

## Custom Designed Schottky Barrier Bulk GaAs Detectors for Neutron Detection

Principal Investigator – Douglas S. McGregor

Funding: Argonne National Laboratories; Dr. Ray Klann

The project involves the use of bulk GaAs devices coupled to low atomic number materials for fast neutron counting. The project is funded through Argonne National Laboratories, Argonne, Illinois.

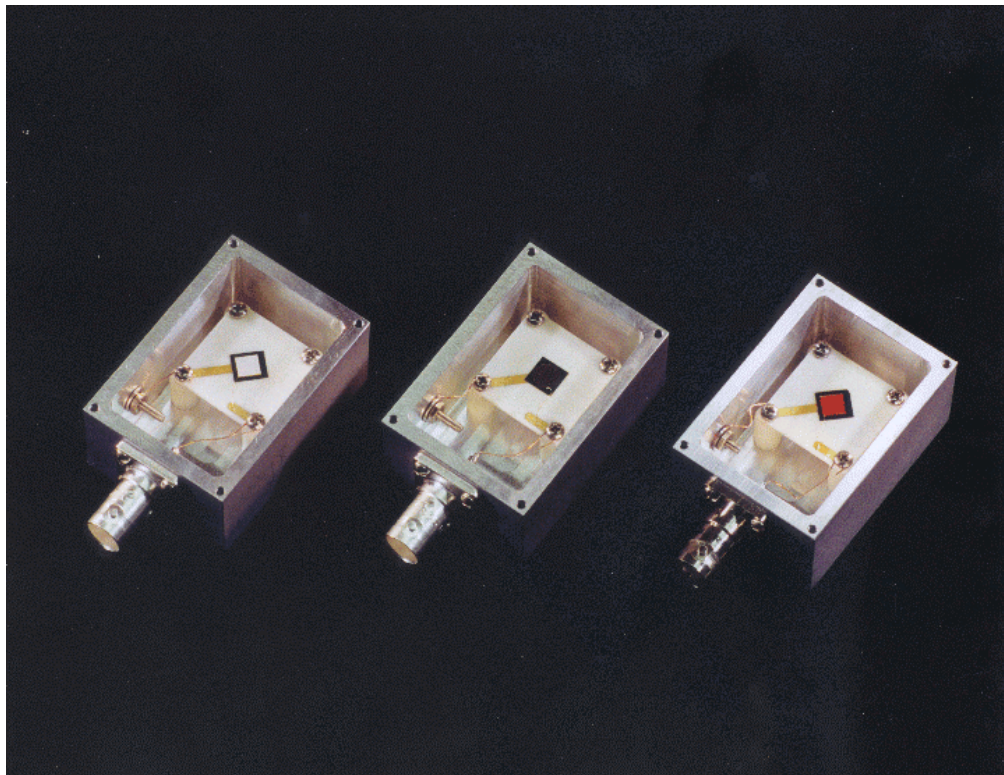


Figure 1: HDPE-Coated bulk GaAs detectors prepared for testing at the fast neutron facility located at Argonne National Laboratories. The devices have proven to be radiation hard and capable of detecting energetic neutrons from a 14 MeV neutron generator. The devices are directionally sensitive and detect neutrons only if they face the general direction of the neutron source.

Bulk GaAs Devices are under investigation as fast neutron detectors. Semi-insulating bulk GaAs Schottky barrier detectors have demonstrated radiation hardness to charged particles at levels above that of typical silicon detectors. Additionally, the material is relatively inexpensive compared to float-zone-

refined silicon and is readily available from a number of commercial vendors.

GaAs detectors coated with high-density polyethylene (HDPE) are sensitive to fast neutrons. HDPE is rich with hydrogen, and neutrons can cause the ejection of energetic protons through (n,p) reactions when they collide with hydrogen atoms in the HDPE material. The (n,p) reaction is primarily a forward scattering phenomenon, in which case only neutrons entering from the front of a device can cause the production of a radiation pulse.

When a voltage is applied across a semi-insulating bulk GaAs detector, a truncated high field or active region is produced near the contact. The incident neutrons are converted into charged particles in the coating, i.e. recoil protons, which excite free charge carriers in the GaAs detector active region. The charge carriers are drifted to the detector contacts, and a preamplifier circuit measures the induced charge. Charges excited in the low field or substrate region are not collected. In addition, because the active region can be kept thin (10-20  $\mu\text{m}$ ), background gamma-ray interactions are reduced. Gamma rays that are absorbed in the active region are easily discriminated from the recoil protons.

Figure 2 shows the detection response from 14 MeV neutrons emanating from a D-T generator. Shown are pulse height spectra from an uncoated device, a forward facing device coated with 125 microns of HDPE, and a backwards facing device coated with 125 microns of HDPE. Figure 2 establishes that the device is directionally sensitive, in which the forward scattered recoil protons can enter the GaAs detector only if it is facing the general direction of the fast neutron source. If the response were due to any other reaction or radiation incident on the detector, the spectrum for the backward facing detector would show a response. Instead, the response of the backward facing detector is statistically identical to the uncoated detector response.

The devices offer a solution to fast neutron directional sensing. Improved versions of the bulk GaAs-based fast neutron detectors are presently in production, and their response to epithermal neutrons is to be determined.

