Emerging 3D Semiconductor Dosimetry for High-Dose Radiotherapy

Heayoung Yoon
Electrical and Computer Engineering

Glenn Sjoden
Civil and Environmental Engineering

Geoff Nelson
Radiation Oncology

Connor Bischak
Chemistry

1U4U Innovation Funding

Funded Project Amount: $30,000

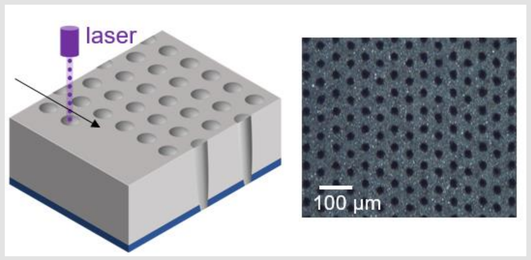
Abstract

Robust radiation detectors are essential in state-of-the-art radiotherapy and cancer treatment.

The objective of our research is to develop novel dosimetry using **three-dimensional (3D) microstructural device architectures**. We incorporate hybrid-perovskite materials to efficiently convert high-energy radiation into low-energy photons. The proximity interaction and conversion strategies enable highly sensitive, real-time detection of a broad range of radioactive particles.

Beyond medical applications, the versatility of our device architecture extends to applications in environmental radiation monitoring, aerospace technology, nuclear diagnostics, and deep-space missions.

Key Techniques

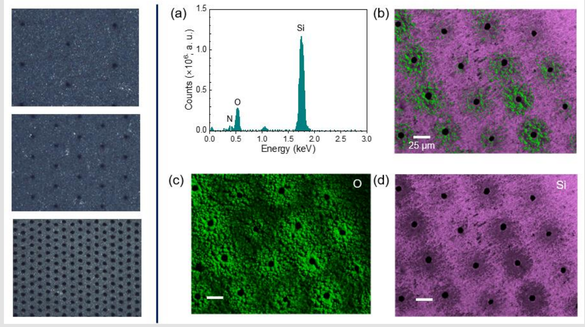


- Nanosecond UV laser beam
  - Diode pumped solid state laser (DPSS)
  - Max. power: 1.5 W
  - Wavelength: 355 nm
  - Tunable beam parameters, such as scan speed, repetition, etc.

→ Robust & Reproducible 3D architectures

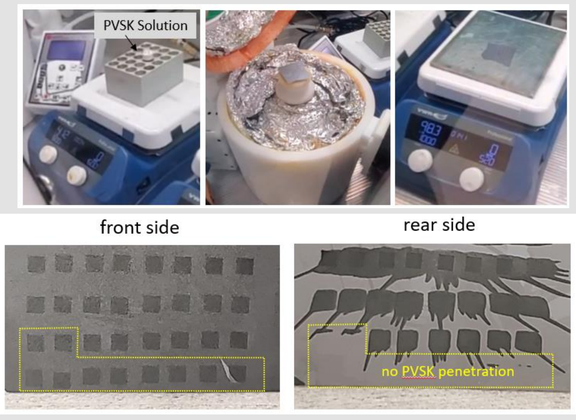
Patterning Approach

- Pilot device architecture with stippled microhole arrays on Si substrates
- Unintended subsurface damage from laser
  - Local heating under ambient air conditions
  - O_2 in the air interacts with Si during laser micro-drilling processes
  - EDS confirms SiOx near microholes.
- Possible mitigation strategy
  - HNA etching (a mixture of hydrofluoric, Nitric, and Acetic acid solutions) on 3D patterned Si substrates.



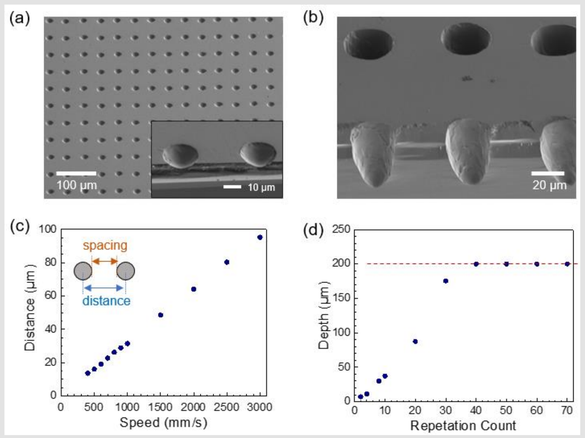
Synthesis of PVSK Materials

- Synthesis of $CH_3NH_3PbI_3$ (methylammonium lead iodide; PVSK)
- Integration: PVSK can be confined within the microhole array structures
  - spin-coating (3,000 rpm for 1 min)



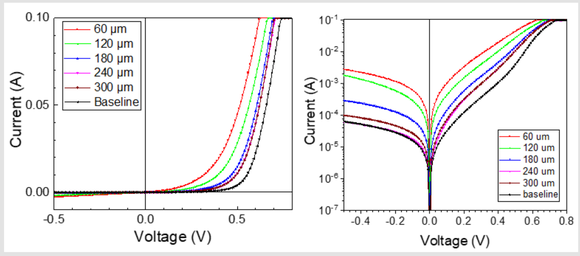
Optimized 3D Depth Profile

- Tunable 3D Microhole Geometry
  - Parameters: microhole diameter, spacing, and arrangement depending on carrier dynamics in semiconductor substrates

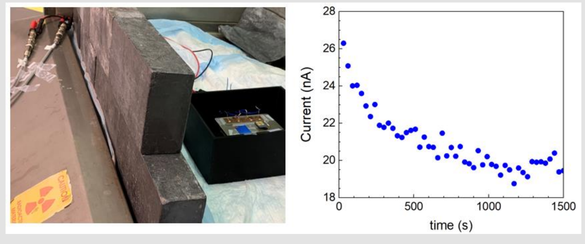


Device Performance

- 3D microhole array devices show the diode behaviors. → well-behaving baseline devices



- (Preliminary) Detection of radioactive particles coming off from Al foil → exponential decay curve.



Conclusion

- We successfully patterned 3D architectures on Si substrates and optimized the fabrication process for reproducibility. Wet chemical etching mitigated laser-induced surface damage, enhancing structural integrity.
- Hybrid-perovskite conversion materials were synthesized and integrated into the patterned microhole structures.
- Preliminary beta-radiation tests demonstrated the feasibility of our prototype for high-dose radiation detection, confirming its potential for next-generation dosimetry applications.

Output and Future Work

- Fostered interdisciplinary collaboration
- Contributed to a patent disclosure and a publication. (1) A. Chowdhury et al., Adv. Eng. and Sust., 2400147 (2024). (2) Patent Pending: Yoon & Sjoden (63/631,197)
- Supported funding proposals with plans for further applications.
- Potential applications in medical imaging, nuclear safety, and space exploration.

Acknowledgements

We sincerely thank the researchers participating in this project, including A. Chowdhury (ECE), A. Mamun (ECE), A. Allison (Reactor), and M. Beitollahi (Radiation Safety).