9.7 Dosimetry Study on A p-n Junction Semiconductor Detector

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ABSTRACT

A p—n junction semiconductor may be used as a radiation detector. Such a study is reported here. Its dosimetry specifities, include dose, dose rate, precision, stability, depth dcse distribution and directional response, were studied in a ^{60}Co field, It is shown that the detector performs well. It exhibited a precision of ±0.05% (std dev.) and a stability of ±0.16% (std dev.), respectively.

KEYWORDS

p—n juncion; detector; ^{60}Co irradiator; radiotherapy.

INTRUDUCTION

Many researchers have reported their studies on various p—n juncion semiconductor detectors (3,6,7). Dixon & Ekstrand (1) reported their work of using a silicon diode to develop a small battery—operated dosimeter with a memory. Their opinion is that it may be used as on alternative to mailed TLD. Grusell & Rikner (2) showed why detectors based on n—type silicon, when radiation damaged, develop a sensitivity drop and a dose—rate non—linearity in pulsed radiation fields. With p—type detectors, the dose—rate non—linearity was eliminated and the radiation damage effect was limited to a moderate loss of sensitivity (4). They also reported how to select shieldings of a p—Si detector for quality independence (5). This kind of work was also done in our institute. With a p—silicon semiconductor, a radiation detector has been developed. It can be used for the dosimetry of photons of moderate dose—rate (the upper limit is about 70Gy/min) in agricultural ^{60}Co irradiators. In China most ^{60}Co irradiators belong in such kinds. It is impossible for them to by "expensive" Farmer Ionization chambers, but there is a great need for such dosimeters. When they plan to do some works on radiation chemistry, food irradiation and sterilization of medical products, they can use the p—n junction semiconductor dosimeters to choose proper positions before irradiating samples or products.

DESCRIPTION OF THE DOSIMETRY SYSTEM

Structure of the p—n Junction Semiconductor Dosimeter

A p—type silicon detector with a sensitive volume less than 0. 3mm^3 were encapsulated in epoxy resin of density 1. 2g/cm^3. A 0. 6mm thick copper cylinder is put around the detector as a cap. Outside is another cap which is made of 4mm thick perspex. Outside diameter of the dotector is 15. 14mm, just same to 0. 6cc Farmer—2571 micro ionization chamber.

Circuit Description

Designing the circuit, two stages integral micro current amplifiers were adopted, for the current is very weak. Integral voltage is monitored by a comparator. When the voltage reaches a set value, a pulse is generated. This pulse ofter shaped is delivered to the counter for counting. In the meantime the pulse is used to trigger a analog switch which discharges the capacitor, thereby starting the next integration period. The meter is controlled by a microcontroller which is a popular one in China. Its block diagram of the hardware system is shown in fig. 1.

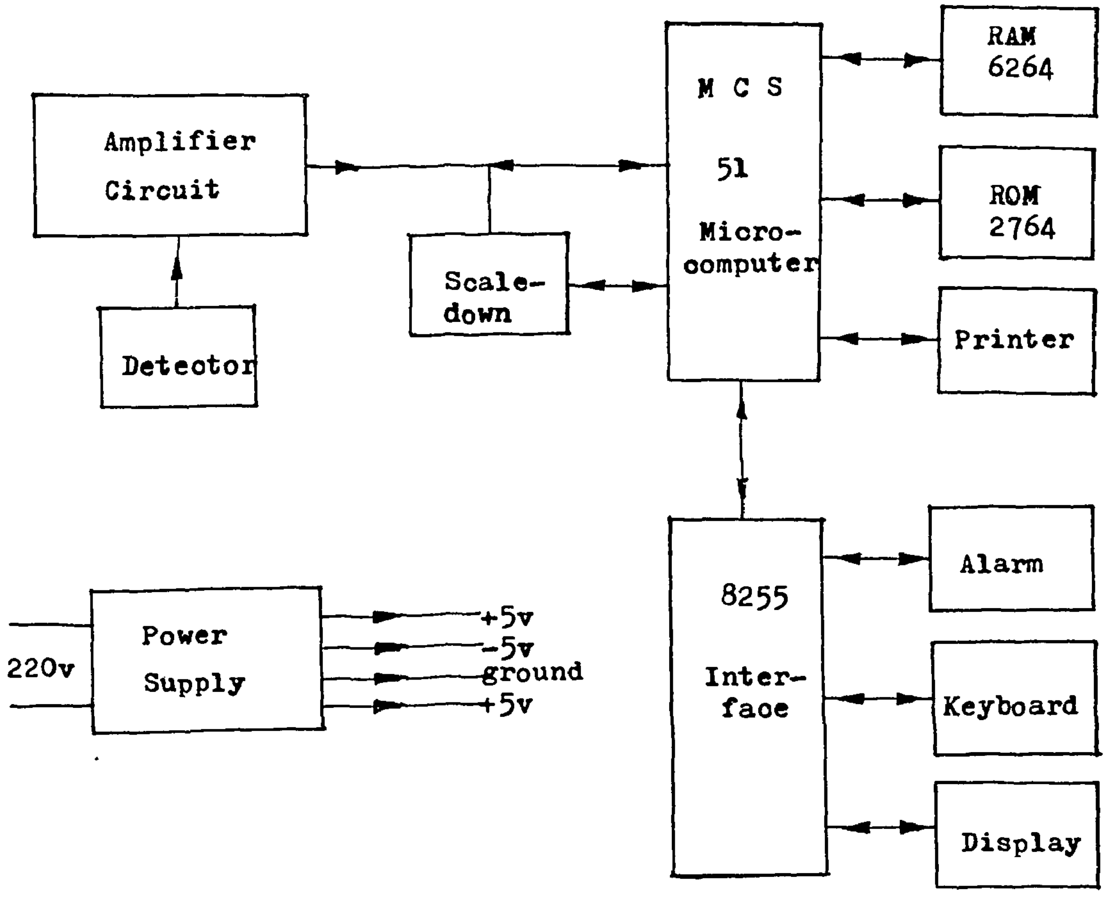

Fig. 1. Block diagram of the hardware system

The hardware system consists of a film keyboard, a microprinter, 7 segment LED displays, a 8031 chip, a 82C55 I/O chip, a ROM 27C64 and a RAM 6264 et al. This dosimeter is named as SDI—100 Radiation Dosimeter.

