PROTON BEAM ENERGY MEASUREMENT USING SEMICONDUCTOR DETECTORS AT THE 45MEV TEST BEAM LINE OF PEFP*

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Abstract

For the pilot and feasibility studies on the development of beam utilization technologies of PEFP (Proton Engineering Frontier Project), the test beam line was installed at the MC-50 cyclotron of KIRAMS (Korea Institute of Radiological And Medical Sciences) [1-2]. The energy measurement of proton beam with high accuracy is very important for the some experiments such as radiation hardness test of semiconductor devices for the spacecraft, detector development and test for the nuclear physics, etc. Energy measurement of 35 MeV and 45 MeV proton beam using a 5 mm thick Si(Li) in air was performed. The energy was controlled by Al degrader in the range of 0.02 mm~6.2 mm. The measured value was compared to the results of code simulation using SRIM 2003.

INTRODUCTION

In recent years, the interests on the utilization of high energetic proton beams have been growing up not only in the fields of therapeutic but non-therapeutic applications. A few tens MeV proton beam is very useful for biological and space technology developments and nuclear physics. The AVF MC-50 cyclotron of KIRAMS has been providing maximum 50MeV proton beam to the domestic users who is interested in the R&D on these kinds of applications during last few years.

In the experiments of biological science, the measurement of dose and depth-dose (i.e. Bragg peak) distribution is most important. In general, the film dosimeter and ionization chamber has been used for this purpose using water or tissue equivalent substitutes as a phantom [3-4]. On the other hand, in nuclear physics and space technology, proton energy is one of the most important parameters which affect to the accuracy of the results on the whole research. The plastic and liquid scintillators have been used widely for the proton energy measurement [5-6] because of their higher radiation hardness characteristics compare to semiconductor detector. But, to get more accurate information such as mean energy and energy straggling, semiconductor detectors is proper because of higher energy resolution compare to scintillator even though the flux should be limited not to be in exceed 1E+6 /cm^2-sec.

In this work, proton energy and straggling measurements are performed for incident proton energies of 35 MeV and 45 MeV in the air under the same experimental condition with the irradiation experiment for space device.

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EXPERIMENT

45MeV Beam Line at MC-50 cyclotron

The 45 MeV beam line was installed at MC-50 cyclotron of KIRAMS to support the basic and pilot studies on the proton beam utilization technologies in 2004 [7]. It was designed suitable for the application to the space and biological technologies. It is composed of Faraday cup, BPM(Beam Profile Monitor), phosphor material coated Al exit window, Au scatterer, Al degrader, PMMA rotating modulator for SOBP (Spread-Out Bragg Peak), dose and depth-dose measuring system and target as shown in Fig. 1.

Figure 1: 45MeV PEFP beam line installed at the MC-50 cyclotron of KIRAMS.

Experimental Set-Up

The 35 MeV and 45 MeV proton beam produced by MC-50 cyclotron exits the vacuum through a 2 mm thick Al window which is coated by phosphor material, P43 on air-side. The collimated proton beam penetrates many thin Al foils in various thickness of 0.02 mm~3 mm which acts as an energy degrader and it is collimated by the collimator installed in front of entrance of vacuum chamber. The vacuum chamber in which Si(Li) detector is installed has 50µm thick Al entrance window. The Si(Li) detector thickness is 5 mm and active area is 10mm^2.

The electronic signal from Si(Li) detector biased by 1kV high voltage is amplified by pre-amp and amplifier and it is analysed by the MCA installed in PC. Figure 2 and Figure 3 depicts a schematic view and photograph of the experimental set-up.

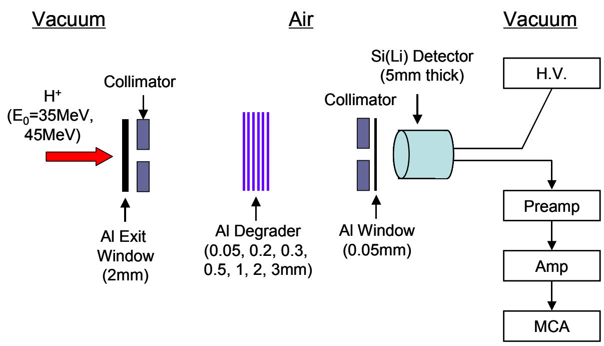

Fig. 2: Schematic view of experimental set-up.

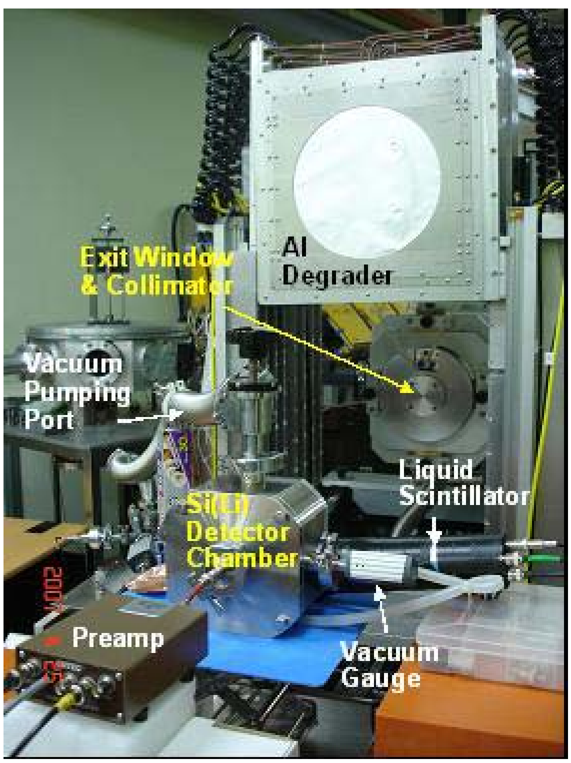

Figure 3: Photograph of experimental set-up.

