PROTON BEAM DOSIMETRY WITH MINIATURE SILICON DOSIMETER

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Two types of miniature dosimeters based upon the silicon[1] semiconductor have been developed for the dosimetry of photon and electron[2] beams. In this experiment, these dosimeters were improved for application to the proton beam dosimetry and the dose distributions in myler, graphite, water, alminum and iron were measured in order to estimate the dose deposited in human body on proton therapy. Figure 1 shows the schematic diagram of the proton dosimeter. It has a form of 0.2-mm diam. by 1.5-mm thick disk and is a junction diode doped boron on a surface of n-type silicon. Its sensing element is supported by 1-mm bakelite plate and both surface of it evapolated with copper are connected to positive and negative electrodes. The thickness of the sensitive region is estimated as 90-μm from the preceding experiments by photons[1] and electrons[2]. The dosimeter as a whole is covered with 25- m thick myler foil to make possible its use in water.

The proton beam current was measured with a Faraday cup of graphite fixed on a beam axis behind the dosimeter or of a water pool in which the dosimeter was inserted for the measurement of depth-dose-distribution in water. In Fig. 2, the proton-induced currents in the dosimeter are shown as a function of the proton beam currents, I_B measured with the Faraday cup. This figure shows that the induced currents have a good linearity to the beam current for $I_B \lesssim 1.8$ nA. If the thickness of the sensitive region and the beam current, I_B are 90-μm as recorded above and 1.8 nA, respectively, absorbed-dose in the sensitive region, D_{ab} and proton number incident to the sensitive region, N_{in} are 468 rad/sec and 2.1×10^7 protons/sec, respectively. D_{ab} and N_{in} were calculated from the following equations, respectively.

$$D_{ab} = I_d \cdot \omega/m \cdot e$$

$$N_{in} = I_d \cdot \omega/(e \cdot L_d \cdot (-\frac{dE}{dx})_{E=52MeV})$$

where I_d, ω , m, e, L_d and $(-\frac{dE}{dx})_{E=52MeV})$ are induced currents, energy for production of an electron-hole pair in silicon, the mass of the sensitive region, elementary charge, the thickness of the sensitive region and the stopping power of silicon for 52-MeV proton, respectively. The saturation for $I_B > 1.8$ nA as shown in Fig. 2 can be considered to be due to the recombination and polarization of electron-hole pairs induced in the sensitive region[3].

The depth-dose distribution(i.e. Bragg curve) in water along the beam axis at $I_B=0.85$ nA is shown in Fig. 3 together with the calculation and the experimental results by M. R. Raju et al[4]. The obtained results are normarized in the figure such that the energy trasferred to 0.2-mm thick silicon by 52-MeV protons incidence is equal to 1. The calculation was carried out under the continuous slowing down model as follows

$$E_{ab}=E_{ab}(L)/E_{ab}(0),$$
$$E_{ab}(L)=E(R)-E(R-L),$$
$$L=L(52)-L(E(R)),$$

where E(R) : proton energy in MeV corresponding to the range in
silicon,

$E_{ab}(L)$: absorbed dose at the depth L in water,

L(E(R)) : range in water corresponding to the energy E(R).

From Fig. 3, the calculated result is in good agreement with the experimental results in hte plateau region and our result is similar to one by Raju et al., but the calculated result is about 3 times larger than the experimental results near the Bragg peak. This may be mainly because the proton energy straggling increases with penetrating in the water. A calculated result with the estimation of this proton energy straggling was good agreement with the experimental result.

References

1) A. Maruhashi et al., Nucl. Instr. Methods, 128 (1975) 441
2) A. Maruhashi, Nucl. Instr. Methods, 141 (1977) 87
3) W. J. Price, Nuclear Radiation Detection, 2nd ed. (McGraw-Hill, New York, 1964)
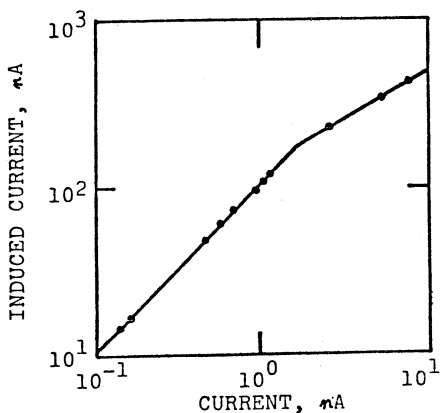4) M. R. Raju et al., Radiation Dosimetry, 2nd ed., vol. 3 (Academic Press, New York, 1969) p. 641

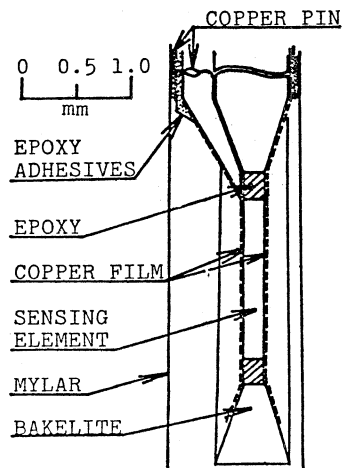Fig.2. Current induced in the dosimeter as a function of total proton current measured with the Faraday cup.

Fig. 1. Cross sectional view of the dosimeter.

CAL, (52 MeV proton)

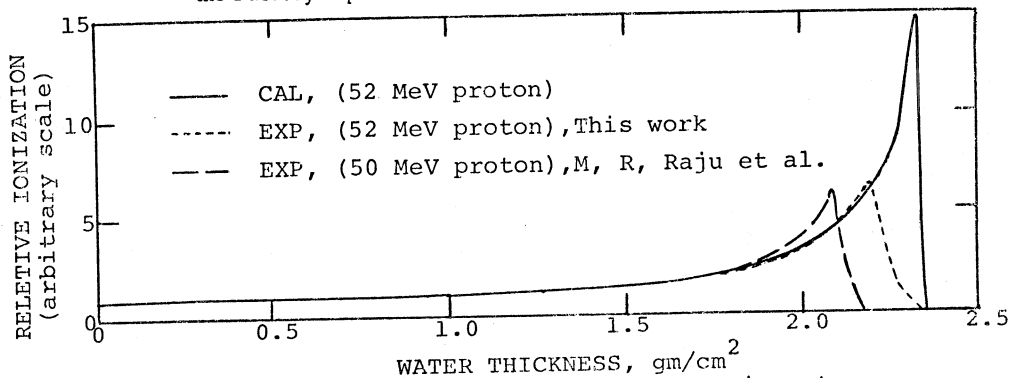EXP, (52 MeV proton),This work

EXP, (50 MeV proton),M, R, Raju et al.

Fig. 3 Depth-dose distribution of proton in water

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