New Material Systems for Neutron Dosimetry

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Background

- Radiation remains a challenging obstacle towards sustained human presence on non-terrestrial bodies.
- Given the trajectory of human space exploration, there is much potential application for thin, flexible dosimeters that can be incorporated into spacesuits at varying locations to measure accumulated, tissue-specific dose.
- Cosmic rays generate neutron secondaries upon impact (Fig. 1), posing a unique health risk to astronauts through nuclear reactions and chromosomal aberrations.

Objective

- Examine novel topological material systems to develop a neutron dosimeter capable of measuring a biologically-relevant energy spectrum.
- Device will complement current radiation monitoring systems to offer redundancy and individual exposures.
- Create a flexible dosimetry scaffolding conducive to spacesuit integration.
- Dosimeter will directly record neutron exposure during astronaut EVA.

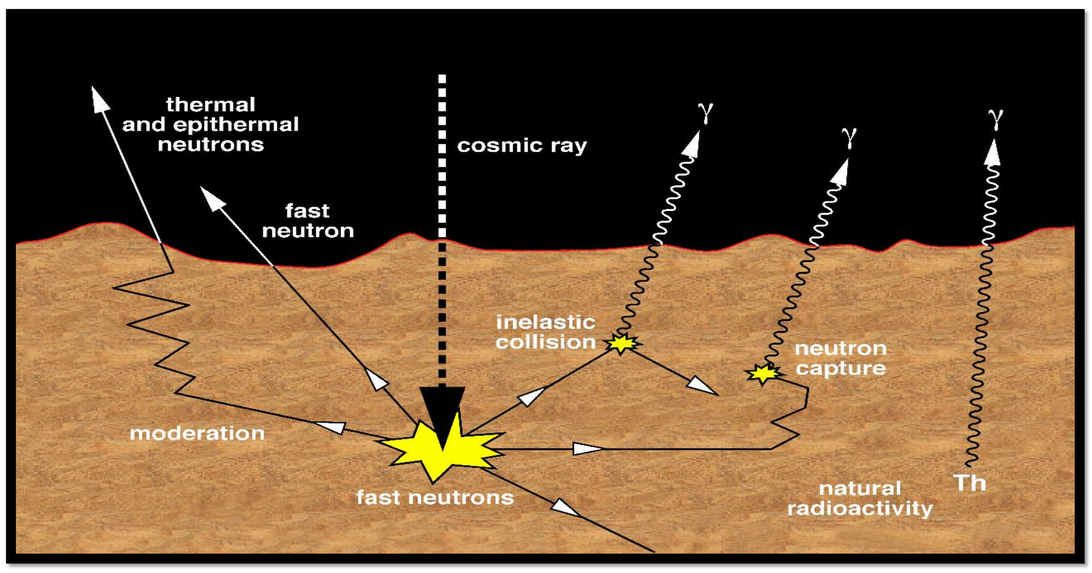

Figure 1. Cosmic ray incident to planetary surface creates neutron secondaries of varying energies [1].

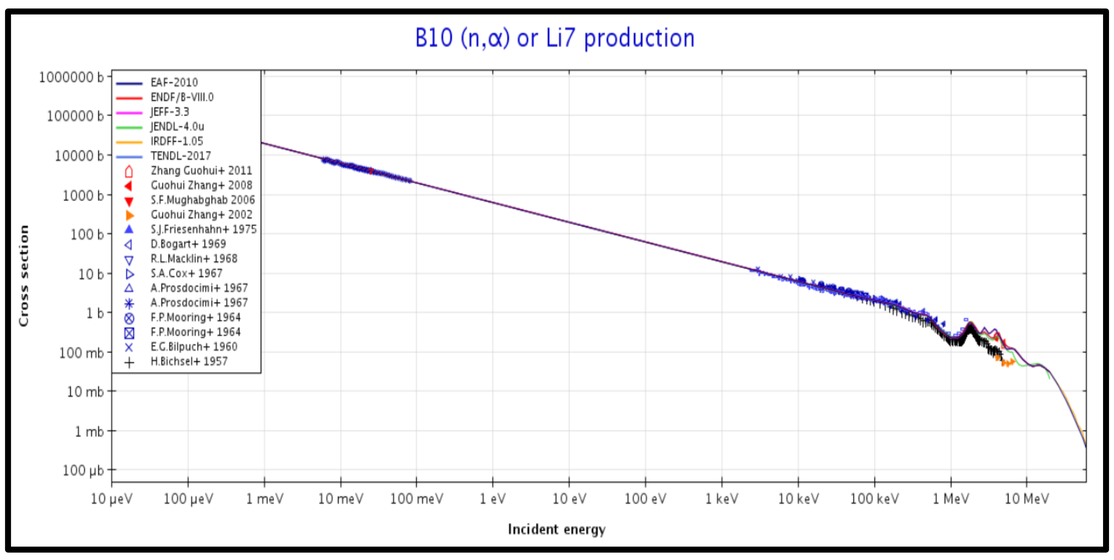

Figure 2. JANIS database for Boron-10 shows neutron capture cross section decrease with incident neutron energy [2].

Current Design

- Resistive graphene field effect transistor (gFET) with an isotopically-enriched B layer and Si absorber layer (Fig. 3).
- ^{10}B has a large neutron capture cross-section (Fig. 2).
- Upon neutron capture, ^{11}B splits into α and Li (Fig. 3), which create charged defects near the conductive layer.
- Local electrical fields gather beneath the graphene layer. As defects accumulate, resistance increases.
- We can correlate ΔΩ to neutron exposure by applying ΔV.