RESULTS AND DISCUSSIONS

Radiation Field and Comparison Dosimeter

Most dosimetry experiments were made in these two radiation fields. One is a single plate ^{60}Co source, its activity is 9.2×10^{15} Bq (250k Ci), ranked third in China. Another is a 2.96×10^{14}Bq (8k Ci) single stick ^{60}Co source. The dosimeters we used for comparison are Farmer 2560, Farmer 2570 and Fricke Dosimeters. They were calibrated by The UK National Physical Laboratory and The Chinese Academy of Metrology.

Relation Between Irradiation Time and Dose

The detector was fixed at a position which is 100cm from the source to measure cumulate doses. Results is shown in table 1.

TABLE 1 Irradiation Time and Dose

Time (S)	10	20	30	40	60	80	100
Dose (Gy)	0.2159	0.4312	0.6476	0.8633	1.292	1.729	2.162

Linear correlation coefficient is 0.999997.

Dose Rate

In the range 15—30cm from source 6 positions were chosen. At each position SDI—100 detector was fixed there to measure a dose rate, then instead of it Farmer 2571 Ionization Chamber was used to measure a dose rate. Table 2 shows the uniformity between these two meters. The main reason for the variance is probably the position can not be repeated well when detectors were exchanged. The source position when it was raised again also cause a variance.

TABLE 2 Comparison Between Two Groups of Dose Rates (Gy/min)

No	1	2	3	4	5	6
SDI—100	31.67	9.733	4.360	1.292	0.336	0.169
Farmer—2571	31.66	9.664	4.402	1.298	0.338	0.167

Precision

Put the detector at a position and read dose repeatly for many times. The positions of detector and source all were not changed. Result shows a precision of $\pm0.05\%$ (std dev.).

TABLE 3 Presision of the p—n Junction Detector

Dose (Gy)					Precision (std dev.)
0.7882	0.7882	0.7885	0.7882	0.7875	±0.05%
0.7888	0.7882	0.7888	0.7882		

Stability

Put the detector at a chosen position and fixed the ^{60}Co source. From a.m. 9 : 00 to p.m. 4 : 00 the dosimeter continued worked for 7 hours and every 35 minutes a datum was read. The variation observed over the period was ±0.16% (std dev.) for ^{60}Co irradiation.

TABLE 4 Stability of the p—n Junction Detector

Dose (Gy)					Stability (std dev.)
0.7881	0.7882	0.7898	0.7908	0.7910	±0.16%
0.7879	0.7883	0.7886	0.7910	0.7903	
0.7906	0.7892	0.7881			

All the 4 tables above are obtained based on the experiments made by Professor Gao Juncheng of Chinese Academy of Metrology, Senior Engineer Han Youdao of Jiangsu Provincial Standards Bureau and Dr. Yang Guangze, director of Lianyungang City Radiohygiene and Radiation Protection.

Depth Dose Distribution

Measurements of depth dose distributions were alternatively performed with the semiconductor detector and the 0.6cc micro chamber Farmer 2571 in a 30×30×30cm phantom in a wide open one single stick ^{60}Co source radiation field. Distance of source to phantom is 95cm. Detectors and source were at a same height (45cm). At each position two data were read by semiconductor detector and Farmer 2571, respectively. Then put a detector backward along the central axis and read data again. This experiment shows that these two groups of data coincide with each other well. Only a slight variation were observed and part of it is probably caused by the uncertainty of detectors displacement and raising source.

TABLE 5 Depth Dose Distribution

d(cm)	2	5	9	13	17	21	26
S/F	1.000	0.999	1.003	1.004	1.011	1.011	1.017

S/F means the ratio in depth doses between semiconductor detector and Farmer 2571 0.6cc micro detector.

Directional Response

The directional response of the semiconductor detector was measured in a single stick ^{60}Co source radiation field. Fig. 2 shows a slight directional dependence of the detector, but this will not cause any practical problems because the detector is always perpendicular to the line between the detector and the source.

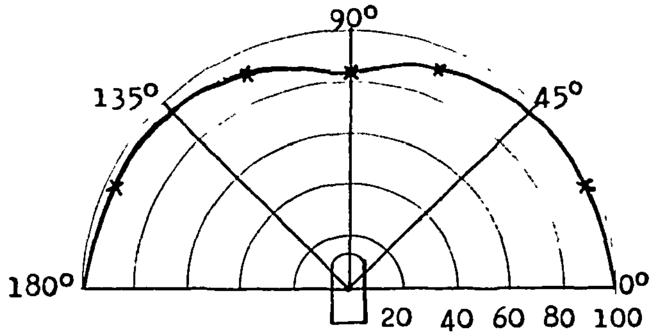

Fig. 2. Directional response of the detector

CONCLUSIONS

A p—n junction can be used as a semiconductor detector to develop a dosimeter. This detector performs as good as a Farmer 2571 micro ionization chamber in some ways, but not all ways. It will be useful in some moderate and small size ^{60}Co irradiators in China, for it has many advantages, such as high sensitivity, ruggedness, not so expensive and et al. Researehers who study on radiation chemistry, radiation processing and food irradiation may measure dose rate with it to choose the proper positions before irradiating samples and products.

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