Study of Low Energy Fragment Measurement Using Energy Time of Flight Method

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journal or publication title	CYRIC annual report
volume	2005
page range	34-36
year	2005
URL	http://hdl.handle.net/10097/50310

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In the evaluation of the single event effects (SEE) which cause semiconductor memory errors, detailed knowledge are required on the charge, mass, and energy not only for primary particle but also secondary particles produced in semiconductor. In particular, fragments produced by ten's of MeV nucleons are important due to the large liner energy transfer (LET) of fragment and high flux of incident particles in space. However, the experimental data of the fragment production are very few due to the experimental difficulty of a small amount of produced fragments, large energy loss, and high back ground of light particles. Especially, the fragment production cross-section in low energy region will be very important to evaluate the SEE because the fragments production cross-section increases toward lower energy. However there is no experimental data. We have been conducting measurement of fragment production using specially developed Bragg curve counter and the energy time-of-flight method. In this report, the energy-TOF method is discussed to measure the fragment production cross-sections in low energy region,

The Energy Time of flight (E-TOF) method can identify the mass of the particles using the energy and TOF information as explained by the equation:

$$E = mv^2/2 = m/2 \times (L/t)^2 \cdots (1),$$

where E is the energy of the particle, m is mass of the particle, L is the flight pass, t is TOF. The advantage of this method is the wide energy range to be covered and there is no low limit in principle. The experiment was carried out in the No. 2 target room of CYRIC. The experimental geometry is shown in Fig. 1. The fragments which was produced by 70 MeV protons were detected by micro-channel plate (MCP) and SSD. Fast preamplifiers were used to achieve good timing resolution over a wide energy region. In the first experiment, analog circuits were used for a signal processing but there were distortions in low energy region due to “walk” on the timing detection. To overcome this problem, the digital signal processing (DSP) technique was introduced. The DSP is a data handling method in which each signal waveform from a detector is acquired as digital data, and the information on the radiation can be derived through the analysis of the signal waveform using computers. By applying DSP, even small pulses were could be without the “walk” by ideal constant fraction discrimination enabled by DSP.

The two dimensional plot of the energy-TOF distribution is shown in Fig. 2. The horizontal axis is energy of the fragments and the vertical axis is $t\sqrt{E}$ which is derived from eq.1. Boundary energy to identify the particles was investigated. Dispersion of each mass line is derived by the propagation of errors and expressed by eq.2, where σ_t and σ_E is the resolution of TOF and energy, respectively.

$$\sigma_{t\sqrt{E}} = \sqrt{E\sigma_t^2 + \frac{t^2}{4E}\sigma_E^2} \cdots (2),$$

σ_t and σ_E were adjusted by the experimental value. The boundary energy was found by changing the resolutions. As a result, the boundary energy became lower owing to improved energy resolution while the boundary energy does not change from the old data with infereior TOF resolution. Additionally it became clear that 2.5% energy resolution is needed to identify above 2 MeV of the carbon particles.

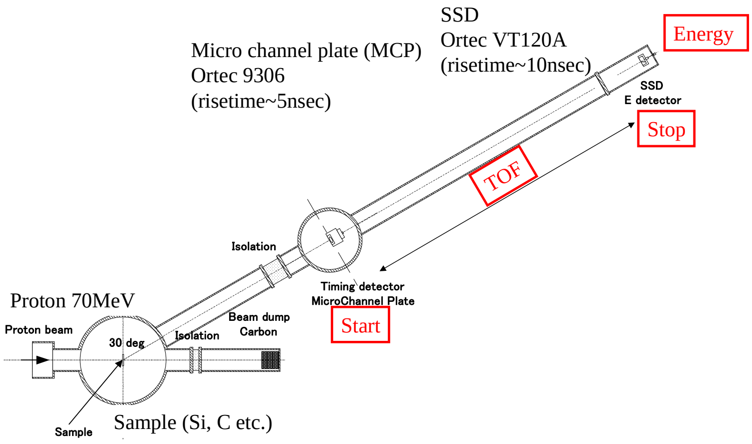

Figure 1. The geometry of E-TOF experiment.

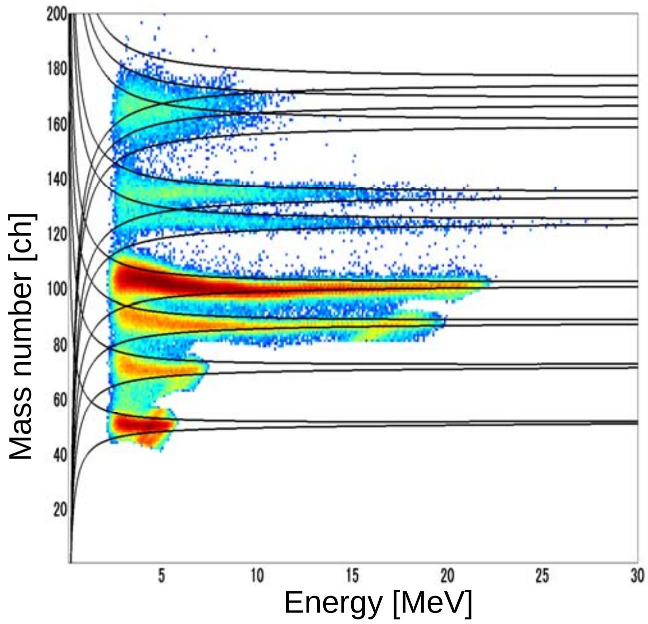

Figure 2. Mass identification by experiment and calculation.