

Self-Biased ^{10}B -Coated High Purity Epitaxial GaAs Neutron Detectors

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SBIR grant in co-operation with Spire Corporation. The project involves the development of MOCVD epitaxially grown high purity GaAs neutron detectors and neutron imaging arrays. The high purity devices establish their own internal voltage, and therefore do not require the application of an external voltage bias.

GaAs has been shown to be radiation resistant to gamma rays, light charged particles, and neutrons. The material can be made in highly pure form and can be integrated upon for electronic circuitry.

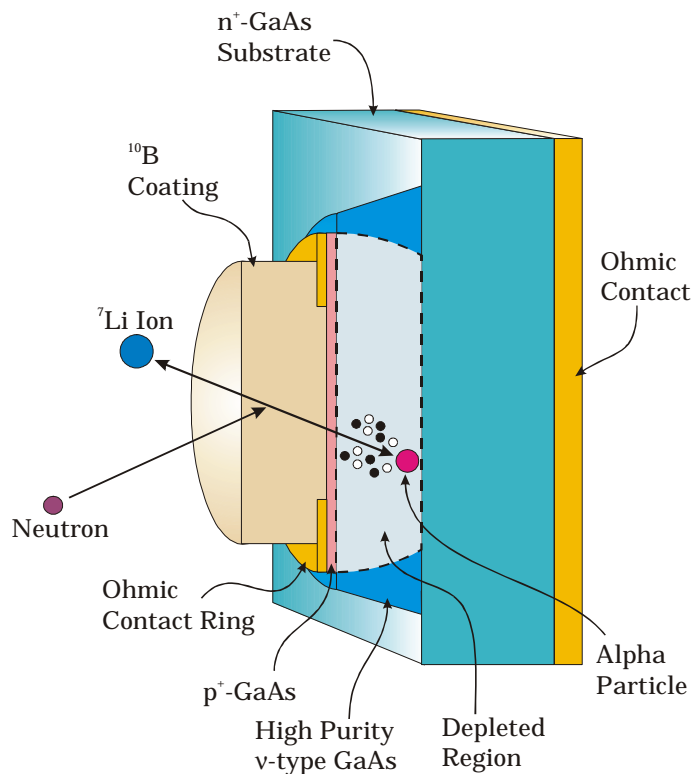


Figure 1: Cross section depiction of a self-biased GaAs neutron detector. The internal potential formed at the p+/v-type junction is sufficient to deplete the high purity GaAs material. The device is coated with pure ^{10}B . Neutrons absorbed in the ^{10}B layer discharge energetic ions (^7Li ions and α -particles) in opposite directions. Charges excited within the depleted region are drifted by the internal potential to form measurable pulses. (*NOT TO SCALE*).

Many research groups have explored coated semiconductor devices as neutron detectors. Most studies were performed on Gd or ^{10}B -coated Si diodes, which showed promise. The radiation hardness and noise needed

improvement, hence other materials were explored, including amorphous Si and diamond films. In searching for a semiconductor alternative, it was found that bulk GaAs structures constitute a more radiation hard device than typical Si diodes. Additionally, it was found that high purity GaAs devices, when designed correctly, operated under their own internal voltage potential.

Figure 1 shows the self-biased design, in which a high purity v-type region of GaAs is grown upon an n+-type GaAs substrate. A very thin p+-layer of GaAs is grown over the high purity v-type material. Mesa regions are etched and isolated from neighboring devices. A conductive ohmic contact is applied to the back substrate and performs as the anode. An ohmic contact ring is applied around the perimeter of the p+-region and performs as the cathode. Afterwards, a ^{10}B film is applied to the cathode. The isotope ^{10}B is chosen as a neutron reactive coating due to its high absorption cross section at thermal energies (3840 barns) and the high energies of the $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction products.



Figure 2: Holly Gersch, a Nuclear Engineering graduate student, operates a ^{10}B -coated self-biased GaAs detector at nuclear reactor neutron beam port. The detector functions *without* an applied voltage. The two major $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction product energy peaks show up clearly on the multi-channel analyzer computer screen.

The internal potential formed at the p+/v junction fully depletes the high purity GaAs. Neutrons absorbed in the ^{10}B film cause the ejection of energetic ^7Li ions (840 keV) and alpha particles (1.47 MeV) in opposite directions. Charged particles that enter into the device depletion region excite electron-hole pair charge carriers, which are swept from the region by the internal potential. The induced charge created by the moving charges forms a measurable pulse, allowing for the detection of a neutron. The very thin depletion region (4 microns) is large enough to absorb all of the reaction product energy, but is too thin to efficiently measure gamma rays. Hence, the device also self-discriminates between neutrons and background gamma rays.

