SILICON PHOTODIODES
FOR GAMMA RAY DETECTION

First Sensor

First Sensor expands its detector series for ionizing radiation. The new X100-7 targets high volume gamma detection applications by combining low dark current and low capacitance silicon photodiodes with reliable and cost-efficient packaging.

Recent events like the nuclear disaster in Japan have raised awareness of risks from nuclear radiation and created an additional demand for commercial as well as personal radiation detection devices.

Typical products of plutonium and uranium nuclear fission processes are isotopes of Iodine ^{131}I and ^{132}I, Cesium ^{132}Cs and ^{137}Cs, as well as Tellurium-132 and Strontium-90. While ^{132}Te, ^{131}I, ^{132}I and ^{132}I are relatively short-lived, ^{134}Cs has a half-live of about 2 years and ^{137}Cs as well as ^{90}Sr even of about 30 years. Accordingly, ^{134}Cs, ^{137}Cs and ^{90}Sr are the dominant radioactive isotopes regarding health impacts months and years after the nuclear disasters of Chernobyl and Fukushima. The mentioned Cesium and Iodine isotopes decay mainly emitting high energy gamma radiation between 300 and 800 keV. ^{90}Sr emits beta radiation of 546 keV energy.

Specifically, gamma radiation from Cesium-137 (662 keV) is often used to identify contamination from the Fukushima disaster.

Solid state detectors provide a reliable and compact solution for radiation monitoring. Generally, solid state detectors can be divided in two groups: scintillator based and direct absorption based detectors.

High performance solid state radiation detectors use the conversion of nuclear radiation into visible light by luminescence of a scintillator crystal such as CsI, LYSO or BGO. The characteristic blue or green luminescence is then detected by a very sensitive photodiode. Such a detector requires a sophisticated crystal coating to reflect all luminescence into the photodiode. The resulting advantage is a high absorption probability even for high energy radiation due to a relatively large crystal thickness. However, the crystals also result in higher manufacturing costs.

First Sensor X10-γ detector

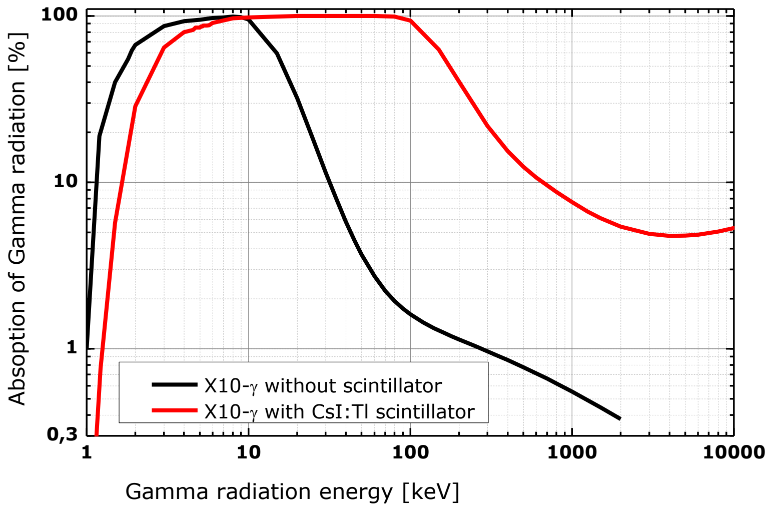

Fig.1. Gamma absorption characteristics of the First Sensor X10-γ detector with and without scintillator.

Figure 1 illustrates this difference for the First Sensor X10-γ detector. To increase sensitivity at low gamma energies a very thin aluminized Kapton window is used. Furthermore, the fully depletable X10-γ detectors are based on ultra-low dark current technology to maximize energy resolution and sensitivity and find application in high performance detector solutions.

However, high volume applications for radiation detection devices demand more cost-efficient solutions. Nuclear radiation meters based on direct absorption in silicon provide a reliable and inexpensive alternative. First Sensor AG developed the direct absorption based X100-7 for this market.

