LARGER VOLUMES OF HgI_2 USED AS
PORTABLE GAMMA-RAY COUNTERS*

by

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ABSTRACT

Mercuric iodide detectors up to 1.5 cm in thickness and with active areas of up to 17 cm² were fabricated and used as room-temperature, portable, gamma-ray counters. Most of the detectors show no photopeak spectral resolution, but the end point energies of various gamma radiation sources are linear with energy. The detectors are biased with about 10³ V/cm, which can be provided in a portable package with a rechargeable capacitor. The nuclear performance of these counters is described.

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Mercuric iodide detectors up to 1.5 cm in thickness and with active areas of up to 17 cm^2 were fabricated and used as room-temperature, portable, gamma-ray counters. Most of the detectors show no photopeak spectral resolution, but the end point energies of various gamma radiation sources are linear with energy. The detectors are biased with about 10^3 V/cm , which can be provided in a portable package with a rechargeable capacitor. The nuclear performance of these counters is described.

1. INTRODUCTION

Mercuric iodide is a wide-gap (2.1 eV), high-Z, semiconductor type nuclear radiation detector material which operates at room temperature. The accepted state-of-the-art¹ of mercuric iodide is that it is an excellent and efficient low-energy x-ray detector² which can reach at room temperature resolutions below 300 eV for the 5.9-keV x-ray emission of ^{59}Fe . However, for higher energy gamma-ray detectors,³

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best resolutions of ~ 5 keV for the 660-keV photoppeak of ^{137}Cs were obtained on thin slices of mercuric iodide, less than 1 mm in thickness. Such a thin detector has a very low efficiency to stop high-energy gamma-rays. Most of the thicker mercuric iodide detectors show very poor spectral resolution, due to the low drifting length of the minor carriers which does not allow full charge collection, thus degrading the spectrum.

Spectral information is not needed in many applications, such as in portable area survey monitoring. It is advantageous for portable detectors to be light in weight, of low volume, and to require low power. Scintillators, such as NaI, require photomultiplier tubes for their operation and are therefore bulky and require a substantial high-voltage supply. This paper describes the advantages and results obtained using thick mercuric iodide radiation counters in portable applications.

2. DETECTOR FABRICATION

Single crystals of mercuric iodide to be used as thick counters are grown from the vapor phase as described elsewhere.⁴ These crystals range in weight from 150 to 200 g and take from one to three months to grow. The "as grown" crystals are then cut and trimmed with a solution string saw. Electrodes of painted Aquadag or evaporated Pd or Ge are desposited on the "C" faces (001 plane) of the crystal pieces. The contact configuration is that of a parallel-plate capacitor. Two or three of these crystal pieces having dimensions of $\approx 1 \times 2 \times 5$ cm are then mounted on a ceramic substrate and connected in parallel to form a gamma-counter (Figure 1) whose sensitivity is equivalent to a 1-1/2-inch by 1-1/2-inch NaI scintillator over a wide range of gamma-ray energies.

The carrier mean free paths in mercuric iodide allow electrons to be collected over a distance of several centimeters but allow holes to be collected only over a 0.5 to 1 mm distance. The thick gamma counters rely on the good collection of properties of the electrons, and ignore the poor collection

properties of the holes. Because of the incomplete charge collection, the spectral output of the thick detectors cannot generally be used for isotopic analysis. The spectrum from a thick counter of a monoenergetic gamma-ray source looks like an exponential decay with an end point (Figure 2), whose position is linear with energy (Figure 3). Typically, the thick counters are used to detect gamma-ray sources from 30 keV to 1.3 MeV.

The "pseudo" single-charge collection of the thick counters has a disadvantage when looking at low-energy gamma-ray sources such as the 60-keV ^{241}Am line. The positive-biased contact is insensitive to shallow penetrating radiation because holes would be doing most of the charge transport. This can be overcome by using two thick counters back-to-back with the low-energy-insensitive contacts facing inwards. This geometry works well in practice. For higher energy gamma-ray sources (>120 keV) this dead layer is not noticed. Efficiency measurements using ^{137}Cs and ^{60}Co gamma-ray sources show detector volumes to be 100% depleted (within accuracy of known source strength).

One of the advantages of using mercuric iodide counters in portable packages is the extremely low power requirements. For practical considerations, the detector bias is kept at ≈ 1000 V/cm. At this bias, the detector leakage current is generally less than 100 pA for a contact area of 16 cm^2 . The detector current is so low that bias can be conveniently provided in a portable package with a high-voltage capacitor, which requires charging only periodically (i.e., once every 8 to 20 hours). This method of providing high voltage cuts down on the total package power requirements, as well as eliminating the problem of shielding a noisy high-voltage power supply.

The electron transit time across the crystal can be as long as several microseconds. This requires that the post amplifier have an integration time of 10 to 20 μs . This large shaping time implies a large low-frequency response for the post amplifier, which makes the electronics inherently more

susceptible to microphonics. Because of this, the detector and preamplifier have to be carefully mounted and packaged to isolate and prevent vibrations (Figure 4).

3. APPLICATIONS

Mercuric iodide thick counters work very well in application where small size, low power, and high sensitivity are required. Mercuric iodide detectors require no photomultiplier tube or well-regulated high-voltage supply. A survey instrument developed at EG&G's Santa Barbara Operations, called HRM-III, utilizes a mercuric iodide thick counter which is equivalent in sensitivity to a 1-1/2-inch by 1-1/2-inch (3.8 cm x 3.8 cm) NaI scintillator (Figure 5). The HRM-III, which includes detector, battery, microprocessor, and display, is only 60% larger than the detector and its photomultiplier tube, alone.

EG&G is currently concluding development of a mosaic mercuric iodide detector which is 1.1 cm thick, has an area of 127 cm², and weighs 880 g. This detector will have a sensitivity approaching that of a 5-inch-diameter by 1.5-inch-thick (12.7 cm x 3.8 cm) NaI scintillator for gamma-ray energies less than 600 keV.

4. CONCLUSIONS

Many gamma-ray detector applications which do not require spectral information can now use thick mercuric iodide detectors in a compact, light-weight, and low-power package. The thick counters work particularly well in portable applications. As larger crystals of mercuric iodide are developed, and charge collection properties are improved, even larger volume counters will be feasible.

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LIST OF FIGURES

Figure 1. Thick HgI_2 gamma-ray counter.

Figure 2. ^{60}Co spectrum from thick HgI_2 gamma-ray counter.

Figure 3. E γ "endpoint" channel number for ^{133}Ba and ^{137}Cs gamma-ray sources.

Figure 4. Detector, preamplifier, and high-voltage capacitor.

Figure 5. Comparison of thick HgI_2 gamma-ray counts to 1-1/2" x 1-1/2"
(3.8 cm x 3.8 cm) NaI(Tl) detector using $\frac{S}{\sqrt{B}}$ as a figure of merit.

Figure 1

S-208-TP

Figure 2

S-298-TP

2-208

Figure 3

Figure 4

S-208-TP

Figure 5

S-200-TP