Thin Film CdS/CdTe Diodes for Nuclear Radiation Detection

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Abstract

In this study we have investigated thin film, polycrystalline CdS/CdTe PN diodes as solid state charged particle detectors. Solid state neutron detectors rely on the indirect detection of neutrons via a nuclear reaction, which produces charged particles detected by a semiconductor diode. The CdS/CdTe diodes were evaluated in terms of their sensitivity to alpha and gamma radiation when connected to a charge sensitive preamplifier. The devices were found to have an alpha particle counting efficiency of > 90%. The pulse height response of these diodes due to alpha radiation is found to be a function of applied bias, angle of incidence, and energy of the incident alpha particles. Preliminary gamma sensitivity measurements indicate an intrinsic gamma detection efficiency of less than $1x10^{-6}$. The CdS/CdTe results were calibrated using a 1 cm^2 Ortec ULTRA silicon PIN detector and were also compared to data collected from silicon detectors fabricated at UT Dallas. The CdS/CdTe devices offer the possibility of large area neutron detectors with high gamma rejection rates and affordable production costs.

Experimental

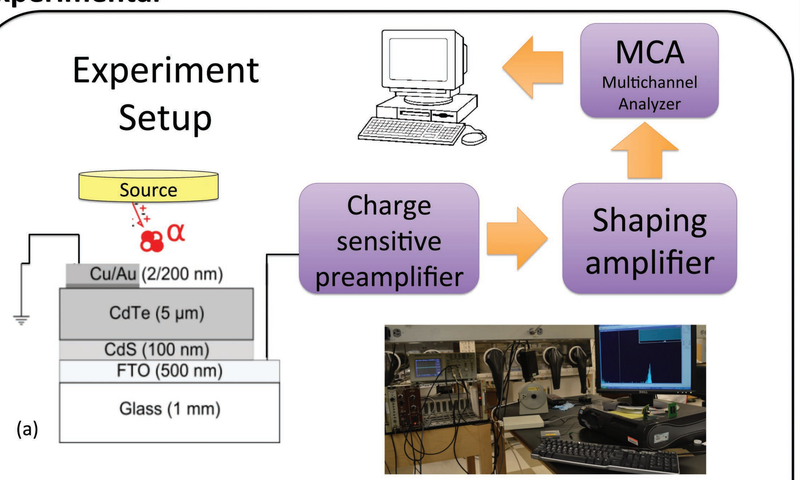
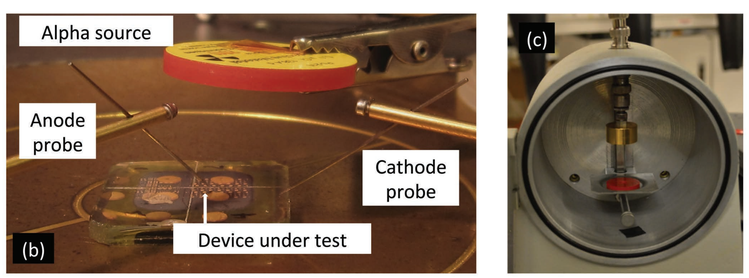


Figure 1
(a) Diagram of amplification and charge collection system, (b) set up with 0.5mm diameter CdS/CdTe device under testing, (c) Ortec diode in vacuum chamber with ^{210}Po source positioned 37mm below the diode.



Results

Counting and Gamma Detection Efficiency

Assuming both the counting and the charge collection efficiency of the Ortec Si diode to be 100%, the intrinsic alpha particle counting efficiencies were calculated to be 94% for the 0.002cm^2 diode and 99% for the 0.1cm^2 diode. A gamma detection efficiency of 0.5×10^{-6} was estimated based on data revealing zero pulses registered above 220keV and calculations showing 2×10^6 gamma rays were incident on the device.

