Charge state distributions of ^{138}Ba ions trapped in the SCRIT

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The self-confining radioactive isotope ion target (SCRIT) method is an internal-target-forming technique for realizing electron scattering with unstable nuclei.[1] Target ions are injected into the SCRIT device and are trapped transversely by periodic focusing forces from electron beam bunches and longitudinally by the electrostatic well potential.[2] While the target ions are trapped in the SCRIT device, SCRIT performance (number of trapped ions, charge distributions, *etc.*) continues to change. Previous studies have shown that the instability of the electron beam is one of the major sources of trapped ions escaping from the SCRIT.[3] The trapping lifetime of the ions with a small mass-to-charge ratio (A/q) is shorter than that of the ions with a large A/q. Therefore, to optimize SCRIT performance, it is necessary to evaluate the charge state distribution of the trapped ions.

After trapping ions in the SCRIT device, the target ions are extracted and transported to an ion analyzer consisting of a total charge monitor, an $E \times B$ velocity filter (Model 600-B, Colutron Research Corp.), and a 43-channeltron array (Photonis Scientific, Inc.).[3] In previous work,[2] the charge state distributions of ^{133}Cs ions were measured by an ion analyzer with fixed electric and magnetic fields in the $E \times B$ velocity filter. The $^{133}Cs^{1+} \sim {}^{133}Cs^{3+}$ ions were identified clearly, but it was difficult to evaluate the abundance ratio of the$^{133}Cs^{1+} \sim {}^{133}Cs^{3+}$ ions because of the difficulty associated with correcting the detection efficiencies of the channeltrons, which depended on the position and angle of incidence and the individual differences in the channeltrons.

We developed a measurement method for the ion analyzer using a fixed magnetic field and an electric field scanning in the $E \times B$ velocity filter. In this method, the same number of trapped ions are injected into all channeltrons by electric field scanning so the detection efficiencies of all channeltrons can be measured simultaneously with measurements of the charge state distributions. The charge state distributions measured by each channeltron are corrected for the detection efficiencies and added to improve the statistical accuracy. The performance of the developed method was evaluated by simulating ^{138}Ba ion trajectories using the Runge-Kutta method, and it was confirmed that $^{138}Ba^{1+} \sim {}^{138}Ba^{10+}$ ions can be identified.

We measured charge state distributions of ^{138}Ba ions using the developed method while varing the trapping times. The incident energy of $^{138}Ba^{1+}$ ions to the SCRIT device was 6 keV. The energy and current of the electron beam were 150 MeV and 210–270 mA, respectatively. The fixed magnetic field was 1850 G, and the range of supply voltages for electric field scanning were 0–2400 V in 10 V steps.

Figures 1 (a), (b), and (c) show the charge state distributions of ^{138}Ba ions at trapping times of 30, 100, and 200 ms, respectatively. The $^{138}Ba^{1+} \sim {}^{138}Ba^{7+}$ ions were clearly identified, comfirming that the ions in higher charge states can be identified compared to measurements for ^{133}Cs ions.[2] The $^{138}Ba^{1+}$ ions were dominant at a short trapping time of 30 ms, but the charge state distributions of the ^{138}Ba ions were bred and spread with increasing the trapping time. The average charge states at trapping times of 30, 100, and 200 ms were 1.3, 2.5, and 3.6, respectatively. These results show that the developed method is useful for evaluating the charge state distributions of trapped ions in the SCRIT.

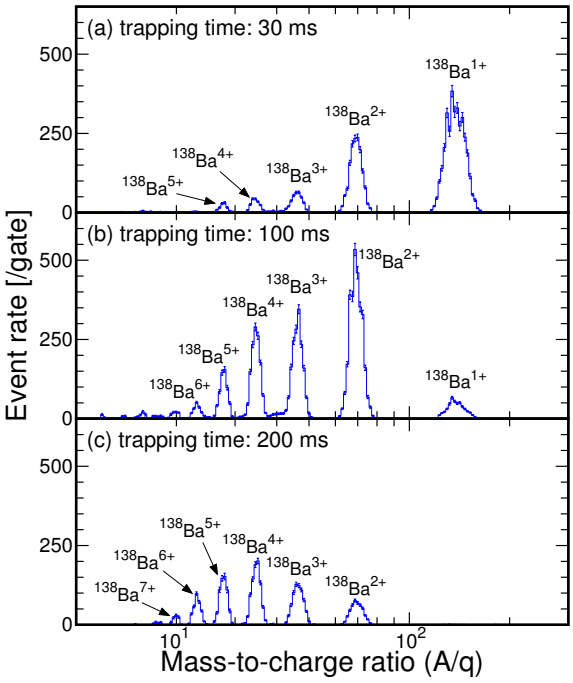

Fig. 1. Charge state distributions of ^{138}Ba ions with trapping times of (a) 30, (b) 100, and (c) 200 ms.

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