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INTRODUCTION TO FIFTH INTERNATIONAL WORKSHOP ON MERCURIC IODIDE NUCLEAR RADIATION DETECTORS*

by

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Mercuric iodide celebrates in 1982 the 10th anniversary of the publication of the first paper which reported its use as a room-temperature semiconductor gamma-radiation detector.[1] This volume of the Proceedings reports some of the progress made with this material in the last decade.

Mercuric iodide is a wide bandgap semiconductor, with $E_g \approx 2.14$ eV at room temperature. Therefore, HgI_2 is totally different from the well-studied, narrower gap, elemental semiconductors such as Si and Ge, and also different in its physical and chemical properties from the known semiconductor binary zinc-blend compounds such as GaAs or InP. The purpose of studies in the last decade was to further our understanding of HgI_2.

The development of a new material poses certain critical technological and basic scientific questions:

- How do you grow very large crystals?
- How do you manufacture the best nuclear radiation detectors?
- What is known about the electrical charged particle transport and trapping mechanism in HgI_2 crystals?

All kinds of scientific information on the basic properties of known semiconductors was missing in 1973 for HgI_2. The fact that only highly

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purified crystals showed any photoelectrical response to radiation became evident to anyone who started research on HgI_2. Therefore, the crystal growth technology was, and still is, the major problem for HgI_2 nuclear detector fabrication.

Progress in developing large-volume, efficient, good-resolution spectrometers from HgI_2 was slow but steady. The first detectors[1] were very thin cleaved sections of HgI_2 having dimensions of $3 \times 4 \times 0.1$ mm^3 and weighing about 25 mg, which did not give a spectroscopic response to higher energies of gamma-rays, such as the ^{137}Cs photopeak of 662 keV. Advances in crystal growth technology have resulted in a method which produces crystals[2-4] of several hundred grams from which detector-grade material could be prepared. Thin-sectioned crystals gave spectroscopic resolution for higher energies, i.e., for ^{137}Cs and even for the 1.3 keV photopeak of ^{60}Co on $10 \times 10 \times 0.5$ mm^3 detectors.[5,6]

While the thin HgI_2 spectrometer is inefficient for higher energies, it is highly efficient for low x-rays.[7] Development of the low-leakage-current HgI_2 spectrometer of only 10^{-12} A made it possible to push the spectral resolution of the 5.96-keV photopeak of ^{155}Fe from 300 eV to below 200 eV today.[8] The low leakage current is unique to HgI_2, and cannot be achieved by the smaller bandgap semiconductors at room temperature.

The most recent progress reported at the 1982 international workshop and published here is the high energy gamma-ray spectroscopic response obtained with spectrometers of HgI_2 having over 10-mm thicknesses.[9,10] The spectral resolution is obtained at a relative low bias voltage of 3 kV after prior conditioning of the detector with radiation and bias voltage. The high efficiency of the "thick" spectrometer at higher gamma-ray energies opens up a field of new applications for HgI_2, where room-temperature operation is essential.

Comparison of the 1982 "thick" high-energy HgI_2 spectrometer with the "ultra thin" low-energy HgI_2 spectrometer back in 1972 shows the interesting progress of HgI_2 over the last 10 years; indeed, Figure 1 shows an increase of the nuclear spectrometer volume by over three orders of magnitude from 25 mm^3 for over 10 cm^3.

Another important development reported at the workshop was the use of HgI_2 photodetectors to replace the bulky photomultiplier in scintillator detectors such as BGO,[11] which could have immediate application in nuclear medicine.

However, the novel potential applications would never have reached this advanced stage without the large amount of basic research on HgI_2 which served

