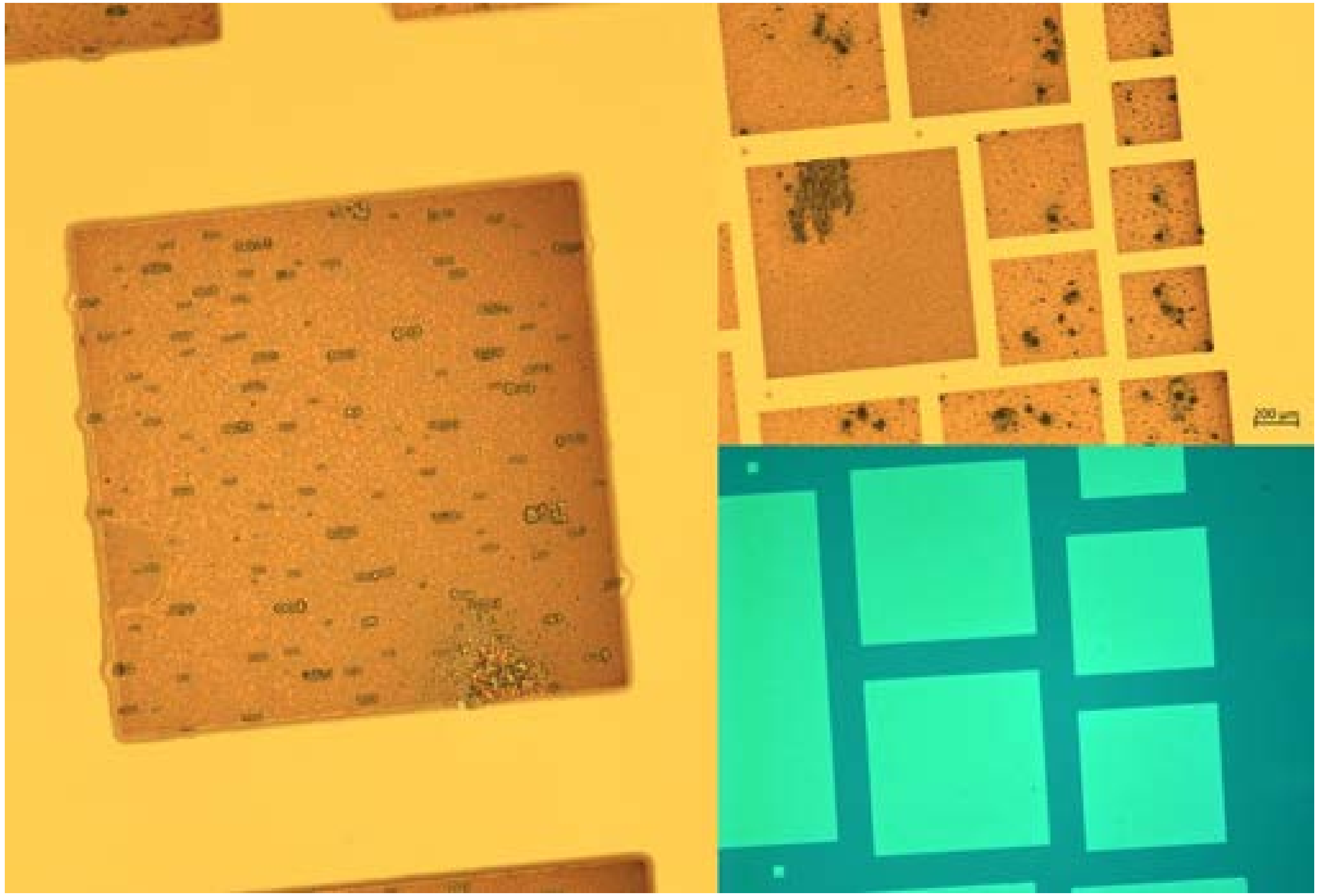
Methodology

- Two types of device fabrication processes were pursued:
  - Zinc thermal evaporation
  - Zn Sputter deposition

