The Development of a Hybrid-Type Radiation Detector with SiC for a Reactor Robot

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1. Introduction

For a robot working in a harsh environment such as a nuclear reactor environment or a space environment, requirements of on-board radiation detectors are not the same as those for environments around human [1]. SiC devices with the wide band-gap are less dependent on temperature than Si counterparts and the can be the better candidate for the high radiation environment [2]. With this background, radiation performance of a commercial SiC detector in a Co-60 gamma-ray environment has been evaluated. In addition to the SiC detector, a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) detector has been incorporated as a backup [3]. With this MOSFET sensor the dosimeter can keep its radiation exposure history even with loss of power. It is not only a redundant feature but also a diverse feature. The dosimetry module can be attached to mobile robot for high radiation environment was developed. This module has both SiC diode and pMOSFET mentioned above. The monitoring program which receives the radiation information from them and gives out the alarm signal when the difference of the two values from them is over the preset level was constructed. Because both the SiC pulse-type detector and the MOSFET dosimeter are small and light weight, they can be easily accommodated on a small print-circuit board for a tight space on a robot arm or for a small spacecraft

2. Radiation Detector/Dosimeter

2.1 Dosimetry and Sensors

Fig.1 shows overall system configuration of Hybrid Radiation Detector/Dosimeter.

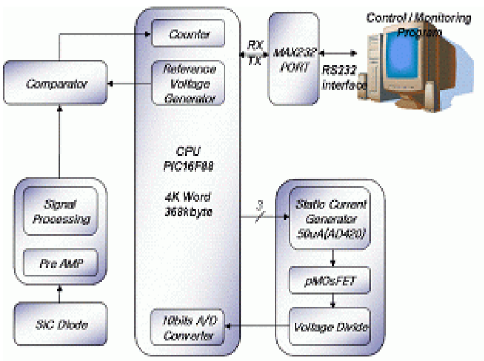

Fig. 1 The configuration of Hybrid Radiation Detector/Dosimeter

For the SiC part, radiation induced charges are collected within the depletion region form by 18V reverse bias. A charge sensitive pre-amplifier generate a matching electrical current pulse that is strong enough to be processed by a signal processing amplifier. The processed pulses are counted by a counter in microprocessor. In a pMOSFET application of the dosimeter, a gate voltage while maintaining a constant drain current (50uA) is regarded as the threshold voltage of the pMOSFET. The threshold voltage is measured continuously though the processor. Figure 2 shows the sensory part in the dosimeter.

Fig. 2 Hybrid sensory part

2.2 Control and Monotoring Program

The system program software consists of a PIC16F88 operation part and control/monitoring part for an external computer. Fig. 3 is the block diagram for the processing board that houses PIC16F88 processor. Program starts by the generation of Timer1 Interrupt and Com Interrupt signals. When the difference between the result from the SiC detector and that from the pMOSFET exceeds a pre-determined level, flashing warning will be issued.

