NEW METHOD FOR ABSOLUTE MEASUREMENT OF GAMMA RAY ABSORBED DOSE WITH A PLASTIC SCINTILLATOR

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Abstract

A new method is proporsed for measureing tissue equivalent absorbed dose with a plastic scintillator coupled with a photo-diode. An average energy expended to emit a photo-electron from the photo-cathode was measured to be 430 ± 20 eV. Preliminary experiments were made with a gamma ray source of Co-60. The results well agreed to calculated absorbed dose rates.

Introduction

Organic scintillators are suitable materials for measuring tissue equivalent absorbed dose from X- and gamma rays because of the similarity of those atomic composition to tissue. So far measurements of absorbed dose has been based on ionization of charged particles in air. W-value, which is defined as an average energy expended per ion-pair, serves to convert total charge of ionization yields to absorbed energy in detector material. In the case of scintillating materials it is difficult to measure the analogous quantity, say, an average energy expended per photon in a scinillation process. However, number of photon-electrons, which are emitted from photo-multiplier photo-cathode coupled with a scintillator, is practically measurable[1]. We can define a quantity an average energy expended per photo-electron emitted from the photo-cathode of a photo-multiplier or a vacuum photo-diode. In this paper, we show an average energy expended per photo-electron measured with a combi nation of a plastic scintillator and a photo-multiplier which is used as a photo-diode and propose new method for absolute measurement of tissue equivalent absorbed dose with an above combination. We also show preliminary experimental results.

Absorbed dose

The absorbed dose is defined by $D = d\bar{\varepsilon} / dm$, where $d\bar{\varepsilon}$ is the mean energy imparted by ionizing radiation to matter in a volume element of mass dm. In the limit, as the volume element of matter approaches zero, the absorbed dose is defined at the point. Also transient electron equilibrium between the absorption of incident photons and the production of secondary electrons should be established.

The number of photo-electrons emitted from photo-cathode is proportional to the number of photons liberated at a scintillation process. The number of liberated photons is also proportional to the energy deposition. The energy E absorbed in a detector is written in the following manner,

$$E = W \times N, \quad (1)$$

where W is the average energy expended to emit a photo-electron from photo-cathode and N the number of photo-electrons.

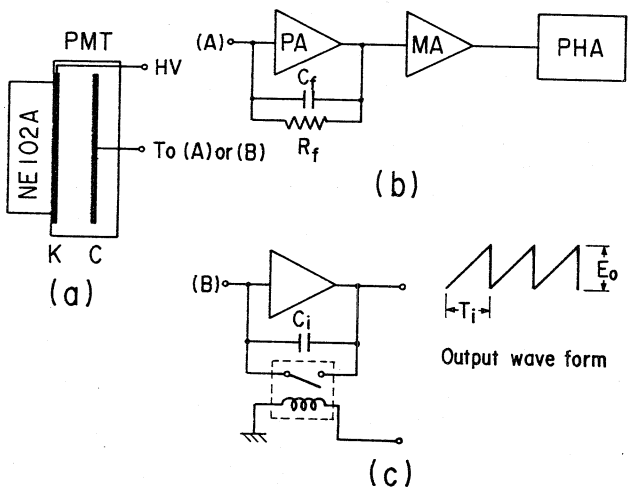

Fig. 1

Experimentals

Experimental apparatus is shown in Fig.1. A plastic scintillator (NE-102A) of which diameter is 3 cm and the thickness is 1 cm is used to measure both the W-value and the energy deposition. A photo-multiplier R-1307(Hamamatsu Photonics Co.) is coupled with the scintillator as a photo-diode. The collector denoted as C in Fig. 1 (a) consists of three electrodes, a grid, 1-st dynode and 2nd dynode of the photo-multiplier and the cathode K is connected together with all other photo-multiplier electrodes. The plastic scintillator was wrapped with aluminized mylar as a reflector.

