Three-dimensional wide bandgap semiconductor radiation detectors and their applications

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The performance and capability of three-dimensional (3D) position sensitive CdZnTe semiconductor gamma-ray detectors have been improved significantly since the first experimental demonstration in 1998 using a $1\times1\times1$ cm^3 crystal with 11×11 pixellated anodes. The energy resolution has been improved from 1.7% FWHM at 662 keV for single-pixel events on the first detector to 0.48% FWHM on one CdZnTe detector with dimensions of $2\times2\times1.5$ cm^3, with a six times larger detection volume. These detectors can provide the energy deposition and position in 3D of each individual radiation interaction. This 3D position-sensing capability enables the determination of incident gamma-ray direction based on photon scattering kinematics if gamma rays undergo Compton scattering within the detector volume.

Since the signatures of radiation interaction with detector material are recorded, it is possible to recognize different types of gamma-ray interactions, such as photoelectric absorption, Compton scattering and pair production. Therefore, the recorded signals can be processed depending on the type of interaction, to improve the signal-to-noise ratio of energy spectrum or to perform gamma-ray imaging. It is also possible to distinguish incident charged particles, which often leave straight tracks through the detector volume, from gamma rays that have discrete interactions. In addition, neutrons can be detected by observing characteristic reaction products of neutron capture. The current development effort on 3D CdZnTe detectors and alternative wide bandgap semiconductor detectors will be summarized, and their applications in nuclear non-proliferation, homeland security, medical imaging, nuclear physics, astrophysics and planetary sciences will be introduced.