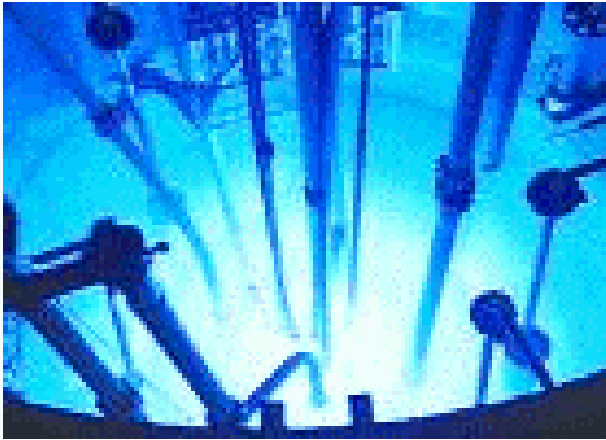


Figure 3: The TRIGA MARK II Nuclear Reactor located on the Kansas State University campus is used to test the self-biased neutron detectors for neutron detection sensitivity and radiation hardness. Four beam ports allow users to test the detectors in various neutron beam conditions. After intense irradiation near a reactor core, the detectors have shown good radiation hardness to gamma rays, light charged particles, thermal neutrons, and fast neutrons.

Advanced devices are now being designed for thermal *neutron imaging* detectors. The first generation design of imaging chips incorporate dual in-line technology coupled to miniaturized preamplifiers. Modified designs will also use a variety of thermal neutron reactive coatings, including ^{10}B , ^6LiF , natural Gd, and HDPE. The devices will be utilized for a number of neutron imaging applications, including neutron radiography, neutron radioscopy, and fast neutron imaging.

Refereed Publications:

1. D.S. McGregor, M.D. Hammig, H.K. Gersch, Yong Hong Yang, and R.T. Klann, "Design Considerations for Thin Film Coated Semiconductor Thermal Neutron Detectors, Part I: Basics Regarding Alpha Particle Emitting Neutron Reactive Films," *Nuclear Instruments and Methods* (2002) in press.

2. D. S. McGregor, R. T. Klann, J. D. Sanders, J.T. Lindsay, K.J. Linden, H.K. Gersch, P.M. De Lurgio, C.L. Fink, and Elsa Ariesanti, "Recent Results From Thin-Film-Coated Semiconductor Neutron Detectors," Proc. of SPIE, (2002) in press.
3. H.K. Gersch, D.S. McGregor, and P.A. Simpson, "A Study of the Effect of Incremental Gamma-Ray Doses and Incremental Neutron Fluences Upon the Performance of Self-Biased ^{10}B -Coated High-Purity Epitaxial GaAs Thermal Neutron Detectors," Nuclear Instruments and Methods, A489 (2002) pp. 85-98.
4. D.S. McGregor, R.T. Klann, H.K. Gersch, and Y-H. Yang, "Thin-Film-Coated Bulk GaAs Detectors for Thermal and Fast Neutron Measurements," Nuclear Instruments and Methods, A466 (2001) pp. 126-141.
5. D.S. McGregor, H.K. Gersch, J.D. Sanders, R.T. Klann, and J.T. Lindsay, "Thin-Film-Coated Detectors for Neutron Detection," Journal of the Korean Association for Radiation Protection, 26 (2001) pp. 167-175.
6. D.S. McGregor, S.M. Vernon, H.K. Gersch, S.M. Markham, S.J. Wojtczuk and D.K. Wehe, "Self-Biased Boron-10 Coated High Purity Epitaxial GaAs Thermal Neutron Detectors," IEEE Transactions on Nuclear Science, NS-47 (2000) pp. 1364-1370.

Conference Presentations:

1. H.K. Gersch, D.S. McGregor, and P.A. Simpson, "A Study of the Effects of Incremental Gamma-Ray Doses and Incremental Neutron Fluences Upon the Performance of Self-Biased ^{10}B -Coated High-Purity Epitaxial GaAs Thermal Neutron Detectors," IEEE Nuclear Science Symposium, Lyon, France, October 15-20 (2000).
2. R.T. Klann, C. L. Fink, D. S. McGregor, and H. K. Gersch, "Development of Semiconductor Detectors for Fast Neutron Radiography," Conference Record of the 15th Int. Conf. on Applications of Accelerators in Research and Industry, November, 2000.
3. D.S. McGregor, R.T. Klann, H.K. Gersch, and Y-H. Yang, "Thin-Film-Coated Bulk GaAs Detectors for Thermal and Fast Neutron Measurements," 2nd International Workshop on Radiation Imaging Detectors, Freiburg, Germany, July 2-6 (2000).
4. D.S. McGregor, S.M. Vernon, H.K. Gersch, and D.K. Wehe, "Self-Biased Boron-10 Coated High Purity Epitaxial GaAs Thermal Neutron Detectors," IEEE Nuclear Science Symposium, Seattle, Washington, Oct. 25-29 (1999).

