AMPTEK X-RAY DETECTOR SELECTION GUIDE

This document discusses which detectors are best for which applications. Please refer also to the document titled "Amptek Detector Performance Comparison". This has plots which supplement the discussion here.

Silicon drift detectors (SDDs)

SDDs are recommended for applications needing the best energy resolution and/or the highest count rate. Amptek's SDD can provide an energy resolution of 125 eV FWHM at the Mn K_α line (electronic noise of 38 eV FWHM or 4.5 electrons rms), a peak to background of up to 20,000:1, an output count rate of >$5x10^5$ sec^{-1}, and can detect X-rays down to the beryllium K_α line (110 eV). There are three SDD variants currently available from Amptek: the standard SDD, the FastSDD®, and the low energy SDD.

- Amptek's FastSDD® is recommended for input count rates >10^5 sec^{-1} (peaking times below 4 μs). The FastSDD® provides resolution comparable to the standard SDD, 125 eV FWHM, but at about four times shorter peaking time and thus four time higher count rates. The FastSDD® and the standard SDD use the same X-ray detector, but Amptek's standard SDD uses a JFET preamplifier while the FastSDD™ uses a CMOS preamplifier to reduce high frequency noise.
- Amptek's standard SDD is recommended for applications needing the best energy resolution but at count rates of <10^5 sec^{-1}. The resolution is also 125 eV FWHM but at a longer peaking time. The peak to background and other characteristics are the same as the FastSDD®.
- Amptek's Low Energy SDD is recommended for measuring X-rays below 1.5 keV. The standard SDD and FastSDD® use a Be window, which has limited transmission below 2 keV. The low energy SDD uses Si_3N_4 window with better transmission at low energies. There are two Si_3N_4 variations, discussed in detail elsewhere. The C2 window is for the very lowest energies, ideal for EDS application, with 50% efficiency at the C K_α line. It is intended for vacuum applications, since air attenuates the low energy X-rays and is not fully light tight.

A silicon drift detector (SDD) is a type of photodiode, functionally similar to a PIN photodiode but with a unique electrode structure to improve performance. It has a very low input capacitance, yielding low noise at short peaking times and enabling high count rate applications. Amptek's SDDs are 500 microns thick with an active area of 25 mm^2 and include a multilayer collimator and a multilayer shield to minimize interferences. Amptek's SDD is a custom design, fabricated on silicon using standard silicon processing methods.

Si-PIN detectors

Si-PIN detectors are recommended for application requiring moderate energy resolution and count rate where cost is most important. Si-PIN devices have a conventional planar structure, with capacitance and thus more electronic noise at short peaking times than an SDD, but they are easier and cheaper to fabricate. They are fabricated on 500 mm thick Si and include a multilayer collimator.

There are three different Si-PIN variations currently available from Amptek, with areas of 6 mm^2, 13 mm^2, and 25 mm^2. The 6 mm^2 detectors provide an energy resolution of 145 eV FWHM at the 5.9 keV Mn K_a line at count rates up to 10^4 sec^{-1}. The 13 mm^2 and 25 mm^2 detectors typically offer energy resolutions of 180 and 210 eV FWHM for the same count rates. SiPIN detectors are available with 1/2 mil Be and 1/3 mil Be windows.

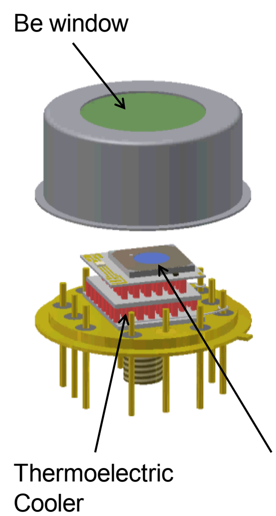
CdTe detectors

CdTe detectors are recommended for applications above 20-30 keV. CdTe has much higher stopping power than Si and can be made much thicker, so has high efficiency for all characteristic X-rays, even up to the K lines of U. The electronic noise of Si is better than that of CdTe detector (CdTe resolution typically 450 eV FWHM at the 5.9 keV Mn K_α line), making a Si detector a better choice for energies below 20 keV. But above 20 to 30 keV, the resolution is dominated by Fano broadening anyway so the difference becomes small, the characteristic X-ray lines are more widely spaced, and the efficiency of the Si detector falls off, making CdTe a better choice. The CdTe detectors is very well suited to measuring the spectrum from an X-ray tube, where efficiency is very important and energy resolution is less critical. Amptek's CdTe detectors utilize a planar geometry with Schottky contacts for good charge collection and low leakage current.