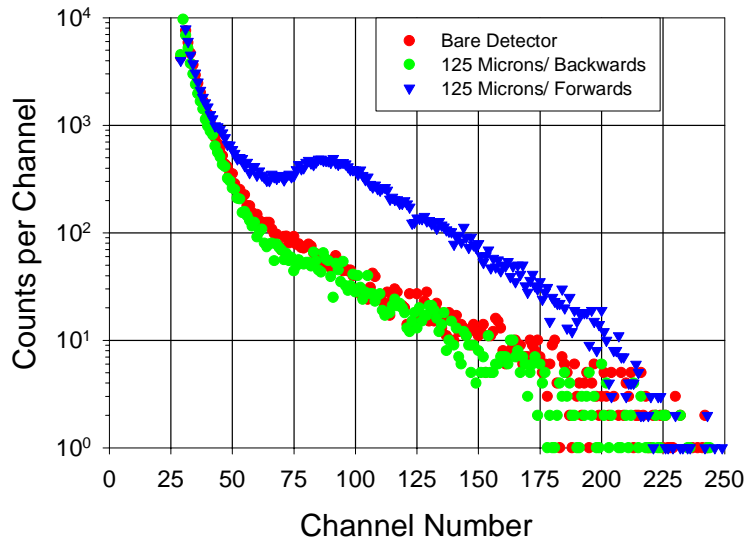


Figure 2: Comparison spectra taken with HDPE-coated SI GaAs detectors of 14 MeV neutrons from a D-T reaction generator. Shown are spectra with a 125-micron HDPE coated detector turned backwards (away from the source), front-wards (towards the source), and a front-wards facing device with no coating for reference.

#### Refereed Publications:

1. 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.
2. P.M. De Lurgio, R.T. Klann, C.L. Fink, D.S. McGregor, P. Thiyagarajan, I. Naday, "A Neutron Detector to Monitor the Intensity of Transmitted Neutrons for Small-Angle Neutron Scattering Instruments," Nuclear Instruments and Methods (2002) submitted.
3. 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.
4. D.S. McGregor, R.T. Klann, H.K. Gersch, E. Ariesanti, J.D. Sanders, and B. VanDerElzen, "New Surface Morphology for Low Stress Thin-Film-Coated Thermal Neutron Detectors," IEEE Trans. Nuclear Science (2002) in press.

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, 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.
7. R.T. Klann, C.L. Fink, D.S. McGregor, and H.K. Gersch, "Development of Semiconductor Detectors for Fast Neutron Radiography," *Proceedings of the 16<sup>th</sup> International CAARI* (2000).
8. R.T. Klann and D.S. McGregor, "Development of Coated GaAs Neutron Detectors," *Conference Record of ICONE-8*, No. 8110, 8th International Conference on Nuclear Engineering, April 2-6, 2000, Baltimore, MD USA.

Conference Presentations:

1. Raymond T. Klann, Charles L. Fink, Douglas S. McGregor, and Holly K. Gersch, "Development of Coated Gallium-Arsenide for Neutron Detection Applications," *Conference Record of the 12<sup>th</sup> Biennial RPSD Topical Meeting*, Sante Fe, New Mexico, April 14-18, 2002.
2. D.S. McGregor, H.K. Gersch, J.D. Sanders, and R.T. Klann, "Designs for Thin-Film-Coated Semiconductor Neutron Detectors," *Conference Record of the IEEE Nuclear Science Symposium*, San Diego, California, Nov. 4-9, 2001.
3. D.S. McGregor, R.T. Klann, H.K. Gersch, E. Ariesanti, J.D. Sanders, and B. VanDerElzen, "New Surface Morphology for Low Stress Thin-Film-Coated Thermal Neutron Detectors," *Conference Record of the IEEE Nuclear Science Symposium*, San Diego, California, Nov. 4-9, 2001.
4. J.D. Sanders, J.T. Lindsay, and D.S. McGregor, "Development of a GaAs-Based Neutron Tomography System for the Assay of Nuclear Fuel," *Conference Record of the IEEE Nuclear Science Symposium*, San Diego, California, Nov. 4-9, 2001.
5. D.S. McGregor, H.K. Gersch, J.D. Sanders, R.T. Klann, and J.T. Lindsay, "Thin-Film-Coated Detectors for Neutron Detection," *Conference Record of the First iTRS International Symposium On Radiation Safety and Detection Technology*, Seoul, Korea, July 18-19, 2001.
6. 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.

7. 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  $^{10}\text{B}$ -Coated High-Purity Epitaxial GaAs Thermal Neutron Detectors," Conference Record of the IEEE Nuclear Science Symposium, Lyon, France, Oct. 15-20, 2000.
8. D.S. McGregor, J.T. Lindsay, Y-H. Yang, and J.C. Lee, "Bulk GaAs-Based Neutron Detectors for Spent Fuel Analysis," Conference Record of ICONE-8, 8th International Conference on Nuclear Engineering, April 2-6, 2000, Baltimore, MD USA.
9. R.T. Klann and D.S. McGregor, "Development of Coated GaAs Neutron Detectors," Conference Record of ICONE-8, 8th International Conference on Nuclear Engineering, April 2-6, 2000, Baltimore, MD USA.