There are several physical processes involved in the gamma photon attenuation. Compton (incoherent) and Rayleigh (coherent) scattering as well as photoelectric absorption are dominant in the gamma energy region of interest between 100 keV and 1 MeV. Absorption probability decreases with increasing energy and is already well below 5% at 100 keV in silicon detectors. Yet, at the same time the amount of charge carriers released upon absorption of a gamma photon increases linear with gamma energy at a rate of about 1 pair per 3.7 eV. That means that if a high energy gamma photon is absorbed a detectable signal of approximately 105 electrons is generated. Additionally, this dependence enables a discrimination of the characteristic radiation energy and hence the source.

To reliably detect such gamma energies in silicon accordingly a large area, low capacitance and low dark current detectors such as the X100-7 are essential. With its active area of 100 mm² it provides a large cross section for radiation detection. Furthermore, the X100-7 is designed to be operated already at relatively low bias voltages to simplify circuit design and reduce dark current to a minimum. Low bias voltage causes a relatively small depletion zone outside of which charge carriers transit slowly by diffusion with transit times around 2-5µs. Using state-of-the-art wafer processing and high quality raw material First Sensor increased the carrier lifetime such that essentially all generated free charge carriers are collected.

A special black epoxy encapsulant guaranties the blocking of light while maintaining small gamma ray attenuation (see figure 2). First Sensor offers the X100-7 both in a ceramic SMD package as well as a ceramic 2-pin THD package up to high volume quantities.

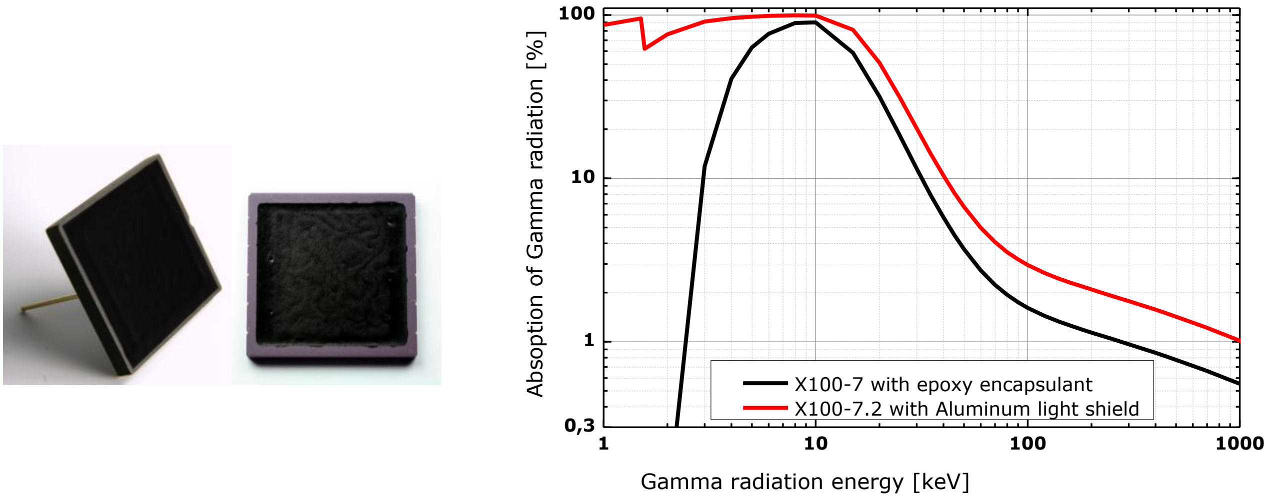

Fig.2. Gamma absorption characteristics of the First Sensor X100-7 detector series as well as pictures of the THD and SMD epoxy version (photo left and middle).

Based on the large resonance of the market, First Sensor currently develops the next generation device: X100-7.2 with increased sensitivity both in low and high energy region. Also, custom specific options including thicker silicon, fully depletable chip designs or scintillator coupled devices are available upon request. Please contact us for full details.