CdTe detectors are available in two different areas (3x3 mm^2 and 5x5 mm^2) and in two different thicknesses (0.75 mm and 1.0 mm). The 5x5 mm^2 device has typically twice the electronic noise of the 3x3. The thinner device has better charge collection, so better resolution and a more Gaussian response but somewhat lower efficiency at the higher X-ray energies.

CdTe detectors are available with three different preamplifier circuit configurations: a reset preamplifier for low noise and count rates up to 100 kcps, a transistor feedback which gives low noise and operates up to 10 kcps, and a resistor feedback with higher noise but the highest count rates. A 4 mil Be window is used with CdTe.

Similarities

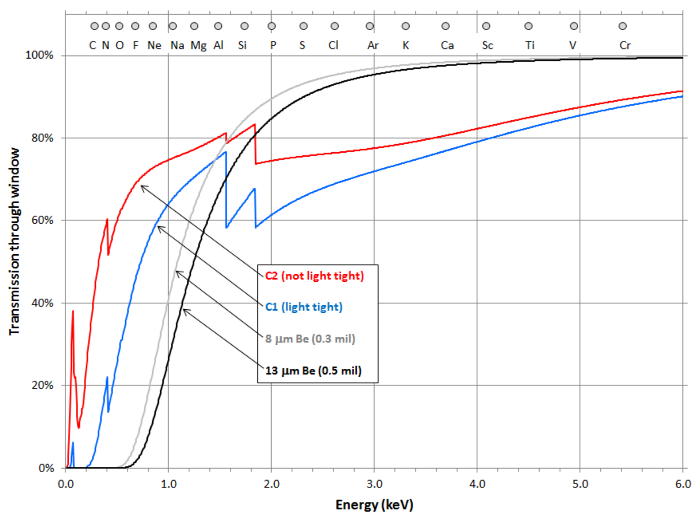


- As shown below, all of Amptek's X-ray detectors are mounted on a thermoelectric cooler to reduce electronic noise and so improve the energy resolution. There is vacuum inside the package for best cooling. The cooler can provide up to 85°C of cooling relative to ambient; operating temperatures<220K are typical in lab conditions and <250K in the field. The cooler draws about 1W at maximum cooling.
- All of Amptek's X-ray detectors are mounted in a 12-pin, TO-8 package. The cover is made of nickel. There is a thin window; the window is necessary for vacuum but it is thin to maximize X-ray efficiency. The cover height and the assignment of the pins vary with detector configuration.
- All of Amptek's X-ray detectors require one of Amptek's charge sensitive preamplifiers. A portion of the charge amp is inside the TO-8 package while a portion is on a circuit board located nearby. There are several different preamplifier options available; these are discussed in more detail elsewhere but include the standard XR100, XR100 with vacuum extender, X-123, PA210, and PA230.
- All of Amptek's detectors require signal processing electronics and power supplies. Amptek has several different signal processors and power supplies available; these are discussed in more detail elsewhere but include the PX5, the X-123, and the DP5/PC5. Customers can also provide their own processors and power supplies. Many digital pulse processors and NIM shaping amplifier work with these detectors. Standard NIM power supplies will not work.

Choosing the detector window

The "window" is a thin membrane, which transmits the X-rays but maintains vacuum pressure inside the detector. Amptek has five different window options.

1) Be, 0.5 mil (13 μm) thick. This is the most commonly used and is recommended for most XRF applications. It has good efficiency >2.5 keV, so covers most elements of interest.
2) Be, 0.3 mil (8 μm) thick. This has better efficiency than the 0.5 mil Be at low energies so is recommended when energies between 1 and 3 keV are particularly important.
3) C2, 40 nm of (Si_3N_4) on a silicon grid. This is recommended for vacuum systems measuring the lowest energies. It has the best efficiency at low energies, transmitting 40% at the C K_α line. But it is not light tight, so must be used in the dark, and can be damaged by the smallest dust particles.
4) C1. This is also made of Si_3N_4 but has enough aluminum to be light tight. Its efficiency is reduced at the lowest energies due to the light-tight coating.
5) Be, 1 mil or more. This is typically used with CdTe detector, which are optimized for higher energies.