- *p*B*pn* detectors were produced to serve as a control

- Electrical measurements taken for all devices included:
  - Dark current
  - Quantum Efficiency
  - Spectral Response



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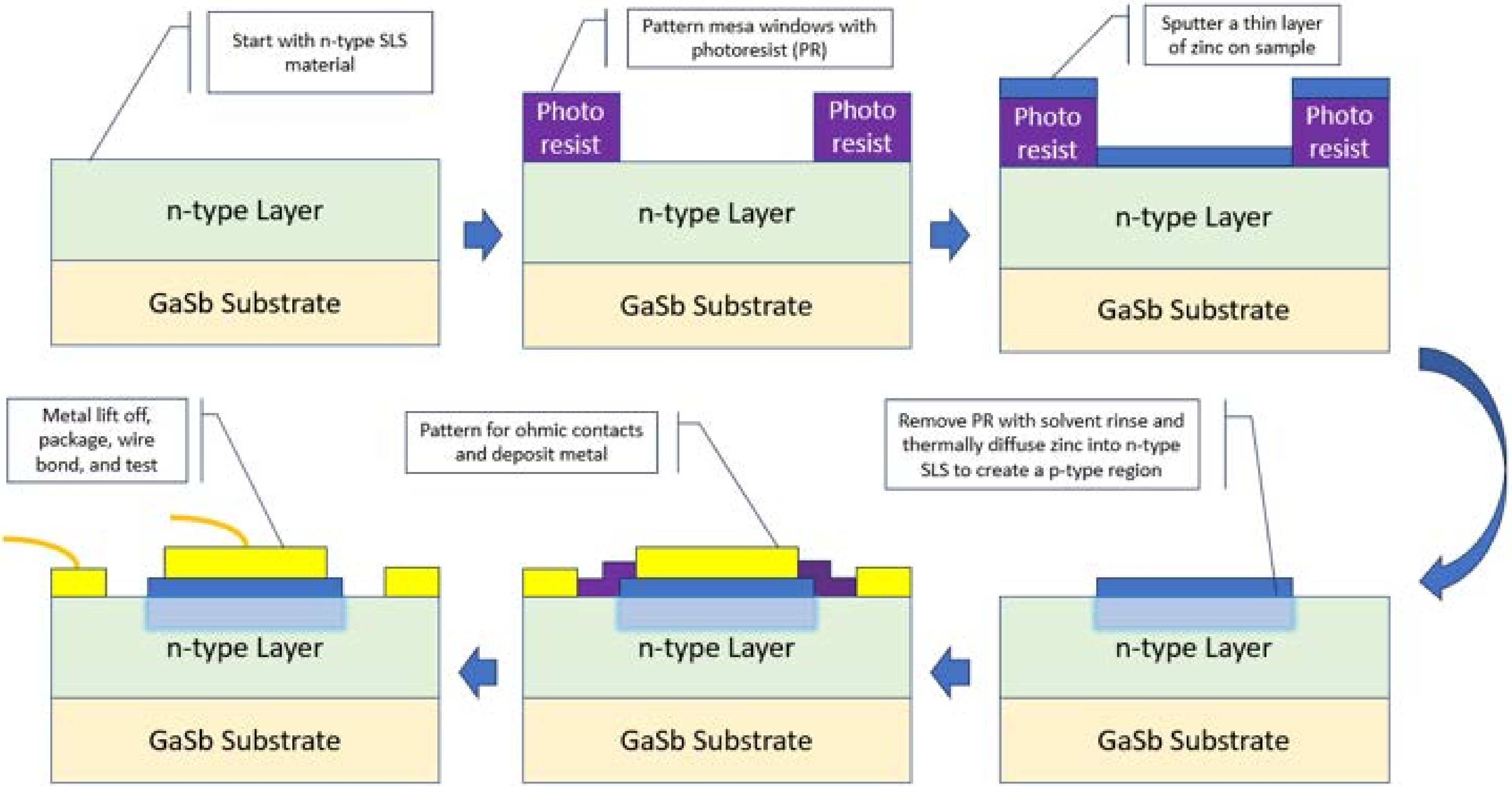
Planar Device Fabrication via Sputtered Zinc