Several customers sucessfully integrated the X100-7 in their compact detectors for gamma radiation of Cesium isotopes to detect contamination connected with the Fukushima disaster (shown in figure 3). Reference information can be found at http://einstlab.web.fc2.com/Xdetector/detector.html or http://einstlab.web.fc2.com/Gamma/spectroscopy.html.

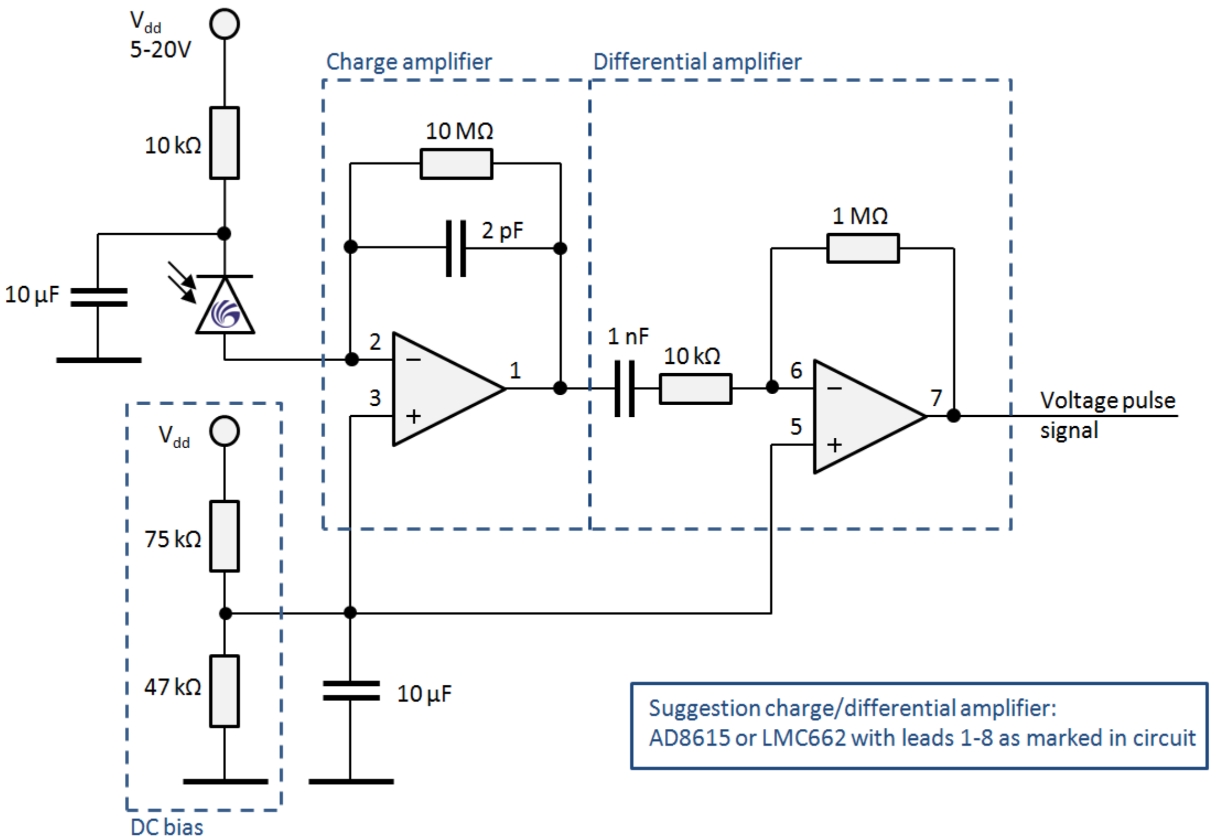

Fig.3. Reference circuit for X100-7 radiation detector by Y. Onodera (http://einstlab.web.fc2.com/Xdetector/detector.html).

First Sensor AG provides cutting edge technology for sophisticated sensor applications. For full details and customization options feel free to contact us at sales.opto@first-sensor.com.

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