The Si(Li) detector was placed at the same position as the irradiation experiment for the semiconductor device for the space application [8]. The total air gap is 1m before and after the degrader, which is necessary to reduce the flux proper to detect SEU (Single Event Upset) frequency.

The proton energies were varied with a degrader consisting of 10 Al plates, which can be moved independently into the beam path. The total thickness of Al can be controlled in the step of 20µm.

Liquid or plastic scintillator was always installed near the entrance of the detector chamber for the monitoring of the flux during the measurement to protect the unexpected radiation damage to the Si(Li) semiconductor detector caused by high proton flux.

Energy Calibration

The Am-241 (0.1 µCi) alpha standard source is used as calibration source for the energy calibration of Si(Li) detector. The 5.443 MeV (12.8 %) and 5.486 MeV (85.2 %) alpha particles extracted from Am-241 source are detected with Si(Li) detector in air and in vacuum. The measured energy spectrum is presented in Figure 4. The channel difference is caused by the 2.2 mm air gap and it is well in accord with calculated results by SRIM 2003.

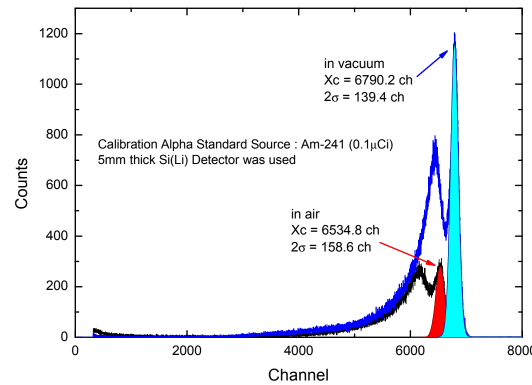

Figure 4: Energy spectrum of alpha particle emitted from Am-241 standard source.

RESULTS

Measurement of proton energy and energy straggling was performed using 5 mm thick Si(Li) detector which is sufficient to stop 30 MeV proton beam completely. The Figure 5 and Figure 6 show the results of energy measurements for transmitted proton which was varied with the thickness of Al degrader for 35 MeV and 45 MeV initial proton beam from MC-50 cyclotron.

The proper range of Al degrader thickness was decided according to the results of SRIM 2003 code simulation. For 35 MeV proton beam, the thickness varied in the range from 0.02 mm to 3 mm and for 45 MeV proton beam, it varied in the range from 2 mm to 6.2 mm.

As you see, the transmitted proton energy was reduced with the Al thickness in the range from 3.4 MeV to 25 MeV in the case of using 35 MeV proton beam and the energy straggling is increased with the thickness of Al degrader up to 10.7 %. And the measured values are well coincident with the calculated values by SRIM 2003.

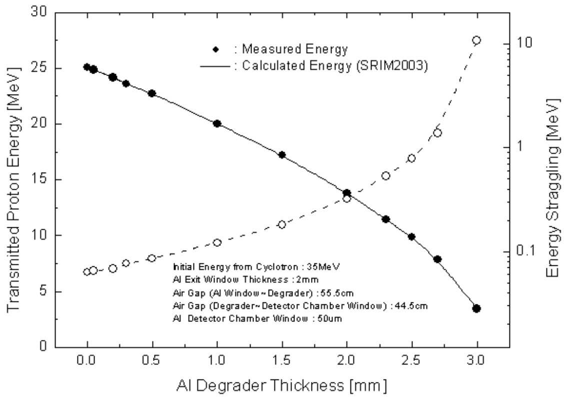

Fig. 5: Transmitted proton beam energy and energy straggling of 35 MeV proton beam with various Al degrader thickness.

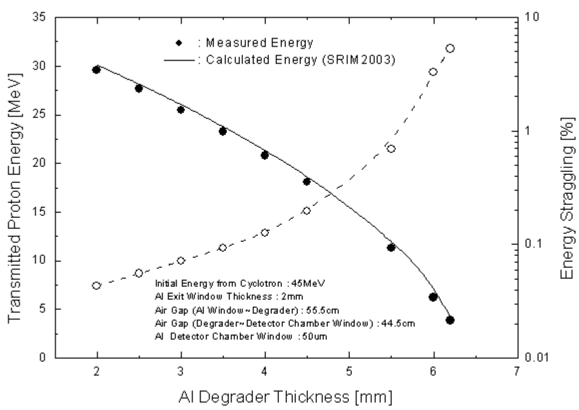

Fig. 6: Transmitted proton beam energy and energy straggling of 35 MeV proton beam with various Al degrader thickness.

CONCLUSION

Energy and its straggling measurement using 5mm thick Si(Li) detector was performed at the 45 MeV beam line which was installed at MC-50 cyclotron in KIRAMS at the same position of irradiation experiments for the test of semiconductor devices for the space application. The 35 MeV and 4 5MeV proton beam energies are reduced by 3 mm and 6.2 mm Al degraders to 3.4 MeV and 4.2 MeV with the increase of energy straggling up to 10.7 % and 5.3 % each. And the results are well coincident with the calculated values by Srim2003 within the 10 % error range. According to the results of this work, we can use the calculated mean energy as a parameter of experiment condition.

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