Average energy expended to emit a photo-electron

The collector C was connected to a low noise charge sensitive preamplifier. Signals from the preamplifier were fed to a main amplifier and output signals from the main amplifier were analyzed with a pulse height analyzer as shown in Fig. 1 (b). On the other hand, the cathode K was biased to - 50 volt with a power supply. The semigaussian shaping was made with the time constant of 4 usec in the main amplifier. The system was well calibrated to get the number of photo-electrons with a precise merculy pulser[1]. At the above bias of the cathode, the saturation of pulse heights from gamma rays of Cs-137 was assured by using a NaI(Tl) scintillator instead of the plastic scintillator. The electronic noise of the amplifier system was measured by the pulser and was 495 ± 2 electrons in full width at half maximum. This is important to determine Compton edges from pulse height spectra of gamma rays because photo-peaks can not be observed in the case of plastic scintillator. The pulse height spectrum of recoil electrons due to Compton effect is superposed with electronic noises which originates in FET at the first stage of preamplifier and in the photo-diode(mainly due to leakage current between the collector and the cathode). The gamma rays of Cs-137, Na-22 and Co-60 were measured. However, the Compton edge of Cs-137 was not determined since the pulse height was too small to discriminate background due to the electronic noises. Three compton edges were determined from the spectra of Na-22 and Co-60. The average energy expended to emit a photo-electron was determined from those three points and was 430 ± 20 eV. Here we neglected fluctuations dependent on energies of recoil electrons. The W-value should be measured with several sources of mono-energetic electrons. The uncertainty of the present result is slightly larger than the above erorr.

Measurement of absorved energy

The collector of the photo-diode was connected with a charge integrator, while the cathode was held at - 50 volt. A well calibrated capacitor of 10 pF(9.52 pF) was used as Ci. The charge of photo-electrons was integrated for Ti and discharged periodically by a relay. The output waveform shown in Fig. 1 (c) was recorded on a strip -chart recorder. The total charge intergated for Ti was calculated from Eo. The charge due to background radiations and leakage current between the cathode and the

collector was measured to be (6.9 ± 0.1) x E-13 coulomb for the integration time of 2 sec. A Co-60 source of 7.9 mCi was used for irradiation of the scintillator. The measured net charges at 29.7 and 139.7 cm were (1.09 ± 0.02) x E-11 and (5.3 ± 0.1) x E-13 coulomb for 2 sec, respectively. The absorbed energies were calculated from Eq.1. Those were (1.46 ± 0.03) x E+4 MeV/sec for 29.7 cm and (6.8 ± 0.1) x E+2 MeV/sec for 139.7 cm. Also the absorbed energies at several points between the above two points were measured. The dependence of the absorbed energy on the distance between the source and the detector was assured to be well fitted to the inverse square law.

Results and discussion

The above measured values are easily converted to the absorbed dose by using the mass of the scintilltor (7.30 g). The dose equivalent rates are (115 ± 2) mrem/h at 29.7 cm and (5.4 ± 0.1) mrem/h at 139.7 cm. In order to compare with the present results, dose equivalent rates were estimated from the intensity of gamma rays of Co-60. The intensity from Co-60 of 7.9 mCi is 6.86 x E+4 MeV / cm**2 x sec at 29.7 cm and also is 3.02 x E+3 MeV / cm**2 x sec at 139.7 cm, assuming the effective energy of photons is 1.25 MeV. The dose equivalent rates are 120 mrem/h at 29.7 cm and 5.30 mrem/h at 139.7 cm respec tively, where the mass energy absorption coefficient of polystylene was used. Both of the experimental results well agree to the above estimated values.

In conclusion, the preliminary results suggest that this method is effective to the absolute measurement of tissue equivalent absorbed dose with a plastic scintill-ator coupled with a photo-diode. The W-value is easily measurable with every combination of a plastic scintill-ator and a photo-diode. Normally, erorrs due to back-ground or scattered gamma rays are involved in the calib ration with a standard source. This method, however, is not affected with those radiations, because the W-value is measured at first and total charge or number of photo-electrons collected at the collector is converted to absorbed energy by using the W-value. In addition, this method makes real time measurement possible with a well calibrated charge integrator. At present, we are developing handy dosimeters of this type.

References

1. M. Miyajima, S. Sasaki and E. Shibamura, Nucl. Instr. & Meth., 224 (1984) 331.