HIGH ENERGY PHOTON DETECTION
BY
FISSION TRACK REGISTRATION

Hiroyoshi Iida and Tokusaburo Koshijima
National Institute of Radiological Sciences
Chiba-shi, Japan

Abstract

An attempt is made in this report to detect high energy photons above 5 MeV by photo fission reaction. A solid state fission track detector, in which one face of a solid block was coated with fissionable material, was used as a high energy photon detector.

Typical results obtained with bremsstrahlung at maximum energy of 29 MV are as follows. Fission track density per 100 R was found to be about 1,000 tracks/cm^2. The number of high energy photons over 5 MeV per 100 R from the total bremsstrahlung was estimated to be 4 x $10^7/cm^2$, assuming that the effective cross section of natural uranium is approximately 0.05 barn for the bremsstrahlung.

The track detector presented in this report may provide a useful means to detect high energy photons even in the presence of other radiations except neutrons, and is expected to be utilized for the monitoring of high energy photons.

Introduction

For the measurement of high energy X- or gamma-rays above several MV or MeV, nuclear reactions of high energy photons have been applied in some instances in addition to usual measurement by ionizing process. The measurement by means of photo fission has an advantage in that the high energy photons can be distinguished from a mixed radiation field except neutrons.

In the present report, a method was examined for high energy photon detection by solid state fission track detector registering the tracks of fission fragments produced by photo fission reaction. A solid state fission track detector which had been previously developed by us for neutron detection was used to detect the high energy photons.[1]

Experiment

The track detector consists of a solid for registration of fission fragment track and fissionable material. There are several ways of combination, e.g., U-doped glass or a glass block in contact with an uranium foil. The method adopted in the present study was to bring a solid in contact with a fissionable material. Silver activated phosphate glass of Toshiba FD-P8-3, a commercially available dosimetric glass, was employed as the solid because of its easiness for etching and optically almost perfect surface. Uranylacetate, $UO_2(CH_3COO)_2 \cdot 2H_2O$, an easily available reagent, was used as a fissionable material. A saturated solution of uranylacetate was made at 30 - 40°C, then 0.1 - 0.2 ml of the solution was applied dropwise and dried on a glass block which was throughly pre-rinsed with distilled water, forming a layer of 15 - 30 mg/cm^2 thickness tightly attached on the surface of the glass block (Fig. 1). The layer is thicker than the maximum range of fission fragments, so that there is no effect of thickness on the track density.

The detectors were exposed in the range of 100 to 200 R to X-rays from the NIRS betatron (Toshiba) without any flattening filter at maximum bremsstrahlung energies of 15 to 29 MV. Exposure was measured by the Victoreen thimble ionization chamber, but the chamber could not be irradiated simultaneously with the detector owing to narrow X-ray beam.

To investigate the effect of exposure rate on track density, irradiation was made at variable exposure rate from 25 to 60 R/min at maximum energy of 29 MV.

After irradiation, detectors were cleaned throughly by use of an ultrasonic washer to remove the uranylacetate layer, and then radiophotoluminescence of the glass block was measured with a photoluminescence reader. Because of the high energy of X-rays in excess of the applicable range for the glass dosimeter, the reading does not correspond to the absolute exposure but rather its relative value. Finally, the glass blocks were etched by a 30 % solution of sodium hydroxide at 80°C for 10 min to make visible tracks which were counted under a microscope (Fig. 2). Track density was estimated by counting the number of tracks in 4 to 5 fields of 2.5 mm^2 on each glass block. Background was estimated from the opposite side of the glass block.

Experiments were carried out in the same way on thoriumchloride.

Result

Hereinafter, the value of radiophotoluminescence in roentgen obtained with the reader is expressed by (RPL).

The track density per 100 R of X-ray at maximum energies of 15, 20, 25 and 29 MV is shown in Fig. 3. The sensitivity of the detector for X-ray at maximum energy of 29 MV is about 1,000 tracks/cm^2 per 100 R, which is the average from several independent experiments. Effect of exposure rate on the track density is small as shown in Fig. 5.

In the case of thoriumchloride, significant result could not be drawn due to the insufficient number of fission tracks.

Discussion

Because of fluctuation in X-ray intensity during irradiation especially at low energy range and of the irradiation process of detector which was not made simultaneously with the ionization chamber, the relative exposure dosimetry with the glass block (RPL) is considered to be more reliable than that with the chamber. Fig. 4 shows the energy characteristic of the detector. The track density per (RPL) tends downward with decreasing energy.

