The Diamond Compton Recoil Telescope

T. Kashiwagi[1], S. Okuno[1], K. Hibino[1], K. Yoshida[1], Y. Uchihori[2], H. Kitamura[2], T. Takashima[3], K. Hayashi[4] and K. Yajima[4]
(1) Faculty of Engineering, Kanagawa University, Yokohama, Japan
(2) National Institute of Radiological Sciences, Chiba, Japan
(3) Institute of Space and Astronautical Science, Sagamihara, Kanagawa, Japan
(4) Department of Physics, Toho University, Chiba, Japan

Abstract

The Diamond Compton Recoil Telescope (DCRT) is proposed for gamma-ray measurement in the 10 keV to 10 MeV range. A concept of the DCRT is constructed of position sensitive layers of diamond-striped detector and calorimeter layer of CdTe detector. The key part of the DCRT is diamond-striped detectors with a higher positional resolution and a wider energy range than silicon detectors. We have developed and tested the diamond detectors. In this paper, we discuss the performance of diamond detector and the design of DCRT.

1. Introduction

The gamma-ray observation in the energy range from 10 keV to 10 MeV is crucial for the study of a rich variety of high-energy astrophysical process, but it is hard pressed to observe gamma-rays in this energy range. The Universe of keV - MeV gamma-ray astronomy has been opened up by the COMPTEL telescope[1] on the Compton Gamma Ray Observatory satellite, which has launched in April 1991. The COMPTEL telescope covered the energy from 750 keV to 30 MeV. After that time, the INTEGRAL satellite, which has launched in October 2002, is taking up the observation of gamma-rays in the 20 keV to 10 MeV.

Although the INTEGRAL performs very well as compared with the COMPTEL, it is far inferior to the sensitivity of the current X-ray observation. Therefore, the next generation observatory has to go for more enhanced sensitivity by using new detector technology.

2. The Artificial Diamond Detector

Diamond detectors have been developed by mainly Russian groups since 1970s[2], and it was shown that these detectors may have the performance which is equal to Si semiconductor detector. However, the performance of those detectors

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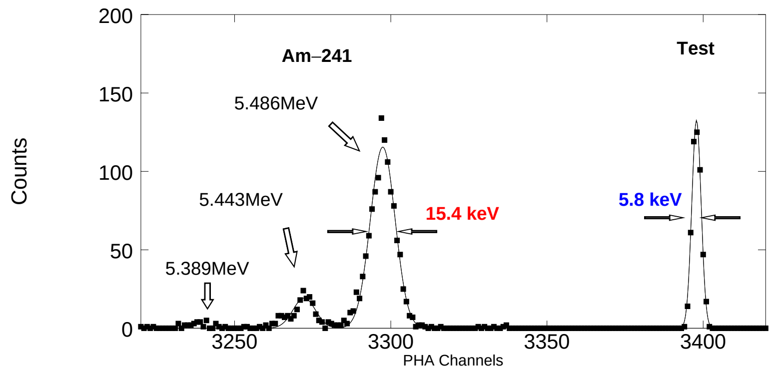

Fig. 1. The energy spectra of α-rays from ^{241}Am obtained with a prototype of the artificial diamond detector.

was unstable and it was difficult to expand effective area. Because conventional diamond detectors have been based on natural diamond, for which it was hard to acquire diamond material with a large area and uniform crystal. Recently, a diamond material come to be made artificially, with large area, uniform crystal and high degree of purity.

Figure 1 shows the energy spectra of α-rays from ^{241}Am obtained with a prototype of the artificial diamond detector. The energy resolution is estimated to be 15.4 keV (FWHM) at the peak of 5.486 MeV. The result indicates that the diamond detector has a comparable performance to typical Si semiconductor ones.

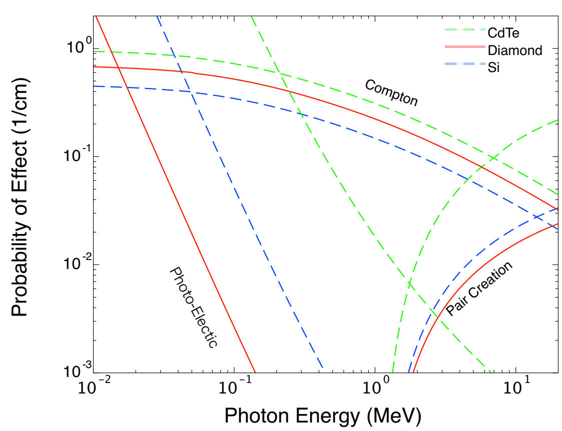

Fig. 2. Probability of various interactions in diamond, Si and CdTe as a function of photon energy.