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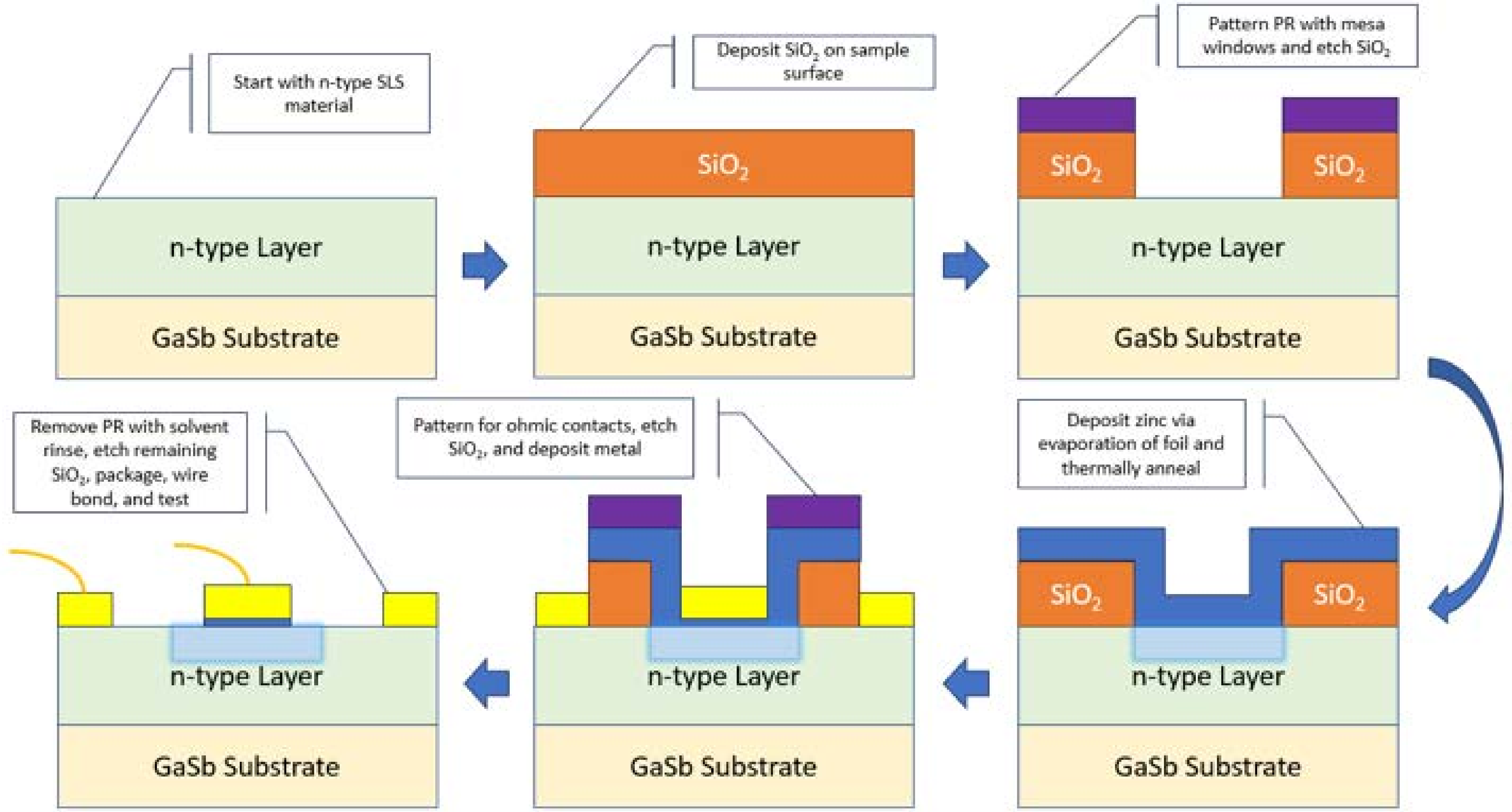
Planar Diode Fabrication via Zinc Thermal Evaporation