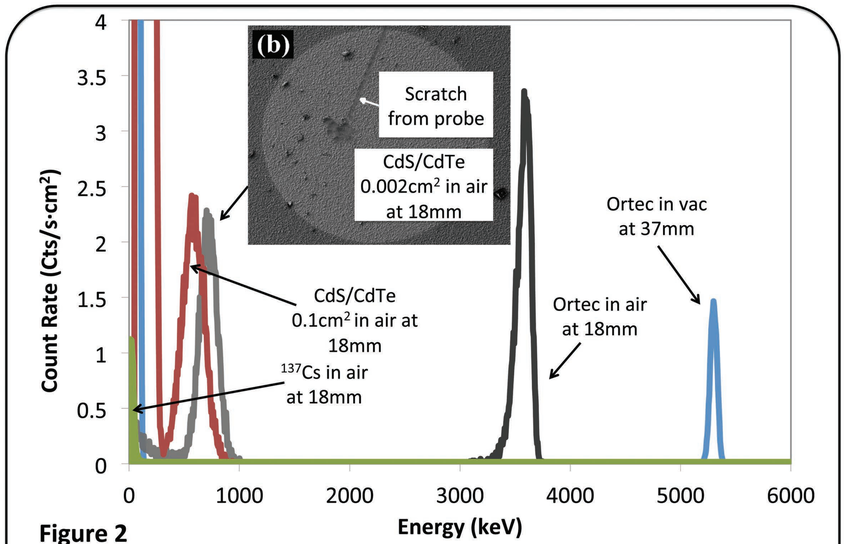


Figure 2
Pulse height spectra showing the response of the 0.002 and 0.1 cm^2 CdS/CdTe diodes in comparison with the 1 cm^2 Ortec Si diode used for source calibration. The decrease in the counting efficiency for the smaller device may be due to defects from probe contact, shown by SEM image (b).

Minimizing Noise

To reduce the internal noise, plastic based masks were placed over two 500μm diameter CdS/CdTe PN and Si PIN diodes to restrict the area where the alpha particles were incident on the devices.

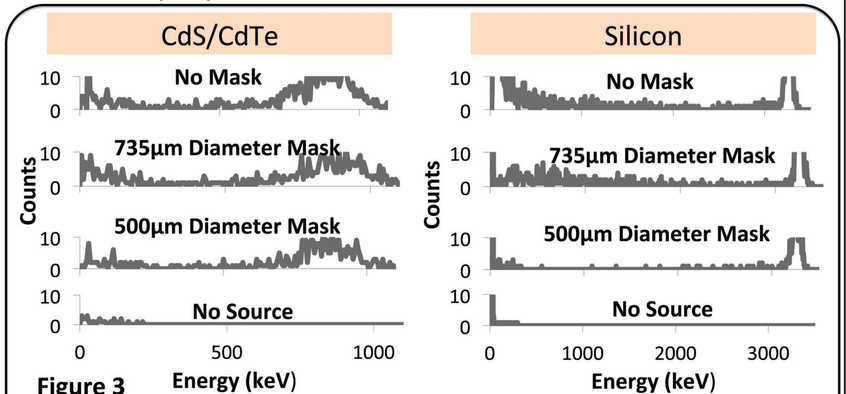


Figure 3
Pulse height spectra showing the effect of the masks to reduce the internal noise between the background (no source graph) and the peak.

Pulse Amplitude Characteristics

The average pulse height varied depending on bias and conditions applied to the source. The amplitude increased with reverse bias, increased when a moderator was applied, and decreased as the angle of incidence approached the normal.

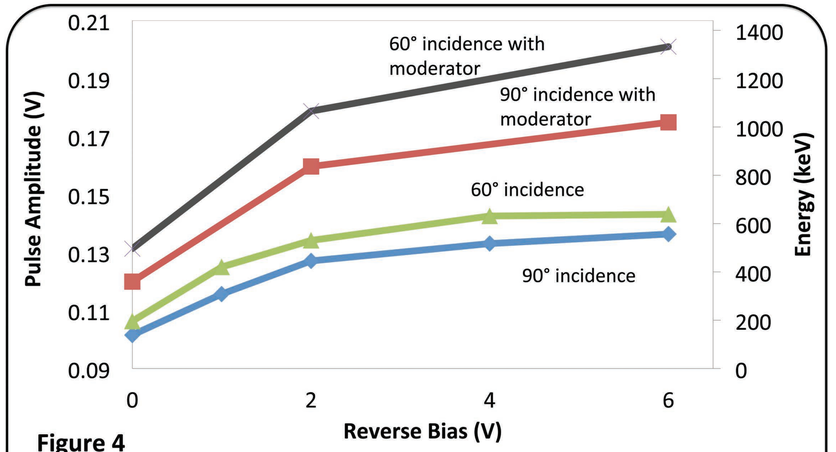


Figure 4
The average amplitude of alpha pulses striking a 6μm thick CdS/CdTe diode as a function of voltage. A 10μm polyimide film was used as a moderator to reduce the energy of the alpha particles entering the diode from 3.5 to 2.2 MeV.

Conclusion

- We have demonstrated that CdS/CdTe diodes can function as charged particle detectors.
- The intrinsic detection efficiency of 661 keV gamma rays was measured to be less than 1×10^{-6} and is expected to be much lower [1].
- We believe these devices offer the possibility of fabricating large-area, low-cost thermal neutron detectors by utilizing current, well developed CdS/CdTe diodes [2].

References

[1] Murphy J. et al, *Appl. Phys. Lett.*, **2012**, *101*, 14.
[2] Woodhouse M. et al, *Materials and Solar Cells,* **2012**, *115*, 199-212.

Acknowledgements

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