3. The Diamond Compton Recoil Telescope

For an application of the diamond detector to a Compton recoil telescope, these is an advantage of a low Z material. The Diamond material is not influenced by photoelectric effect as compared with Si and CdTe material. Therefore, the diamond detector is expected to work efficiently to detect gamma-rays with energy from 10 keV to 10 MeV for Compton scattering, as shown in Fig. 2.

In order to determine the arrival direction and primary energy of gamma-ray of this domain, it is necessary to measure correctly a track and an energy of electron by which Compton scattering is carried out and total energy of scattering gamma-ray. For that purpose, the basic detector design for DCRT is composed of layers of diamond-striped detectors for position and energy measurement and a layer of CdTe detector for calorimeter.

The diamond-striped detector is in the middle of development, and then, we examined the performance of DCRT by the simulation. The used code of the Monte Carlo simulation is EPICS[3].

The model of DCRT used for the simulation consist of the diamond of 4 cm $\times$ 4 cm $\times$ 0.5 mmt of 20 layers for tracking measurement of recoil electrons and the block of CdTe of 10 cm $\times$ 10 cm $\times$ 4 cmt as a calorimeter layer.

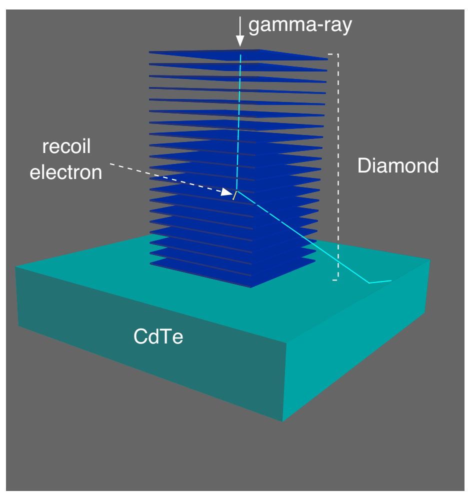

Fig. 3. The example of an event for the gamma-ray of 500 keV which carried out Compton scattering at once in the diamond layers by the simulation.

Figure 3 shows an outline of the detector, and shows the example of an event for the gamma-ray of 500 keV which carried out Compton scattering at once in the diamond layer. At this time, detection efficiency of this prototype model was calculated. In order to determine the arrival direction from single or multi Compton scattering, it must be scattered around in diamond layers and must stop in a CdTe layer. Figure 4 shows the peak detection efficiency in the case of the 20 layer diamond detector by using by Monte Carlo simulation, which is ∼ 24 % at 20 keV and ∼ 13 % at 200 keV. From this result, it became clear for a diamond detector to be able to use for gamma-ray observation above 10 keV. However, it turns out that about 60 % or more of gamma-ray of all events will be scattered around upward in this model. This result shows that the detection efficiency could be improved further, when preparing the CdTe layer in the form surrounding diamond layers.

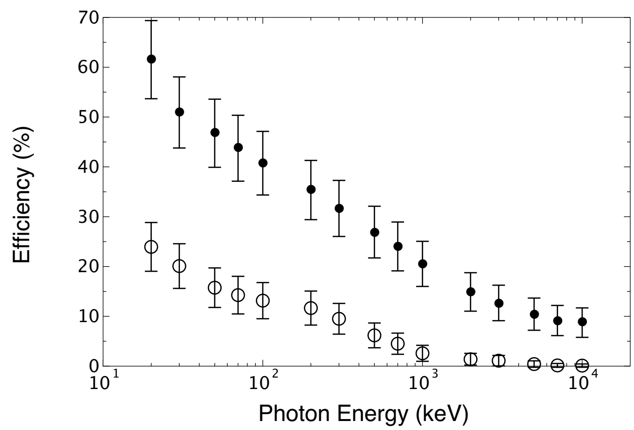

Fig. 4. Peak detection efficiency of 20 layer diamond detectors by using Monte Carlo simulation. Filled circles indicate event ratio which carried out Compton scattering about two or more times, and open circles indicate event ratio which it was scattered about and stopped in the CdTe block.

4. Conclusion

Although the result shown this time was preliminary, it was shown that DCRT is effective in gamma-ray observation of 10 keV - 10 MeV. A prototype will actually be developed and the fine parameter will be determined from now on.

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