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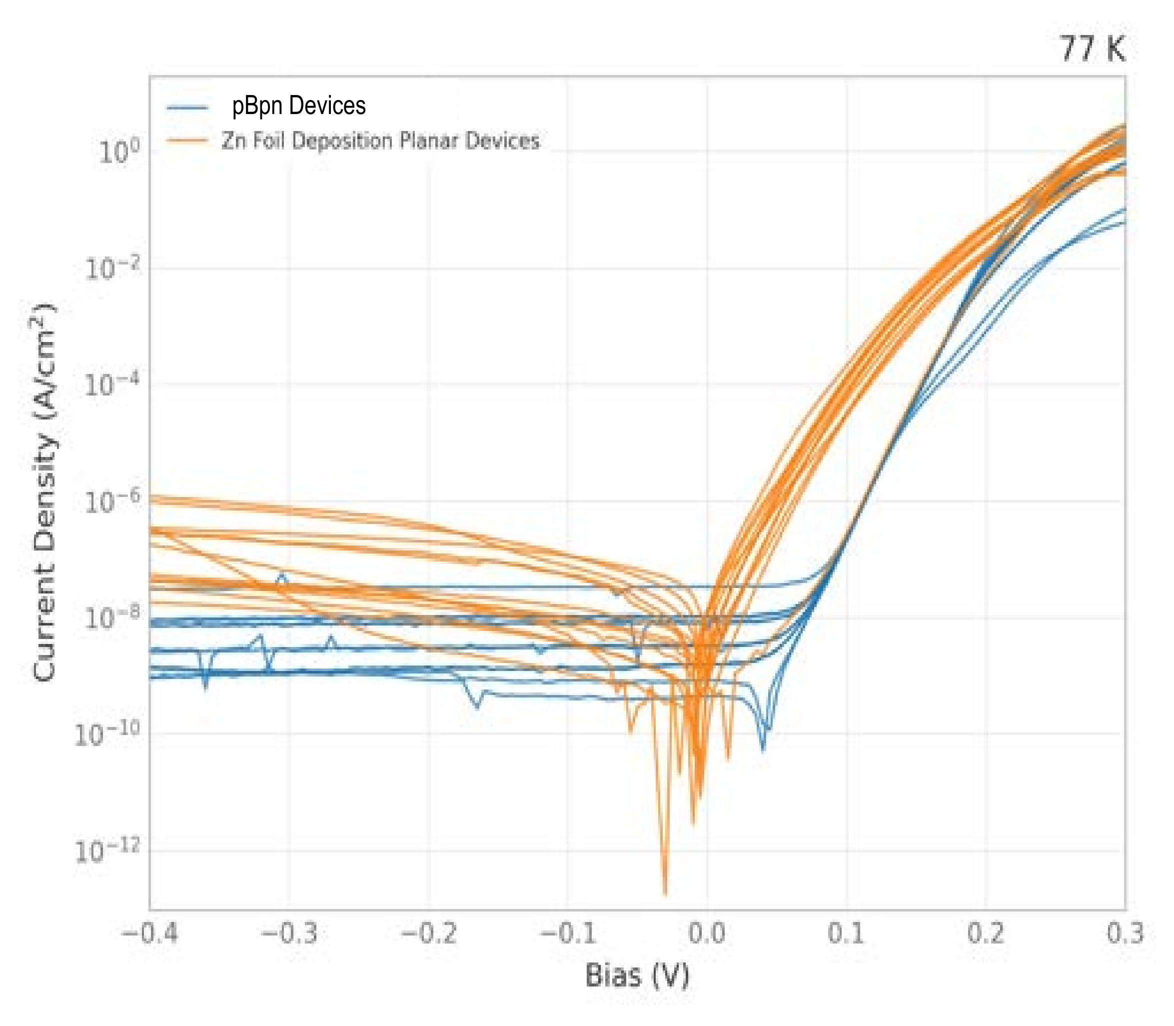
Dark Current of the MWIR Detectors