Advantages

- Size and flexibility allows for spacesuit integration.
- Multiple device placement possible for tissue-specific effective dose calibration.
- Mechanism of detection offers *cumulative* radiation dose and instantaneous read-out.
- Only requires power during resistance measurement.
- gFET radiation hardness offers mission-scale lifetimes.

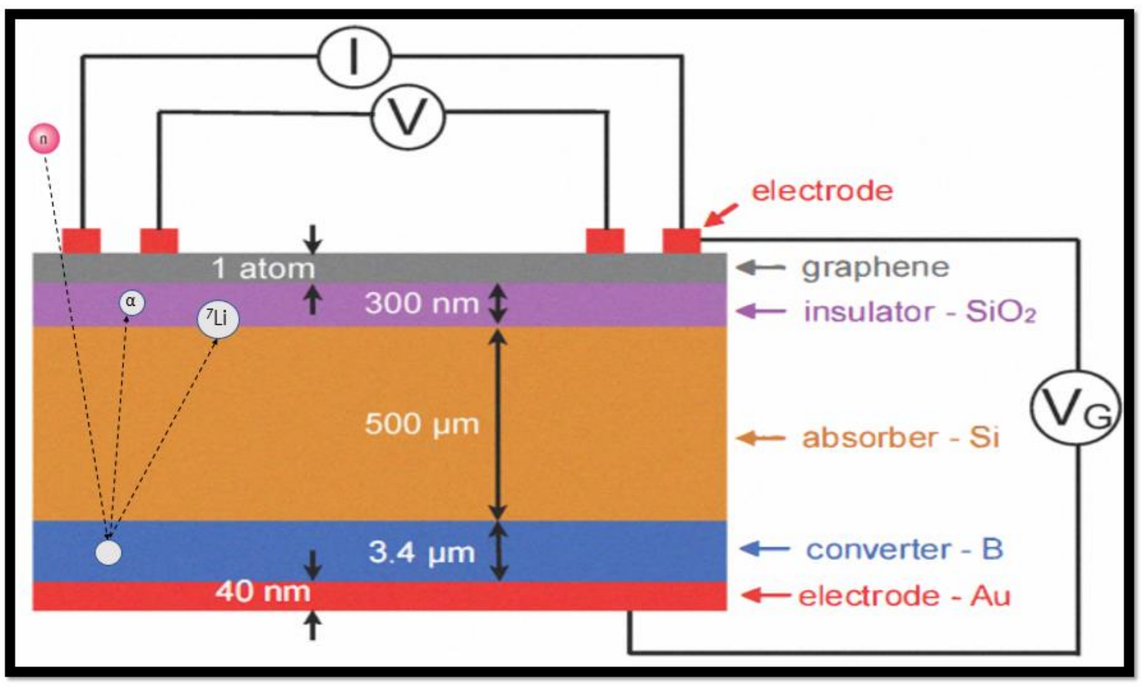

Figure 3. Schematic for prototype neutron dosimeter [3] (not to scale).

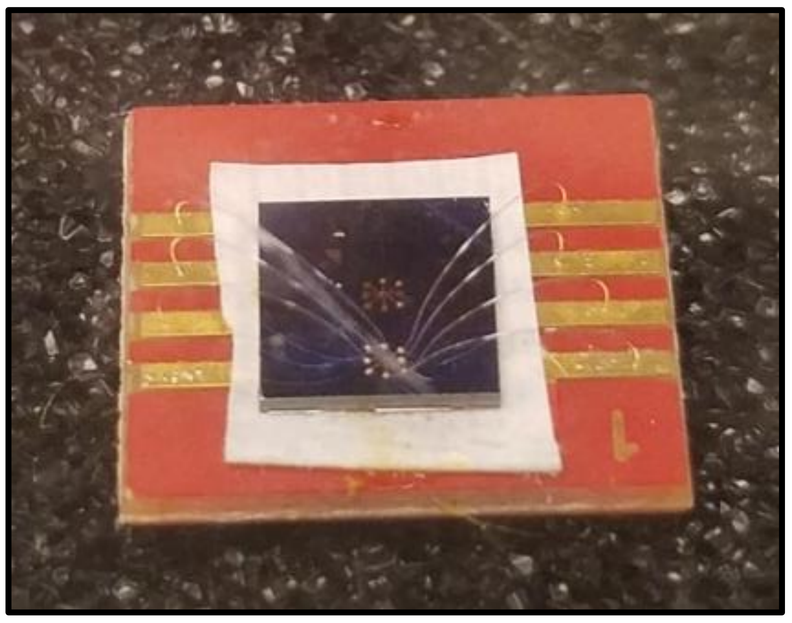

Figure 4. Wire-bonded resistive prototype on Si.

Acknowledgements

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References

[1] S. Kraft *et al.*, "Development and Characterization of Large La-Halide Gamma-Ray Scintillators for Future Planetary Missions," *2006 IEEE Nuclear Science Symposium Conference Record*, San Diego, CA, 2006, pp. 3798-3804.
[2] JANIS Database: http://www.oecd-nea.org/janisweb/renderer/1044.
[3] Foxe, M. *et al.*, Graphene-Based Neutron Detectors. IEEE Nucl. Sci. Symp. Conf. Rec. 2011, 352–355.
[4] Orlando, T. *et al.*, "Radiation Effects on Volatiles and Exploration of Asteroids and the Lunar Surface." Chem 2018, 4 (1), 8–12.