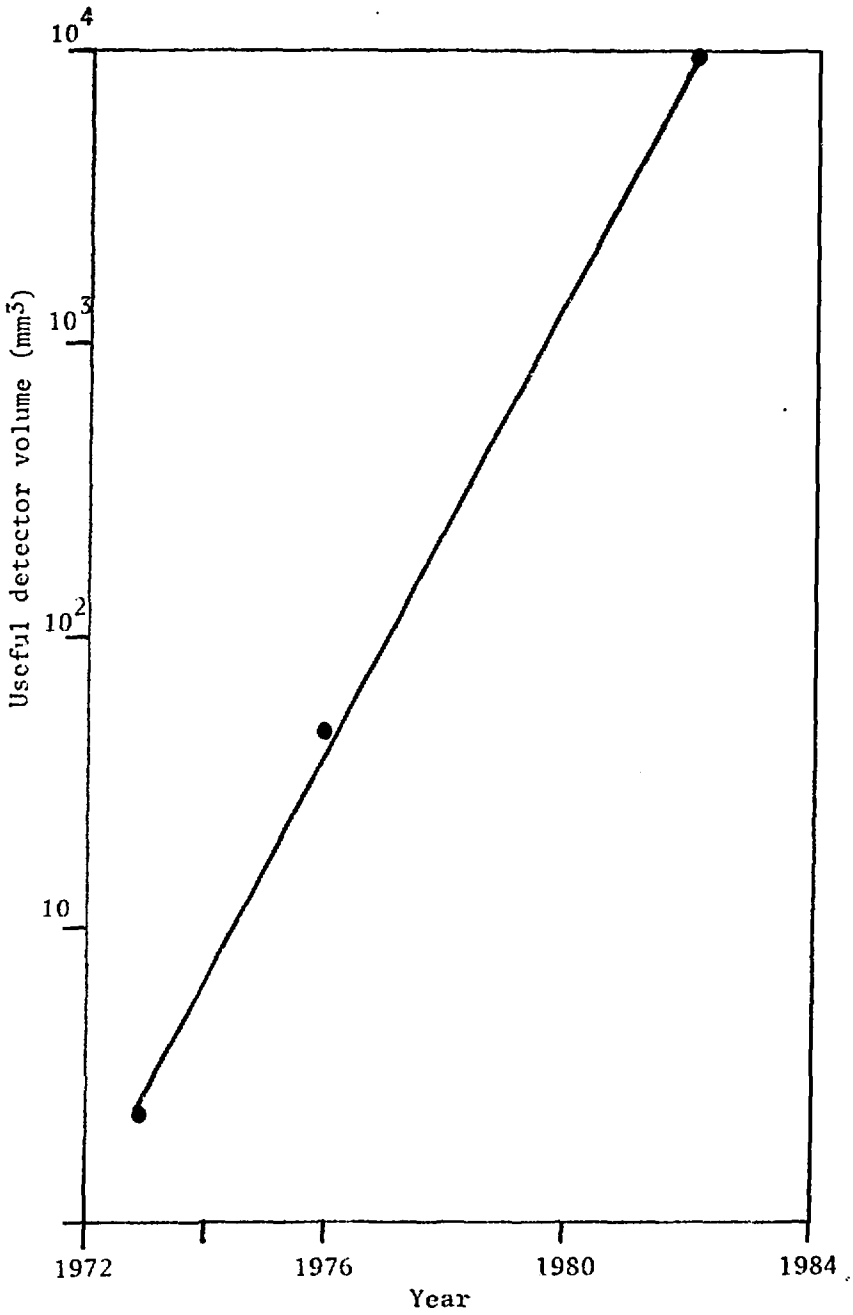

Figure 1. Variation of the useful spectrometer volume of HgI_2 in the period 1972-1982

as a scientific infrastructure to these studies. Development of special characterization studies, both physical and chemical, and their correlation to the nuclear spectroscopic response of HgI_2 has contributed much to advances in the application areas announced for the first time at this workshop. For example,

Merz reported correlation of low-temperature photoluminescence studies[12] with stoichiometry, while Siffert[13] reported correlation between thermal stimulated current studies with chemical determination of the stoichiometry and nuclear response of HgI_2. The latter confirms that the closer HgI_2 is to stoichiometry, the better a detector it is. Several other characterization methods mentioned in this volume, such as mechanical properties, mass spectrographic analyses, x-ray topography, etc., were not yet correlated to the nuclear detector response of HgI_2. Such a future correlation would indeed further our understanding and improve the performances of HgI_2 detectors.

It is interesting to note that even quality control of the fabrication process of HgI_2 detectors from the grown single crystal required development of special characterization methods. For example, HgI_2 slices cut by an automatic cleaver give a more uniform gamma-ray diffraction rocking curve and a more uniform nuclear spectroscopic resolution.[14] Also, etching the HgI_2 slice at a lower temperature produces less surface trapping than does etching at slightly higher temperatures.[15] Another important development in the fabrication process is the successful production of multielement arrays using a photolithographic technique,[16] which will allow use of HgI_2 detectors as position-sensitive imaging devices.

The International Workshop of CdTe nuclear detectors in Strasbourg in 1971 announced for the first time the compatibility of HgI_2 to operate as a nuclear radiation detector at room temperature.[17] The Jerusalem workshop in 1982 presented the first successful fabrication of a new room-temperature semiconductor gamma-ray radiation detector, CdSe.[18] The detector still has poor resolution (about 40% for the 59.6 keV photopeak of ^{241}Am), but it is free of polarization and has a stable counting rate with time. It should be mentioned here that besides HgI_2, CdTe, and CdSe, other wide bandgap semiconductor materials could be good candidates for room-temperature gamma-radiation detectors. ZnTe is such a candidate and it is hoped that research will start soon on this and other similar type materials.

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