Development of intense ^{22}Na beam for application to wear diagnostics

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The industrial cooperation team in RIKEN and SHIEI Ltd. are developing a method for application to the wear diagnostics of industrial materials using RI beams as tracers. RI nuclei are implanted in the near surface of machine parts within a depth of 100 μm, and the wear-loss of the near surface is evaluated by the decrease in the measured radioactivity. Continuous γ-ray detection from outside the machine enables real-time diagnostics of wear in running machines. For this purpose, we studied intense RI beams of ^{22}Na ($T_{1/2}$ = 2.6y) at the RIPS separator with an energy of 26.6 MeV/u[1)], and ^{7}Be ($T_{1/2}$= 53d) at the CRIB separator with an energy of 4.1 MeV/u [2,3)]. From the point of view of beam cost and beam-time flexibility, the low-energy RI beam production at CRIB using the AVF cyclotron independently is favorable. Then, we studied a low energy ^{22}Na beam production using CRIB.

The ^{22}Na beam was produced via the p(^{22}Ne,^{22}Na)n reaction. A primary beam of $^{22}Ne^{7+}$ with an energy of 6.1 MeV/u and intensity of 0.3 pμA was introduced to the cryogenic gas target[4)]. The H_2 gas at a pressure of 400 Torr was cooled to 90 K and was circulated to the gas cell at a rate of 17 slm. The primary beam was focused on a Havar foil placed at the entrance of the gas cell with a spot size of diameter 1 mm. The target was stable during this experiment. The produced ^{22}Na beam was introduced to the F2 focal plane without a degrader foil at F1. Contaminant nuclei of $^{19}F^{9+}$ (stable) and $^{22}Ne^{10+}$ (primary beam) were then observed (Fig.1). The ^{22}Na beam had two components with different charge states: q=10+ and 11+. Because the $^{22}Na^{10+}$ component had large $^{22}Ne^{10+}$ contamination, we have investigated the optimum magnetic rigidity for the $^{22}Na^{11+}$ beam.

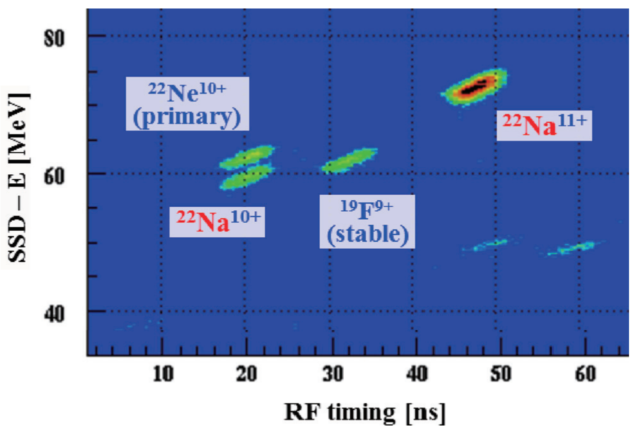

Fig. 1 Contaminant nuclei at optimum magnetic rigidity for the $^{22}Na^{11+}$ beam.

The magnetic rigidity of the CRIB separator was scanned in the range of 0.53 – 0.59 Tm (Fig.2). At the optimum condition of 0.5535 Tm, the energy and radius of the $^{22}Na^{11+}$ beam were 81.2 MeV (3.7 MeV/u) and σ = 1.6 mm, respectively, with a momentum slit of ± 3.1% (± 50 mm) at F1. The ^{22}Na beam was 78 % in purity. The intensity was 3.1×10^{7} pps and was obtained by the following γ-ray measurement. To investigate the implantation-depth profile of ^{22}Na, a stack of 2-μm-thick aluminum foils with 16 mm diameter were irradiated. After irradiation, the stack was disassembled and the intensity of the γ ray (Eγ = 1274 keV) was measured using a Ge detector. From the obtained profile, ^{22}Na was implanted in aluminum at 38 ± 6 μm with a total approximate activity rate of 0.9 kBq/1h irradiation.

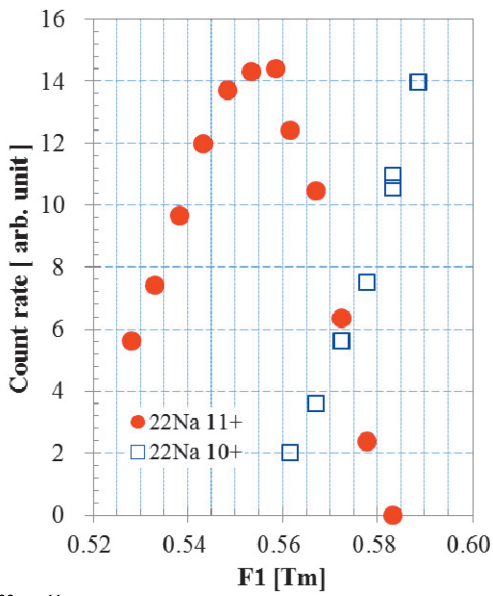

Fig. 2 $^{22}Na^{11+}$ beam intensity dependence on the magnetic rigidity.

The total activation rate of $^{22}Na^{11+}$ beam using RIPS was 5 kBq/1h irradiation[1)], which is five times greater than the intensity of CRIB. However, this difference is nearly compensated with the difference in beam production cost between RIPS+RRC and CRIB+AVF.

References

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