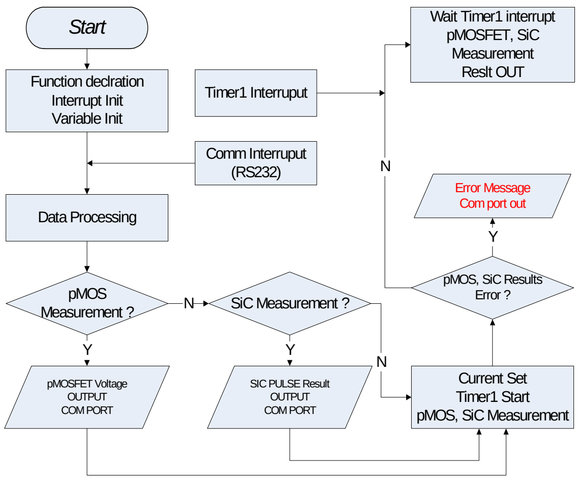

Fig. 3 block diagram for the processing board

Control/Monitioring window has five panels that show the electrical parameters from both SiC diode and pMOSFET, the converted dose and dose rate from each of them, and the accumulated dose from the diode. To be sure of the stability of the radiation detectors, this program also has a function to compare the two dose values from each sensor. In the case that a discrepancy is greater than the preset value, it turns a white alarm indicator to red and gives an alarm sound to notify the operator of an error status in radiation detection. As the accuracy of radiation sensing is important and critical in the high radiation working area, this hybrid radiation detector increases the reliability of environmental data acquisition by applying redundancy and diversity concepts

3. Experiment and Results

Irradiation tests for A JEC1 SiC photodiodes with integrated filters from HAMAMATSU were performed in a Co-60 gamma-ray facility in order to know their characteristics as radiation detectors. At each dose-rate step, the number of current pulses generated from the diode was measured in-situ. The dose-rate values were set by taking the various accidential conditions of CANDU nuclear reactors into consideration. Irradiation tests for commercial power pMOSFETs(J182) were performed sililar to those of SiC diode. The results of SiC are plotted in Figure 4 over the dose-rate range of three orders of magnitude wide. It demonstrates excellent linearity between radiation count-rate and reference dose-rate, so it turned out to be excellent detector system.

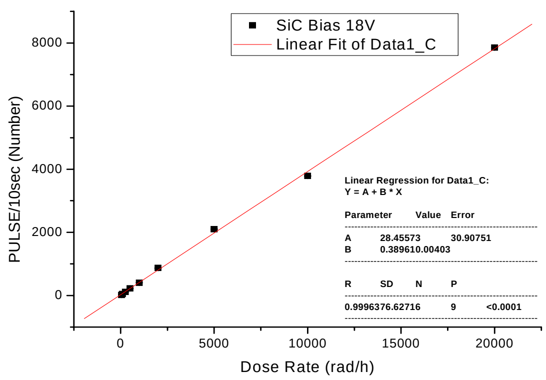

Fig. 4 Linear fitting of pulse counts of SiC to dose rate

The data can be fit by the strait line;

$$Y = 0.3896*X + 28.4557 \quad (1)$$

Here, Y is the pulse number and X is the dode rate (rad/h). Fig.5 shows the linearity in the threshold voltage shift of the J182 as the radiation dose increases. This implies the good performance of the J182 pMOSFET as an ionizing radiation dosimeter. The dose calibration formula Y = a* X + b, which relates the threshold voltage (Y) with the radiation dose (X) on the pMOSFET, has been acquired by linearly fitting the curves in Figure 11 and expressed as follows;

$$Y = 0.029*X + 1.506 \quad (2)$$

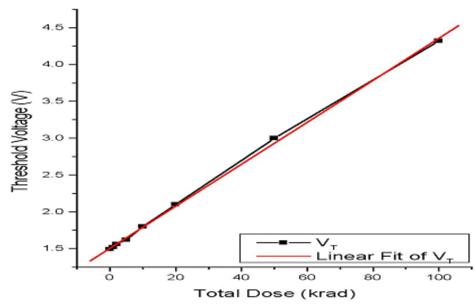

Fig. 5 Linear fitting of the threshold voltages of pMOSFET to dose

4. Conclusion

This paper presents the experiment about a radiation sensor and dosimeter with SiC and pMOSFET. As a result of the investigation we can use a SiC diode for a dose rate sensor and pMOSFET as accumulated dose meter in high intensity gamma field.

On the basis of two experiments, small radiation detection module with the two sensors has been developed. It compares the integration of dose rate of SiC diode with the value of dose rate which is measured from MOS. If the difference between two values is greater than the expectation, the monitoring system gives a warning that some problems are existed while detecting radiation. This attempt using two sensors which detect same radiation improves reliability and stability at high intensity radiation detection in nuclear facilities. It uses the concept of diversity and redundancy.

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