PRINCETON GAMMA-TECH

How to Choose a Ge Detector

The first and most important factor in selecting a germanium detector, just as with any analytical instrument, is the application. What is the purpose for using the detector and what will be the future uses of the detector? Often the purpose can also be defined as the energy range of interest. If the energy range of interest is as broad as possible, i.e. from < 5KeV to several MeV, then the choice has to be a coaxial detector. If the energy range of interest is only the very low range of the spectrum, having to do with naturally occurring x-rays and those produced by fluorescence, then an x-ray detector is the appropriate choice. For an area of interest that includes low energy x-rays but also energies up to a few hundred KeV, then a semi-planar detector might be the best choice. Princeton Gamma Tech defines germanium detectors into these categories. Crystal choice, along with cryostat configuration, is the most important factors in choosing your germanium detector.

The following describes the different types of germanium detectors as well as the terms used in developing performance specifications. We invite you to click on CRYOSTATS to become familiar with the large variety of configurations available with PGT germanium detectors.

Coaxial

These detectors are by far the most popular type of germanium detectors. Coaxial detectors have the broadest energy range. Gamma rays below 5 KeV and up to several MeV are detected and quantified using a coaxial detector. Coaxial detectors are typically right circular cylinders. One of the unique features of a coaxial detector is its ability to process photons from one end of the cylinder as well as the entire side area of the cylinder. Since coaxial detectors are available in sizes from <5 cm x 5 cm to >8 cm x 8cm, this results in a great deal of surface area and the probability of interaction of radioactive decay from a given sample in the crystal is very high. Resolution does not vary a great deal in coaxial detectors as a function of crystal size, so the choice of coaxial detector size has more to do with the anticipated sample activity and, of course budget. A larger crystal will be more efficient and will cost more money. Please visit the pages for P-type and N-type coaxial detectors for more details.

Typical applications of coaxial detectors include:

- Environmental counting over a broad energy range including cesium 137, cobalt 60 as well as uranium, radium, americium and medical isotopes.
- Nuclear power radiochemistry on low, moderate and high count rate samples.
- A variety of physics applications that require higher energy efficiency.
- Neutron activation analysis.
- Homeland Security screening.
- Ultra low activity sample counting.

Semi-planar

These detectors are used in the energy range of less than 5 KeV to a few hundred KeV. The energy resolution of semi-planar detectors significantly exceeds that of coaxial detectors up to a few hundred keV. At that point, the lack of electrical field uniformity starts to affect energy resolution and peak symmetry. However, this is not an issue for photons lower than 200-300 KeV and semi-planars offer both high resolution and excellent efficiency for this energy range.

Semi-planars are cylindrical crystals that are wider than they are long and typically present only one surface that is used to detect photons. This geometry is perfect for most accelerator applications, planchette counting and whole body counting as well as any application for detecting photons of this medium energy range emanating from a specific location.

Unlike coaxial detectors, differences in the physical size of semi-planar detectors has a great effect on energy resolution and the resolution requirement for the potential application will often dictate the maximum diameter and thickness of the crystal. Crystal thickness determines efficiency as a function of energy and all PGT semi-planar detectors of a particular diameter are available in a variety of thicknesses.

Typical applications of semi-planar detectors include:

- In-vivo lung monitoring for actinides
- Pb-210 counting of soil sediments
- In-situ neutron analysis for explosives detection
- Accelerator physics experiments
- Fuel rod enrichment measurements

X-ray detectors

Princeton Gamma Tech manufactures traditional P-type planar detectors and the IGX series of x-ray detectors for X-ray analysis. These crystals range from 10 square millimeters of surface area to 100 square millimeters of surface area. They are specifically designed for energies ranging from less than 1 KeV to 60 KeV, although the largest IGX can be used above 100 KeV effectively.

What these detectors lack in size, they make up with the best energy resolution of any solid state detectors. PGT manufactures a full line of Silicon Si(Li) detectors as well as Silicon drift detectors but the energy resolution of IGX series detectors is the best available.

Light element windows and a variety of vacuum interface designs are available to allow use inside vacuum chambers attached to EDS or XRF systems or accelerator ports for industrial and research applications including analysis to energies as low as 180 eV.

Typical x-ray detector applications include:

- Slurry analysis
- Materials analysis
- Surface analysis
- X-ray telescopes

Terms: The definitions listed below are the more typical terms used to describe germanium detector performance and have evolved into benchmarks that the IEEE has determined to be the most important.

- **Resolution**: Energy resolution defines the detector s ability to produce narrow peaks in the spectrum. Energy resolution is affected by detector geometry and electronic noise. Resolution is generally specified at 1.33 MeV and 122 KeV for most coaxial detectors and 5.9 KeV and 122 KeV for most semi-planar and X-ray detectors. Resolution is typically measured as the width at the full width at half maximum for the given energy. In all cases the smaller the number specified for energy resolution is best and gives the user a better probability of separating peaks for easier isotopic identification.
- **Efficiency:** There are three types of detector efficiencies used when describing germanium detectors. The most common has to do with the size of a coaxial detector. In fact this is a specific measurement and is more correctly called relative efficiency . It is described in IEEE standards and means the counts in the 1332 KeV peak of cobalt 60 detected from a point source placed 25 cm from the center of the flat face of the crystal relative to the number of counts that would be detected by a 3 by 3 NaI detector with the energy source, source to detector distance and count time.

  Sometimes the terms absolute efficiency and intrinsic efficiency are used. These terms are relevant to any photon detector. Absolute efficiency is the measure of photons detected from a specific source vs. the number of photons emitted from that source. Intrinsic efficiency is the ratio of counts in a given photopeak vs. the number of those photons that impact the crystal. Higher efficiency means greater sensitivity. The benefits of higher efficiency include shorter count times and better peak to background ratios at higher energies. The downside may include count rates that are so high that they cause high dead times and higher backgrounds interfering with delectability of weak lower energy photons.

- **Peak to Compton Ratio** This is another specification that has to do only with a coaxial detector and cobalt 60. The P/C ratio is the number of counts in the peak channel of a 1332 KeV vs. the integral of the counts in the spectrum ranging from 1040 KeV to 1096 KeV. The P/C ratio is interesting because it is a detector characteristic that takes both efficiency and energy resolution into account. A higher efficiency detector will have more 1332 KeV counts in the photopeak. With better resolution, the photopeak will be narrower forcing the peak channel counts to increase.
- **Peak Shape:** This is typically more important for higher energies. As energy increases, the crystal charge collection is an increasingly more important factor and the electric field within a large crystal is never 100% uniform.. Photopeaks displayed on an MCA are ideally Gaussian, but that is not always attainable. A ration of the tenth maximum to the half maximum is going to vary from the ideal with increasing detector size. Peak asymmetry will be displayed as an increasing number of counts skewing the lower energy side of the photopeak. Germanium coaxial detectors are often specified to have tenth maximum to half maximum ratios ranging from 1.9 to 2.0. Sometimes the full width fiftieth maximum to full width half maximum is of interest and generally is specified as less than 2.8/1. once again, peak shape is almost always specified at 1332 KeV.

The links listed below all contain data for the entire PGT detector line and include the specifications such as relative efficiency, energy resolution, P/C ratio and peak shape. The specification sheets are available for downloading.

All Princeton Gamma Tech germanium detectors are available with appropriate signal processing electronics and software. PGT can provide with the complete spectroscopy package in any application that uses germanium detectors. More information is available under the headings of particular detector types on this web-site. You can call PGT directly at 609 924 7310 or contact your PGT representative in your area for further information.