- Planar diodes were fabricated using MWIR *n*-type SLS and the Zn Foil Deposition process.
- Rectification of 6 orders of magnitude was achieved with the diodes from three separate samples.
- Devices from the *pBpn* structure may still have lower dark current. The reverse bias current is below the detection floor.
- Conclusion: Evaporated zinc can dope *n*-type MWIR SLS material *p*-type and create planar diodes.



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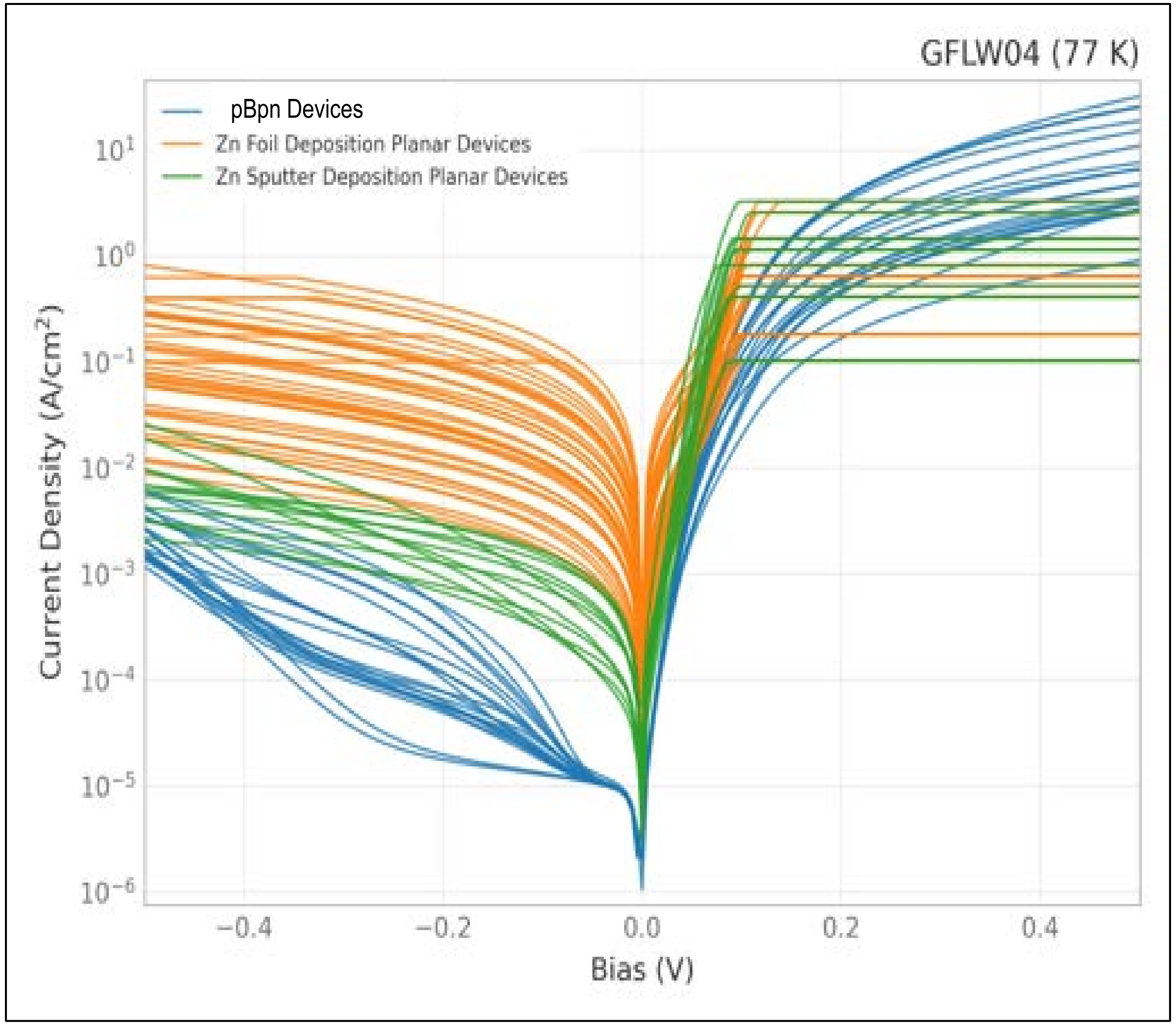
Dark Current of the LWIR Detectors