Fig. 6 shows photo fission cross section of uranium and thorium[2]. Maximum cross section for photons was found to be about 15 MeV for both uranium and thorium. The higher the maximum energy of X-ray, the higher efficiency of detection was observed on the fission track detector as shown in Fig. 4. This seem to be due to the fact that the X-ray spectrum is continuous and that for the same exposure the photons of over 5 MeV is fewer at low maximum energy than at high maximum energy. In mono-energy photon flux such as gamma-rays, the highest efficiency of detection may be obtained at about 15 MeV. In either case, the detection of photons of below 5 MeV is impossible, since the cross section for them is practically zero.

The number of high energy photons contained in 100 R of X-rays at maximum energy of 29 MV are calculated as below. The relation between track density ρ and photon flux Φ is given by

$$\rho = \Phi \cdot \sigma \cdot N \cdot f$$

where σ is the photo fission cross section of uranium, N, the number of uranium atoms in 1 mg of uranylacetate, and f, the ratio of track density to the number of fissions occurred in 1 mg of uranylacetate layer which has a thickness larger than the range of fission fragments. From the experimental data on neutron irradiation, the value of f is estimated at 10/3(track$\cdot$ cm^{-2}/fission$\cdot mg^{-1}$). The number of high energy photons over 5 MeV per 100 R of X-ray was calculated to be approximately $4 \times 10^9/cm^2$, assuming that the effective fission cross section of uranium is 0.05 barn for the X-ray.

The tracks on a glass block indicate only the existence of high energy photons over 5 MeV in radiation field except neutrons. Therefore, the exposure of X-ray which has continuous energy spectrum of photons can not be determined from the track density. In such a case as to investigate the primary effect of high energy photons, the fission track detector may provide a useful means for the counting of high energy photons even in the presence of other type of radiations except neutron, and is expected to be utilized in the monitoring of high energy photons.

References

1. H.Iida, T.Koshijima and H.Takahara: "Neutron Detection by Fission Track Registration" Austl. Radiol. 16, 427-433 (1972)
2. J.E.Gindler, J.R.Huizenga and R.A.Schmitt: "Photofission and Photoneutron Emission in Thorium and Uranium" Physical Review 104, 425-433 (1956)

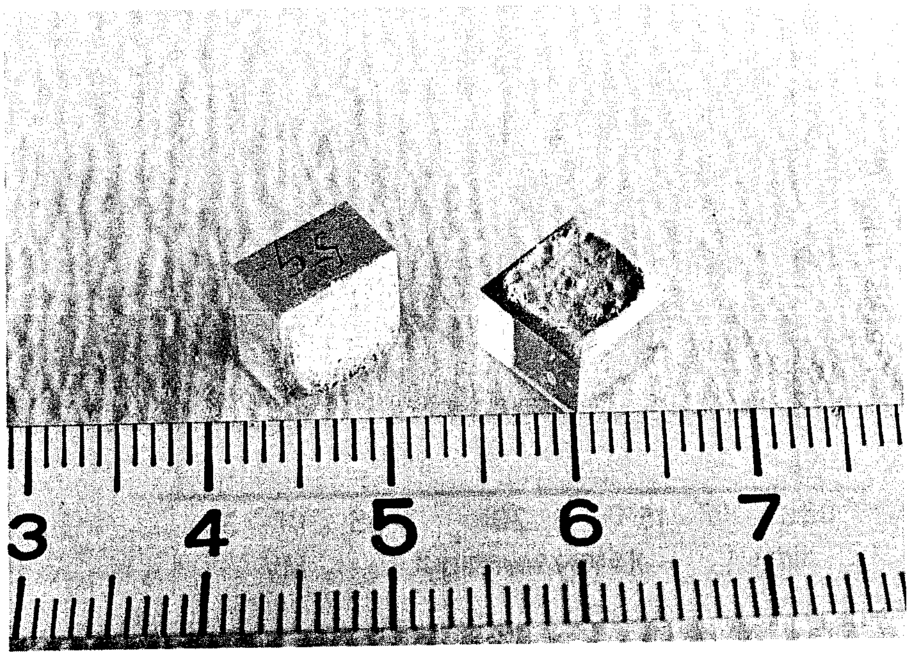

Fig. 1. Detectors, minor unit of scale in mm.

