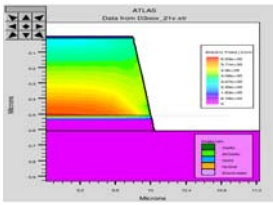
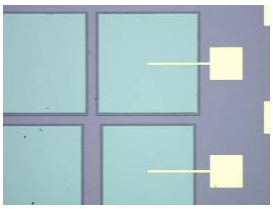
Project Summary

Gamma ray and neutron spectroscopy are well established techniques for determining the chemical composition of planetary surfaces, and small cosmic bodies such as asteroids and comets; however, new technologies with the potential to significantly improve the performance of planetary nuclear spectroscopy are emerging in response to demands in other fields such as homeland security.

In this work, we propose to develop new gamma-ray and neutron detectors based on wide-band-gap solid state photomultiplier (SSPM) photodetectors coupled to emerging scintillation materials such as Cs_2YLiCl_6:Ce (CLYC), and $CeBr_3$ for gamma and neutron spectroscopic studies of planet surfaces and small cosmic bodies. The proposed SSPM photodetector for scintillation readout is based on AlGaAs, a wide-band-gap compound semiconductor with aluminum concentration between 60% to 90%. The band-gap energy of this material is engineered to provide high photo sensitivity between 300nm to 500nm, which matches well with the emission spectrum of both CLYC and $CeBr_3$. The wide-band-gap nature of AlGaAs also provides much lower dark noise and better radiation tolerance than Si-based detectors. Compared to conventional PMTs, the compact size, low voltage operation, and lighter weight of AlGaAs SSPM is more ideal for spaced based instruments, and coupled to CLYC and $CeBr_3$ scintillation materials, is an ideal match for the next generation gamma neutron spectrometers for planetary science.

In Phase I, We performed Monte Carlo simulations on the interactions of secondary nuclear byproducts from a small planetary body with the proposed neutron/gamma detector. We designed and simulated new AlGaAs based Geiger mode photodiodes, which will be integrated into SSPM arrays to improve the signal-to-noise ratio, provide optimal coupling to proposed scintillation materials, reduce power consumption, and increase radiation hardness. The characteristics of the photodetectors were simulated in a device simulator supporting AlGaAs technology (Silvaco TCAD). The device simulations showed that several candidate diode designs exhibit excellent electrical behavior, low operating bias (<20V), and excellent quantum efficiency (>50% @ 400nm) in the 300nm to 500nm range. Following design and simulation, we developed process recipes for the fabrication of prototype structures. During process recipe development, preliminary diode devices were fabricated and initial characterizations showed promising results such as low breakdown voltage, low dark current, and good breakdown characteristics. Also in the Phase-I work, we obtained and characterized the proposed scintillation materials to ensure desired properties such as high light output, dual gamma/neutron discrimination can be achieved.

Phase-I Feasibility Criteria:

- Demonstrated the feasibility of AlGaAs GPD designs with both mesa and planar guard-ring structures (top left).
- Demonstrated a recipe for fabricating AlGaAs devices and Fabricated AlGaAs test diodes using preliminary recipe (top right).