- Both thermal evaporation and sputtering resulted in planar diodes in LWIR *n*-type SLS.
- Zn evaporation was more repeatable, but the range of dark current values was larger.
- Zn Sputter process only worked once but produced lower dark current and had smaller range of values.
- A rectification of at least 2 orders of magnitude was achieved with both processes.
- Conclusion: Sputtered zinc can dope *n*-type LWIR SLS material *p*-type and create planar diodes. Reproducibility needs more work.



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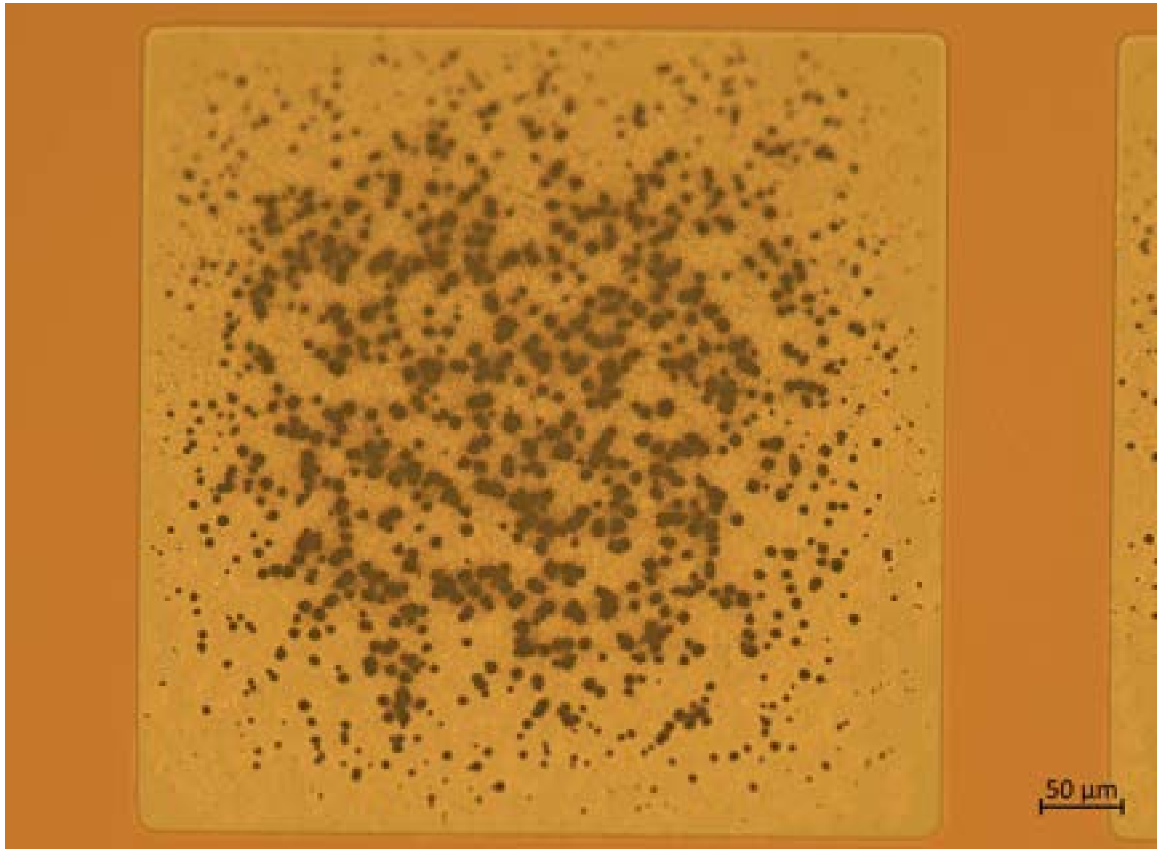
Evaporation vs Sputter Deposition