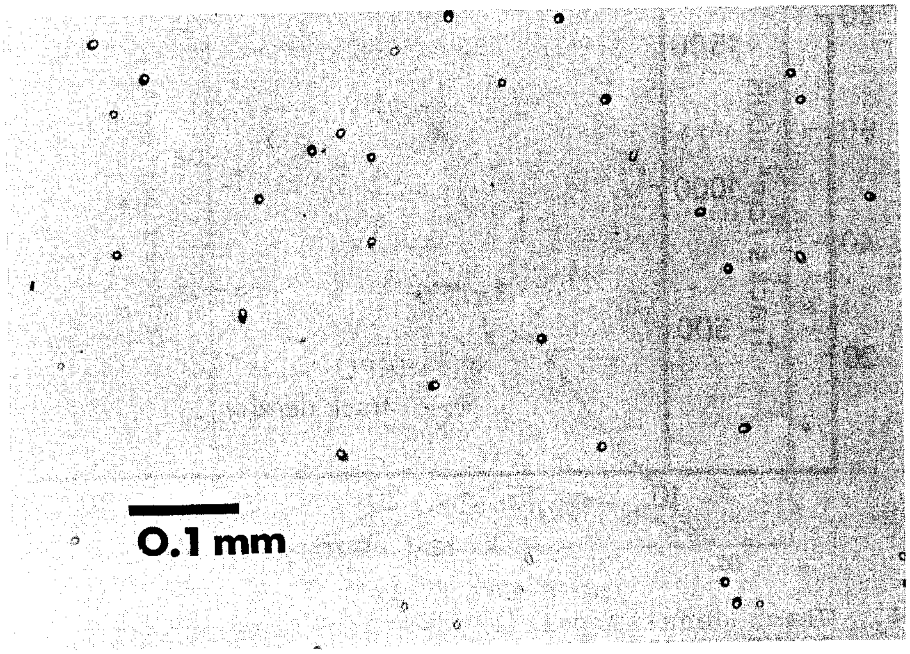

Fig. 2. Fission track etch pit in glass irradiated by X-ray at maximum energy of 29 MV from betatron.

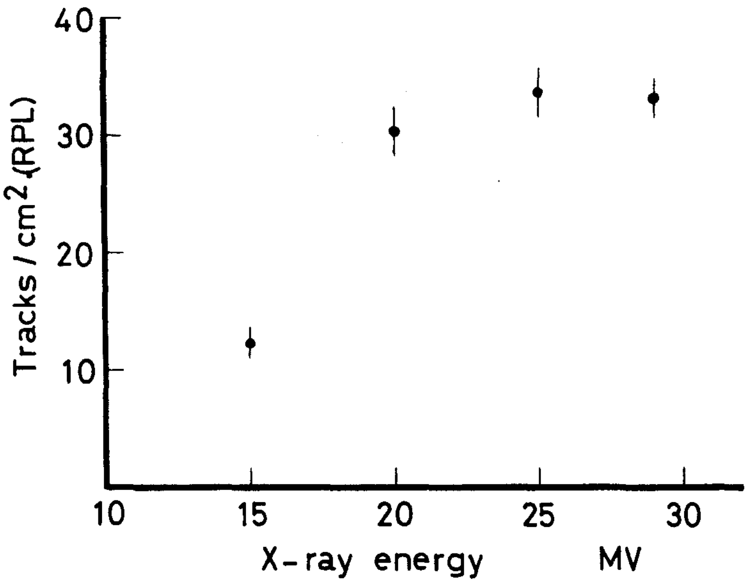

Fig. 3. Track density per 100 R of X-ray at maximum energies of 15 to 29 MV and (RPL).

