29th International Cosmic Ray Conference Pune (2005) **00**, 101-104

Radiation test for electric parts of EUSO Photo Detector Module

Y. Uchihori[a], F. Kajino[b], T. Sawabe[b], Y. Kawasaki[c], Y. Takizawa[c], M.Sato[c], T. Ebisuzaki[c]and EUSO collaboration.
(a) National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage, Chiba 263-8555, Japan
(b) Department of Physics, Konan University, 8-9-1 Okamoto, Higashi-nada, Kobe, Hyogo 658-8501 , Japan
(c) RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
Presenter: Y. Uchihori (uchihori@nirs.go.jp), jap-uchihori-Y-abs1-he15-poster

The EUSO telescope will be irradiated with space radiation for 5 years while on a low earth orbit. Many parts of the telescope are of a new design and have no data regarding radiation damage. In order to investigate the effects of radiation damage to the electric parts while in a low earth orbit, photodetector modules (PDM) [1] and glass windows for the Multi-Anode Photo-Multiplier Tubes (MAPMT) in the telescope [2] were irradiated with medium energy (70 MeV) proton beams from an accelerator at the National Institute of Radiological Sciences (NIRS) in Japan. Based on these results, the capability of these parts when exposed to an actual space radiation environment after 5 years can be estimated.

1. Introduction

The space radiation environment in the ISS is affected by trapped radiation, galactic cosmic rays and solar particles. Trapped radiation is mainly composed of electrons and protons which are trapped in a geomagnetic field. Usually the radiation exists at very high altitude and it forms in an outer and inner Van Allen belt. In the South Atlantic Anomaly (SAA) Region on the Atlantic Ocean near Brazil, the inner Van Allen belt has fallen down to a lower earth orbit. The radiation intensities significantly increase when the International Space Station (ISS) passes on the SAA region. The galactic cosmic rays are a form of stable radiation from the outer solar system. Their component is mostly proton or helium but included heavy ions. The heavy ion has a high linear energy transfer (LET) and their effect on the electric parts must be taken into account. Solar energetic particles are unexpected events but are of very high intensity. However, their total fluence is not statistically significant and they will be ignored in this discussion.

The spectrum of trapped electrons and protons in free space can be calculated using the AE8 and AP8 models at NASA. If we assume an expected thickness of materials before parts, the absorbed dose for these parts can be calculated. Research has documented that the radiation dose from protons for 10 years can be 1k rad for silicon parts with a 1 mm aluminum shield at 500 km and at a 51.6 degree orbit.[3]. We researched the radiation effects for these parts and glass plates up to 100k rad using proton beams.

2. Exposures

The experiments were performed in a beam port of the medical cyclotron in NIRS. The beam profile was tuned to a 10 cm diameter with scattering material (0.5 mm aluminum) and wobbler magnets; its uniformity was confirmed by a wire chamber. The beam intensity was confirmed at a beam shutter and fluctuation of beam intensity was less than or equal to 20%. The parts were located on the beam line and unexposed parts near these target parts were shielded by a thick brass plate. The total beam fluence was controlled by exposure time.

The same electronic parts, including DC-HVDC converters, DAC's, Bipolar Transistors, OP Amps and Photo-Relays for the HV supplier to the MAPMT's [4] were watched their electric properties with ampere meters, voltage meters and oscilloscopes. These parts were not determined to be adapted to the actual telescope but were considered viable alternatives to the electric parts actually used. Digital parts like DAC's were sent data and their responses confirmed during exposure. The glass windows of the MAPMT's were investigated for their transparencies before and after being irradiated.

3. Results

An OP Amp was irradiated with 100 pA, 1000 pA and 10000 pA proton beams. Its electrical current consumption and output voltage were measured during its exposures. The OP Amp was broken after 39k rad exposures and had no output voltage. Simultaneously, the current increased rapidly which indicated that the OP Amp short-circuited. This is a very dangerous concern in real-life space environments and must be avoided. Another type of OP Amp that we used did not malfunction or break even when exposed to 100k rad.

For a bipolar transistor, a direct current gain hFE should be measured; its base current and collect current were observed. The direct current gain hFE was decreased exponentially with a small amount of beams. Finally, the degradation was ΔhFE/hFE = - 64% at 100k rad. Here, the base current did not changed but the collect current did.

Two power MOSFET's (#1 and #2) were irradiated and measured for gate current and drain current. The current of both power MOSFET's were not changed after 100k rad exposures. However, after irradiation, the relationship between the gate-source voltage (V_{GS}) and the drain current (I_D) was changed. The I_D consistently increased, even V_{GS} was 0 volt in the case of MOSFET #1 while, in the case of MOSFET #2, the threshold voltage of $V_{GS,}$ where I_D was turned on, became lower than it had been prior to exposure. Both MOSFET's had radiation damage after 100k rad exposures.

A Digital to Analogue Converter (DAC) measured output voltage and current consumption. This DAC was controlled to an alternative output 0 volt and 3 volts each second. The current consumption was increased about 100 times after 20k rad exposure and, simultaneously, the offset of the output voltage could not be 0 volt but 0.3 volts.

Table 1. Summary of radiation damages for electric parts by proton exposures.