Thermal evaporation of zinc leads to nonuniform deposition pattern

Uniformity of sputtered zinc films could decrease variations in level of doping

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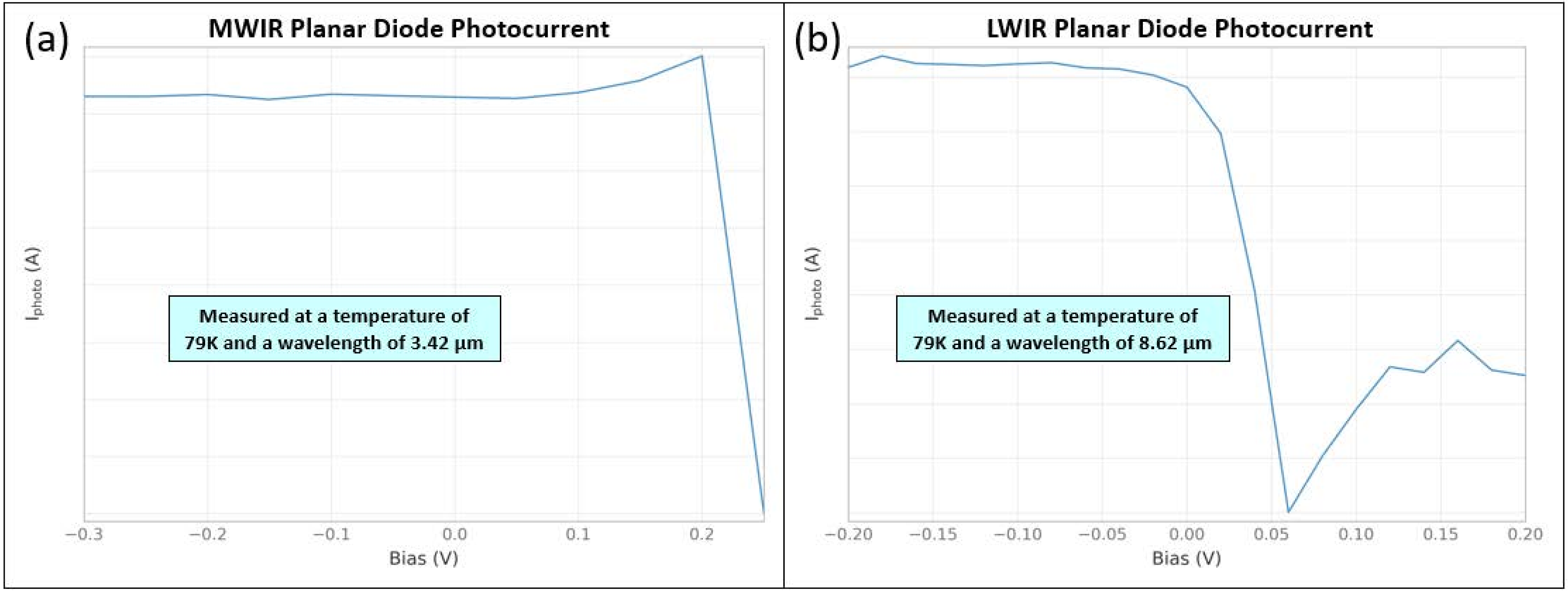
Photocurrent vs Bias Data



