Response of polyimide films to U ion beams as etched-track detectors

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The polyimide Kapton retains its excellent physical, electrical, and mechanical properties over a wide temperature range between 4 and 673 K, and hence, it is considered an attractive candidate for a nuclear track membrane. Size-controllable nuclear pores on the sub-micron scale have been fabricated in the polyimide films by chemical etching, subsequent to irradiation with heavy ions.[1-3] Such nuclear membranes have been used in nanopore membranes, templates for metallic nanowires, aerosol filters, and gas separation films.[4-6] Applicability of the polyimide films as etched-track detectors for research on ultra-heavy cosmic rays has also been suggested; in this case, relatively long etchings are performed prior to the surface observations on the micron-scale under optical microscopes.[7] Few studies have been carried out, however, on the response of the polyimide for U ions, even as fundamental studies,[8,9] different from that on polyethylene terephthalate.[10] In this report, we describe the first result on the detection threshold and sensitivity of Kapton for U ions.

Commercially available Kapton films (from Nilaco) with a thickness of 125 μm were stacked and exposed to 345 MeV/n U-238 beams in air at the port of BigRIPS(F12), covering the stopping powers up to 20,000 keV/μm. After the exposure, the films were etched in a sodium hypochlorite solution kept at 55°C.

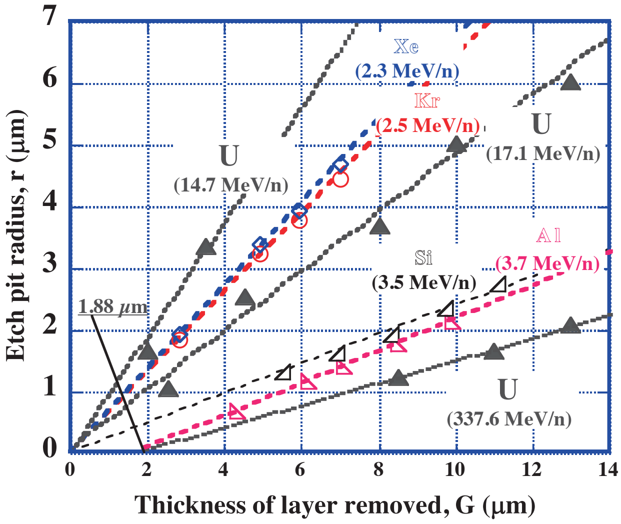

Fig. 1. Etch pit growth curves for U ions (14.7, 17.1 and 337.6 MeV/n), Xe ions (2.3 MeV/n), Kr ions (2.5 MeV/n), Si ions (3.5 MeV/n), and Al ions (3.7 MeV/n). Each energy for other indicating ions is close to that of the Bragg peaks.

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Figure 1 shows typical growth curves of etch pit radius r against the thickness of layer removed G for U ions and other indicating heavy ions. During the etching, the films were reduced in thickness by $2G$. With increasing energy of U ions, the fitted slope for each data set decreases. The observed linear relation allowed us to use the conical assumption in evaluating the etch rate ratio V, which is the ratio of the track etch rate V_t to the bulk etch rate V_b.[7] The etch rate ratio was assessed by the following relation:

$$V=\{1+(dr/dG)^2\}/\{1-(dr/dG)^2\} \quad (1)$$

where (dr/dG) is the slope of the fitted line. The sensitivity of etch pit formation is defined as V-1. Figure 2 indicates the sensitivity of U ions, as well as other heavy ions, as a function of the stopping power. The threshold of U ions for etch pit formation is 3,439 keV/μm, which is higher than that of other heavy ions. The threshold is also observed in the growth curve (Fig. 1), as the intersect of the fitted line for 337.6 MeV/n U ions with a depth of 1.88 μm.

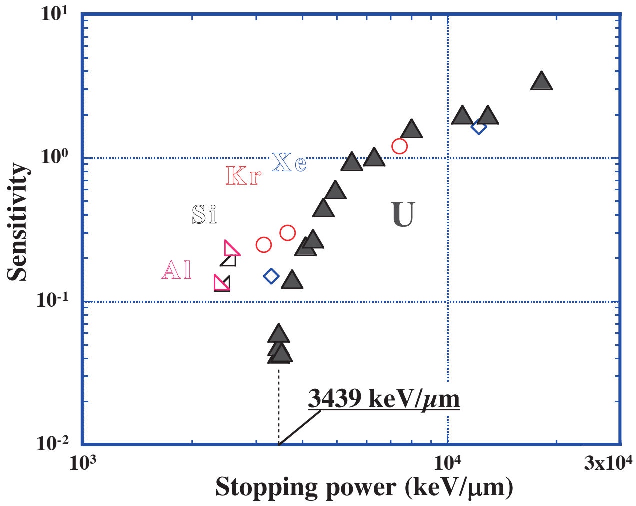

Fig. 2. Sensitivity of Kapton for U ions and other heavy ions against the stopping power.

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