CR-39 imaging method to estimate microbeam profiles produced by tapered glass capillary optics

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To perform accurate ion microbeam irradiation on biological targets, such as the nucleus of a mammalian cell, bacterium, and a small organ of an insect, the beam profiles should be quantitatively estimated to obtain the narrowest beam spot. We employed tapered glass capillary optics with an end-window at the thin outlet to produce microbeams of MeV ions. This optics realizes the irradiation whose target is even in air or liquid. The beam structure produced by the capillary optics was already reported to have core and halo components.[1)] The ions without any scattering on the inner glass wall maintain their initial directions and generate a sharp spot known as the core. The other ions suffering from the scattering may form a broad spot, which is called a halo component. The halo component should be suppressed to obtain narrower beam size, thereby resulting in good position resolution for irradiation experiments.

A plastic tracking detector CR-39 is available for the observation of microbeam profiles, where the ion hitting point appears as a pit with a diameter of a few μm after etching with, for example, 7N-NaOH for 2 h. However, the standard CR-39 detector is not suitable for H ions owing to low linear energy transfer (LET). In this study, a CR-39 with higher sensitivity, whose product name is HARZLAS, was employed. Although it is generally difficult to implement the analysis of pit distribution created by microbeam because the pits in the spot overlap each other, the parametrization of the halo component can be free from overlapping. Here, we report an analysis of the microbeam profiles of H ion with an energy of 2.8 MeV to aim at a small-sized spot (several tens of μm) at an irradiation distance of 1 mm or divergence of 1°.

We have started the trial of using the brightness (darkness) information of each unit area in a microscopic photo of a piece of CR-39 as the density of the pits, assuming that all pits are separated and are approximately of the same size. This method cannot be implemented to the center of the core. However, it can be possibly applied to the halo component and the region outlining the core. An H^+ beam accelerated by the RIKEN Pelletron accelerator was transmitted through a capillary with an outlet of 9.9 μm. Then, a spot was formed on a piece of CR-39 at an irradiation distance of 1 mm, which is shown in the upper panel of Fig. 1 (a). The green histogram in the lower panel expresses the sum of darkness along with a horizontal thin zone shown as the slice area in the upper panel. The histogram was analyzed to have two Gaussian peaks with 176 and 575 μm in FWHM corresponding to the core and halo component, respectively. However, the core size is not used in further analysis because the darkness density at the center is already saturated. The ions in the halo component had relatively lower energies, which can be stopped if Al layers with a thickness of 11 μm are inserted. Figure 1 (b) shows the decline of ion energy as the layers were added according to the SRIM simulation.[2)] Figure 2 shows the beam spots and the histograms showing the spot sizes. As shown in Fig. 2 (e), the narrowest spot was obtained with four layers. The energy of ions was estimated to be 1.08 MeV with a standard deviation of 52 keV regarding the simulation. This method can determine the accurate number of Al layers to obtain the narrowest spot.

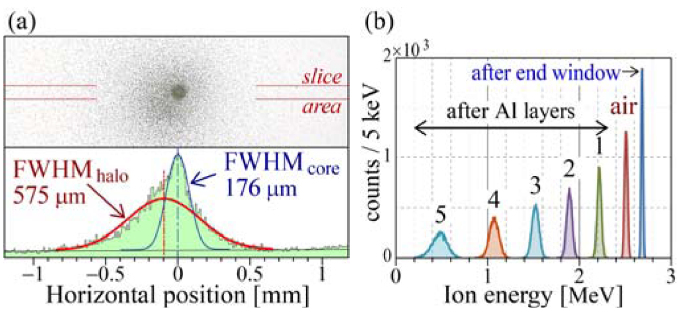

Fig. 1. (a) 2.8 MeV H^+ microbeam spot on CR-39 and the histogram along with slice area. (b) Ion energies after transmitting the materials estimated by SRIM simulation. No ions were transmitted through more than five layers.

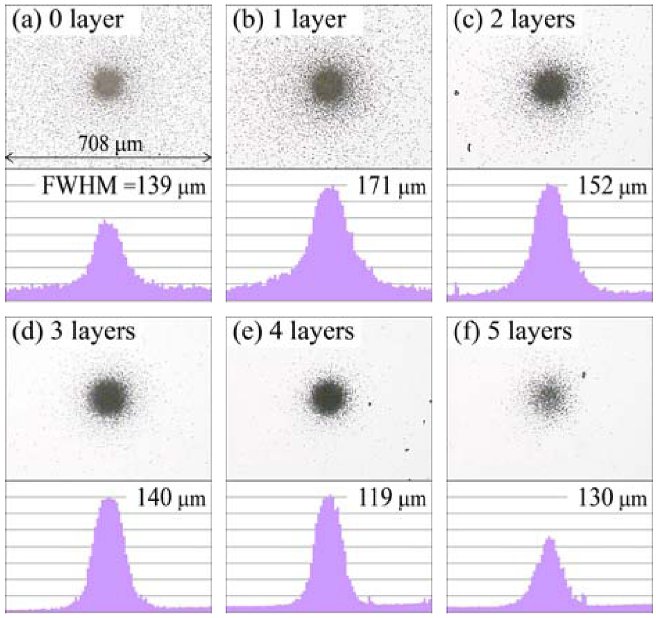

Fig. 2. Spot sizes according to the number of Al layers with thickness of 11 μm. Panel (e) shows the narrowest spot.

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References

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2) Simulation code, SRIM-2003, http://www.srim.org/.