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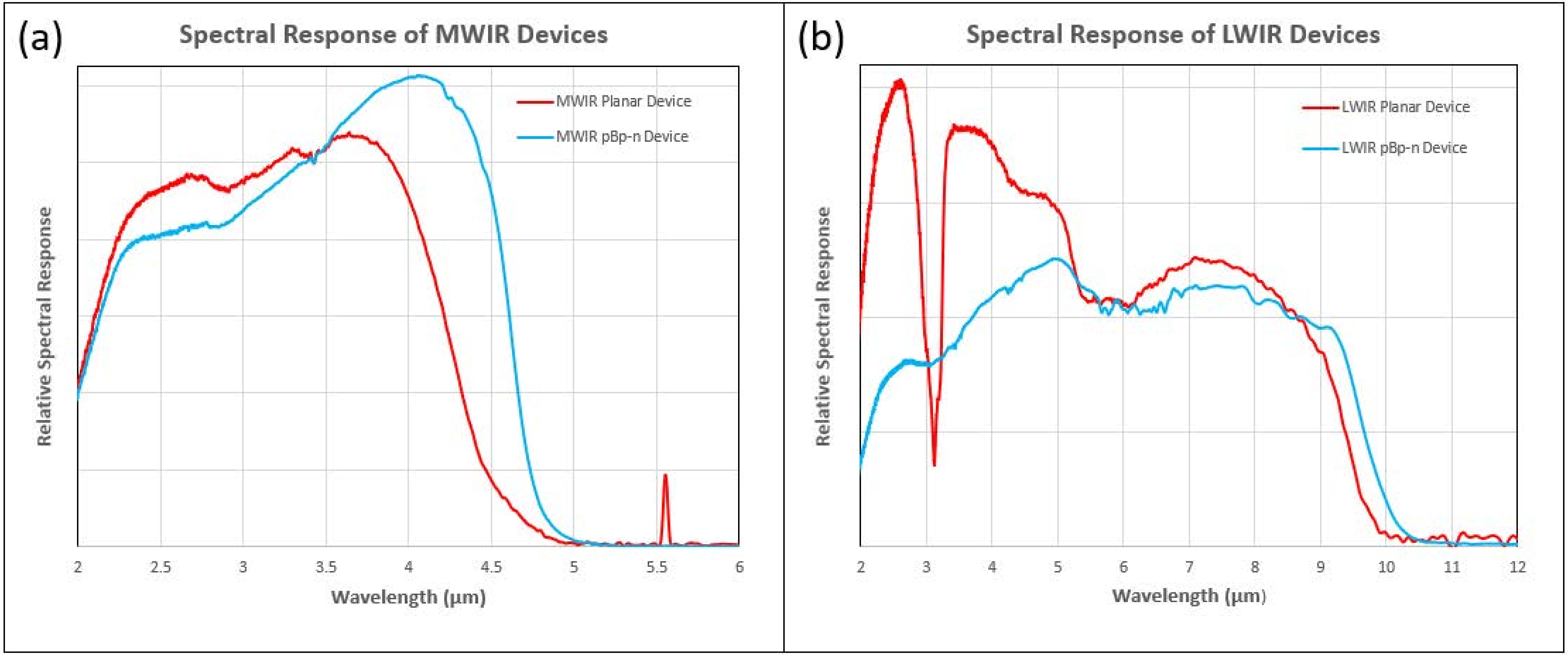
Spectral Response Data



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Conclusion

- Thermal diffusion of zinc into n-type SLS material can result in diodes. This applies to both MWIR and LWIR material.
- Rectification of 6 orders of magnitude for MWIR diodes and 2 orders of magnitude for LWIR diodes was measured.
- Spectral responses were measured across the expected wavelength ranges for both the LWIR and MWIR devices, albeit with a noticeable blue shift.
- Dark current performance of planar diodes still lacks in comparison to their commercial *p*B*pn* counterparts.
- Further process development can improve the consistency of planar diode fabrication.
- Most importantly, thermal diffusion of zinc has been shown to dope *n*-type SLS.
- Further research can now be done to dope “pinned” sidewalls of *pn* diodes in SLS material as a method of device passivation.

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Acknowledgements

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QUESTIONS?

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