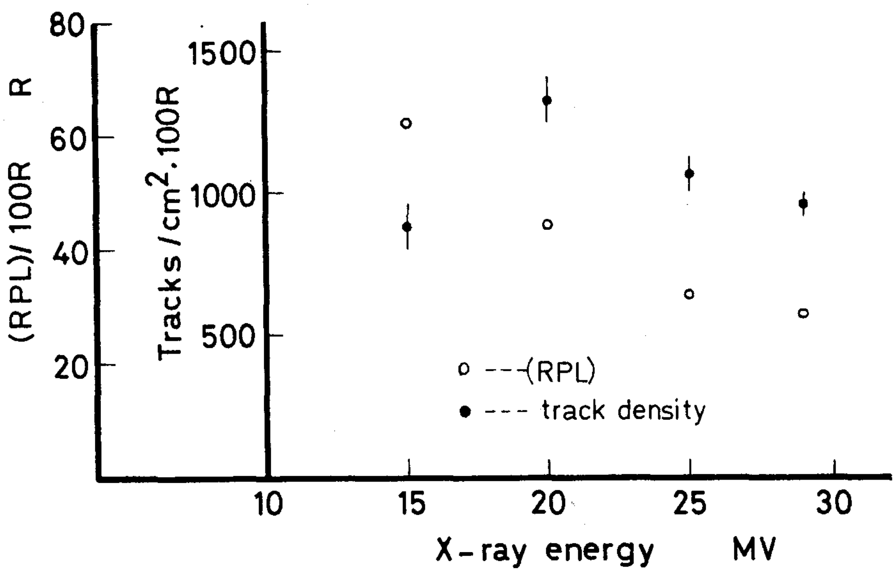

Fig. 4. Track density per (RPL) at maximum energies of 15 to 29 MV.

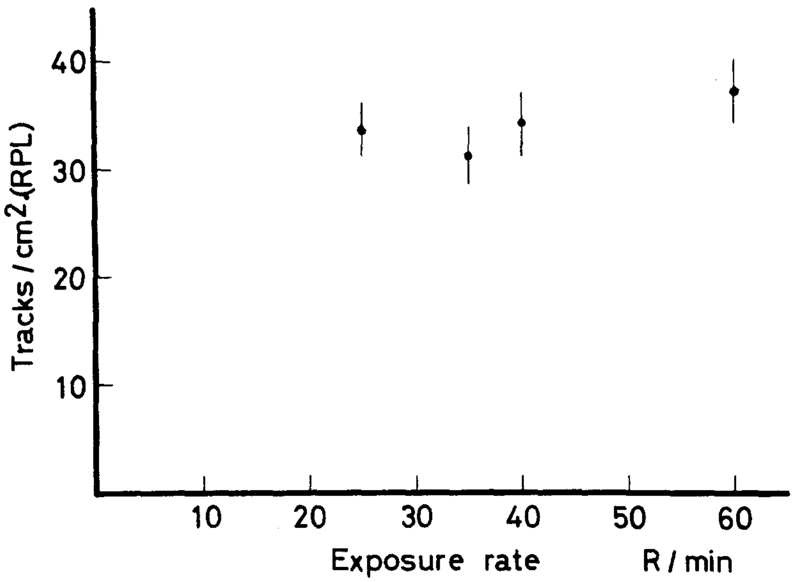

Fig. 5. Effect of exposure rate on track density at maximum energy of 29 MV.

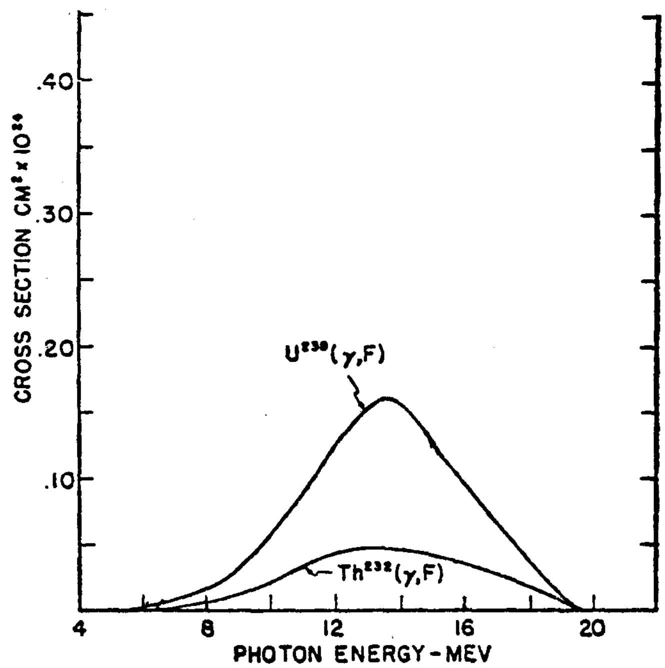

Fig. 6. Photo fission cross section of uranium and thorium.