Online measurement of the BEPCⅡ background using RadFET dosimeters

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Abstract To monitor the integral dose deposited in the BESⅢ electromagnetic calorimeter whose performance degrades due to exposure to the BEPCⅡ background, a 400 nm IMPL RadFET dosimeter-based integral dose online monitor system is built. After calibration with the ^{60}Co source and verification with TLD in the pulse radiation fields, an experiment was arranged to measure the BEPCⅡ background online. The results are presented.

Key words BEPCⅡ background, BESⅢ EMC, 400 nm IMPL RadFET dosimeter, TLD

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1 Introduction

To search for new particles and phenomena, the Beijing Electron-Positron Collider (BEPC) and its detector, the Beijing Spectrometer (BESII), are upgraded to BPECⅡ and BESⅢ[1], respectively. Electro-Magnetic Calorimeter (EMC), one of the major sub-detectors, consists of more than 6000 CsI crystals and can precisely measure the energies and positions of electrons and photons. The performance of EMC degrades[2] measurably due to the accumulated absorbed dose at a low level of 1 Gy, which will certainly be reached by EMC according to the BEPCⅡ radiation background calculation. Thus the monitor of the integral dose deposited in EMC is necessary for the EMC data correction. Furthermore, the space around EMC, less than 30 mm × 15 mm × 8 mm, is limited for dosimeter installation.

The RadFET dosimeter[3], which has the advantages of small size, immediate online readout and low price, is a good choice to meet the requirements of an integral dose monitor for EMC.

2 RadFET dosimeter

The RadFET dosimeter, a p-channel Metal Oxide Semiconductor Field Effect Transistor (MOSFET), is dedicated to the integral dose measurement.

The gate region is the sensitive field and the sensitivity depends on the bias voltage of the gate electrode. When irradiated in the radiation field, its threshold voltage ($V_{\rm T}$), which can be measured by applying a constant current[4], increases as a function of the integral dose (D). The response curve ($V_{\rm T}$ versus D) is non-linear and needs to be calibrated. After calibration, the integral dose can be calculated by measuring the threshold voltage.

400 nm implanted gate oxide RadFET from NMRC[4] (referred as 400 nm IMPL RadFET) is selected in our design. Each RadFET chip contains 4 sensors with different size, two of them with a W/L (Width/Length) ratio of 300/50, the other two with a ratio of 690/15. All 4 sensors have a 400 nm thick gate oxide.

A multi-channel RadFET readout electronics[5] is designed, and the threshold voltage can be measured with a precision of 1 mV.

3 Calibration with the ^{60}Co source

The performance of IMPL RadFET has been studied before being applied to monitor the integral

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dose deposited in EMC. The data are taken with the ^{60}Co source under different bias voltages (positive and zero bias voltage) and dose rates (8.91, 3 and 0.5 cGy/min)[6].

The calibration shows that RadFET chips exposed under different dose rates have different response curves, known as dose rate dependency and the threshold voltage degrades slowly after removing from the radiation field, known as fading phenomena. The RadFET sensors irradiated with zero gate bias voltage have much lower dose rate dependency and fading effect than those under positive gate bias voltage. 300/50 sensors have a little lower fading effect but higher sensitivity than 690/15 sensors.

According to the calibration, the two 300/50 sensors inside each RadFET chip configured with zero gate bias voltage are finally used to measure the integral dose.

4 Verification with TLD

The RadFET dosimeters are calibrated under a stable radiation field, but the BEPCⅡ background around EMC is a pulse field with a small duty factor. In order to verify the measurement of RadFET dosimeters in the pulse radiation field, an experiment was made using TLD (Thermo Luminescence Dosimeter) at NSRL (National Synchrotron Radiation Laboratory). This experiment employed 4 RadFET chips and 8 TLDs, which were installed at the four sides (upper, lower, left and right) around the linac beam pipe. At each side, one RadFET chip and 2 TLDs are installed close to each other. The measurements of 4 RadFET chips are given in Fig. 1. When the linac was running, the integral dose increased linearly as a function of time. When the linac was turned off, the integral dose remained nearly stable and the slow pileup was caused by residual radioactivity.

The measurement error of the employed TLD is less than ±5%. The average dose of the two TLDs in each position is listed in Table 1, in which the integral dose measured by RadFET chips and the small relative difference between them are also given.

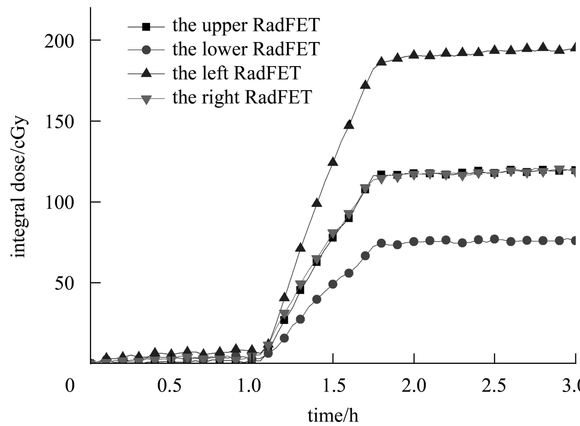

Fig. 1. The integral dose curve of 4 RadFET chips.

Table 1. The measurement of RadFET dosimeters and TLD.

	measurement of RadFETs/cGy	measurement of TLDs/cGy	relative difference(%)
upper	1.21	1.22	0.82
lower	0.78	0.80	2.50
left	1.97	2.02	2.48
right	1.21	1.24	2.42

5 Measurement of the BEPCⅡ background

The BEPCⅡ beam tuning was carried out before all BESⅢ sub-detectors were installed to avoid un-necessary irradiation. The open space around BEPCⅡ IP (interaction point) during this period allowed the free installation of RadFET dosimeters to measure the BEPCⅡ radiation background.