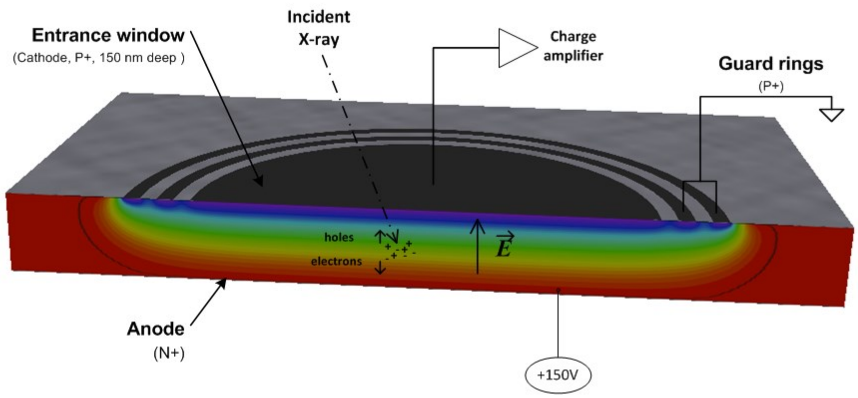


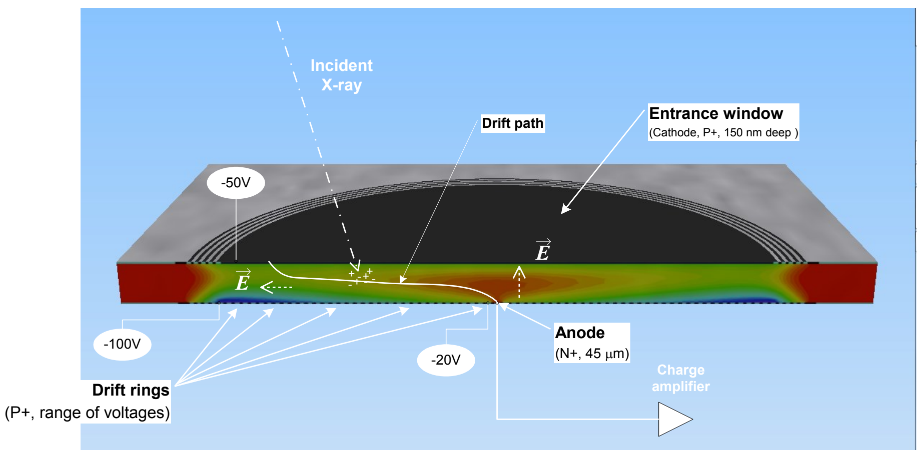
All of these windows are relatively fragile. They cannot be touched, by anything, or they will break!! The windows operate normally at atmospheric pressure and at vacuum and can be cycled many times with no problem. They do not break under normal usage.

But they cannot be cleaned or touched. If they are touched by a finger during installation, they will break. The C windows are not damaged when the pressure changes, but when a vacuum system is vented or pumped, dust particles or debris in the chamber can be blown against the window, and the window will break.

Difference between SiPIN and SDD detectors

The plots below illustrate the different structures in an SiPIN (top) and an SDD (bottom). These are discussed in the document entitled “Understanding Amptek Silicon Drift Detectors”.





Notes on specifications

- The "area" shown in the specifications is the electrically active area. This is surrounded by electrically inactive silicon. Many detectors include an internal collimator, which masks off regions of poor charge collection that would otherwise contribute to background. The “collimated area” is defined by this collimator.
- The "resolution" is the full width at half maximum (FWHM) of the 5.9 keV Mn K_{α} line for SDD and SiPIN and at the 122 keV ^{57}Co γ-ray line for CdTe. It is guaranteed to be within the range listed, under the specified measurement conditions. It is measured for each detector sold.
  - The resolution for each detector is measured at the listed peaking time, using an Amptek digital processor.
  - The performance is measured at Amptek at ~1,500 cps and full cooling ($T_{detector}$ <225K).
- The results shown in “Amptek Detector Performance Comparison” are typical results, not guaranteed and not tested with each unit.
- The peak to background ratio is the ratio of (a) counts in the peak channel at 5.9 keV to (b) the average counts in a region of interest, centered at 1 keV for the SDDs and at 2 keV for the SiPIN detectors. The specification table lists the typical value.

- The preamp gain is the step size out of the preamplifier. This is positive (negative) polarity for the SDD (SiPIN and CdTe) detectors. The specification table lists the typical value.
- The bias voltage listed in the specifications is typical. The ideal or recommended value may vary from one detector to the next, since it depends on the depletion voltage of the silicon, and there is some manufacturing variability.