Part Name	Damage by Proton Exposures
OP Amp #1	Broken with 39k rad exposure
OP Amp #2	No change to 100k rad
Bipolar Tr.	ΔhFE/hFE = - 64% / 100k rad
Power MOSFET #1	Change of I_d vs. V_{gs} after 100k rad
Power MOSFET #2	Change of V_{gs} threshold after 100k rad
DAC	Degradation with 20k rad
DC-HVDC #1	ΔV/V = - 16% / 100k rad
DC-HVDC #2	Degradation with 20k rad

The glass windows of the MAPMT's were made of UV glass. The damage from the proton radiation has not been investigated. At this time, 8 glass samples were irradiated with 70 MeV proton beams. Their transparencies were measured by an optical spectrometer before and after irradiation. Figure 1 shows their picture after irradiation. It is not easy to see from the picture, however above 100k rad exposures, the glass turned a brownish color. In Figure 2, the change in transparency based on the three different wavelengths is shown. The decreasing quality of transparencies was observed above 30k rad by optical spectrometer. Because the glass window of the MAPMT will be located outside of shielding in a space environment, radiation to the glass is significantly higher than other parts of the EUSO telescope. However, we have to take into account the thickness of an optical filter which is pasted on the glass window.

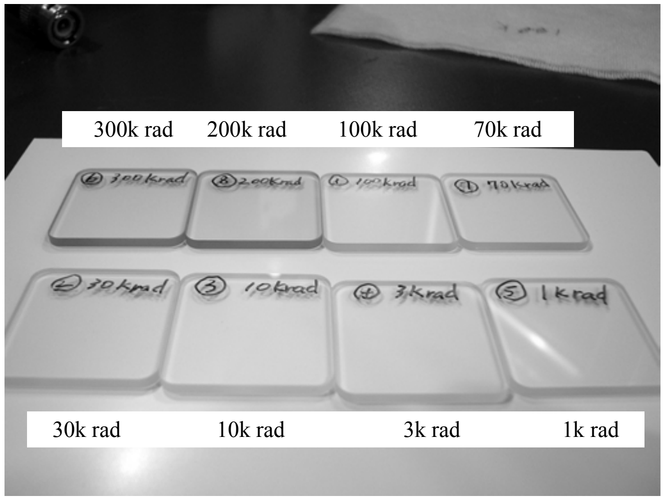

Figure 1. The irradiated MAPMT's glass windows. It is confirmed that the glasses irradiated above 100k rad are colored.

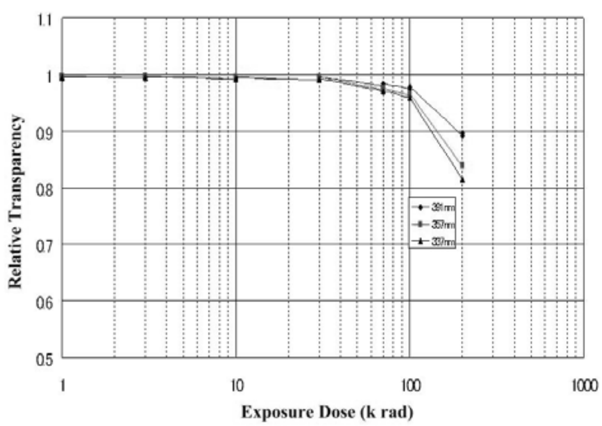

Figure 2. Relative transparencies with exposure doses. Above 30k rad exposures, transparency was decreased for all wavelengths.

Photo relays were irradiated with proton beams; simultaneously their operation was confirmed. When they were irradiated with a beam intensity of 1k rad/min, one of ten photo relays was broken with 6k rad exposure and all ten photo relays were broken with 8.3k rad exposure. On the other hand, when a relatively low intensity beam (0.1k rad/min×79min and 0.3k rad/min) was exposed to ten photo relays, only one of ten photo relays was broken with 8.1k rad exposure and all of the ten photo relays were broken with 9.5k rad. Therefore, higher exposure intensity induced a high probability of photo relay breakage.

3. Conclusions

Electric parts of the EUSO telescope were exposed to medium energy proton beams most of the electric parts broke at high exposure doses. Although our exposure doses were unusually high for experiments in our atmosphere, it was representative of normal usage in 5 years at a low earth orbit and produced realistic radiation damage.
Although the glass windows of the MAPMT's went from clear to colored under very high exposure doses; this did not happened with realistic exposure doses at the EUSO operation.
The electronic component results may be due to a single event effect with high LET (Linear Energy Transfer) like heavy ions. Therefore, we are planning to expose these electric parts to heavy ion beams from the HIMAC at the NIRS in Japan.

4. Acknowledgements

We would like to thank the medical cyclotron operators and Dr. Honma for their effort in supplying the proton beams used in our study. We acknowledge Mr. H. Kitamura for his support to these exposure experiments. This study is partially supported by Grant-in-Aids of the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

[1] Y. Takizawa et al., This conference proceedings (2005).
[2] Y. Kawasaki et al., This conference proceedings (2005).
[3] J. Adams and J. Watts, EUSO internal report.
[4] F. Kajino et al., This conference proceedings (2005).