8 RadFET chips are installed around IP as shown in Fig. 2. RadFET #4 is installed close to the left Y-shape branch pipe, RadFET 0 to 3 are installed beside the magnet with a distance to the pipe of 0.3, 0.4, 0.5 and 0.6 m respectively. RadFET 5 to 7 are installed with a distance of 0.4, 0.5 and 0.6 m.

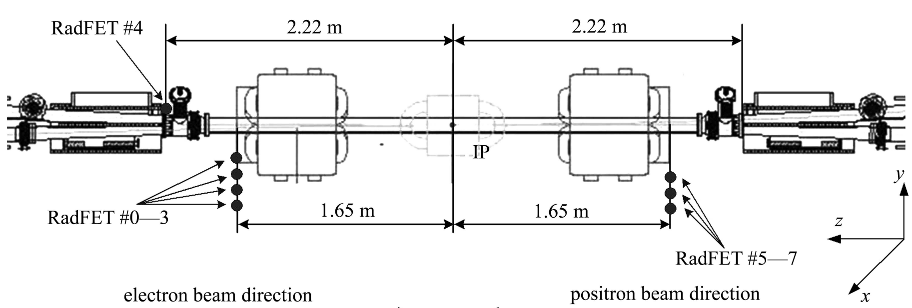

Fig. 2. The installation positions of 8 RadFET chips.

Most of the secondary particles produced outside the beam pipe by the lost electrons or positrons are emitted forward. So the closer to the beam pipe, the stronger the radiation background is. The measurements of the two RadFET groups are shown in Fig. 3 and Fig. 4, respectively. The RadFET #4 is even closer to the beam pipe and shows 4000 cGy in the same time period.

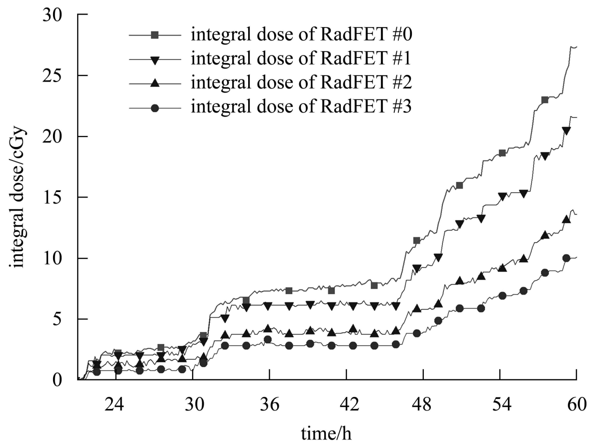

Fig. 3. The integral dose curve of the first RadFET group.

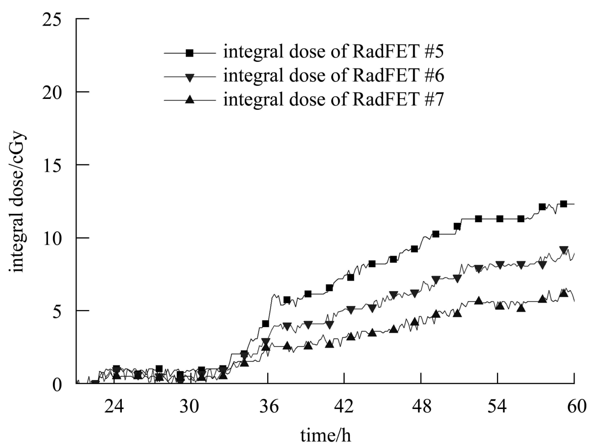

Fig. 4. The integral dose curve of the second RadFET group.

The Y-shape branch pipes at both sides have a smaller inner diameter than the other part of the beam pipe. The electrons and positrons are mainly lost near the branch pipes. Since most of the secondary particles are emitted forward, the lost electrons mainly influence the first RadFET group and the lost positrons mainly influence the second RadFET group.

The measurement of the RadFET dose shows a strong relation to the beam current, as shown in Fig. 5. It can be seen that the integral dose changing tendency of RadFET #1 correspondings only to the electron beam status and RadFET #5 correspondings only to the positron beam status.

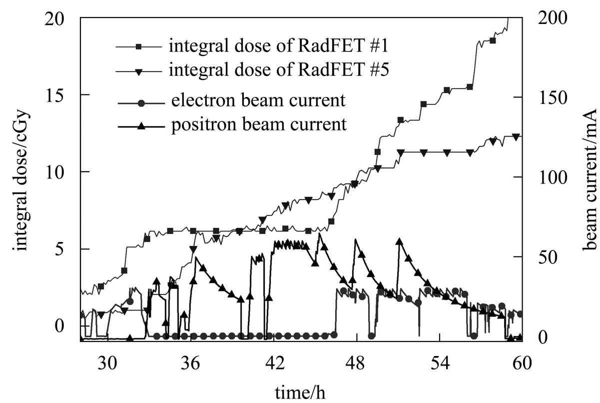

Fig. 5. The integral dose curve of RadFET #1, 5 and beam current curves.

This experiment shows that the RadFET dosimeters and the readout electronics worked as expectation under the BEPCII environment.

6 Conclusion

The 400 nm IMPL RadFET dosimeter is selected to monitor the integral dose deposited in the BESIII EMC for data correction for its small size and capability of online readout. The performance of RadFET is calibrated with the ^{60}Co source and verified with TLD in a small duty cycle pulse radiation field at NSRL. The measurement of the BEPCII background shows the whole design is suitable for BEPCII.

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