Construction of implantation beam line for the verification test of ^{107}Pd transmutation

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The nuclear transmutation of long-lived fission products (LLFP) is one of the solutions for the disposal of high-level radioactive waste.[1)] It allows LLFP to be converted into stable or short-lived nuclides and rare metals including LLFP to be reused. Palladium is a useful material for industrial use and one of the target nuclides for recycling by nuclear transmutation. To investigate reasonable nuclear reaction paths for ^{107}Pd, an experiment to obtain the cross sections for proton- and deuteron-induced spallation in inverse kinematics was conducted at the RIKEN Radioactive Isotope Beam Factory (RIBF).[2)] The experimental results implied ^{107}Pd can be converted into ^{106}Pd by a proton or deuteron. However, considering the actual system, LLFP should be irradiated by ion beams.

In order to investigate the feasibility of this system, we conducted a verification test to transmute ^{107}Pd by deuteron beams produced by the accelerator. To prepare a ^{107}Pd target, we procured ^{107}Pd-condensed material, in which the concentration of ^{107}Pd is 15%. In addition, it is necessary to concentrate ^{107}Pd up to almost 100% in the sample to detect the nuclear transmutation reaction effectively. We constructed the ion-implantation beam line to concentrate ^{107}Pd.

In this paper, the construction of the implantation beam line for the verification test of ^{107}Pd transmutation and some experimental results of the implantation samples are reported.

The implantation beam line consists of an ion source, an 80-cm-radius double-focusing 90° bending magnet, a target chamber, and other components. The ion source is a negative plasma-sputter-type ion source.[3)] Negative ions of palladium are produced from the palladium target and extracted with an acceleration voltage of 20 kV. Palladium ion beams are mass-analyzed and focused on the target in the target chamber. A single slit with a diameter of 2, 3, 5, or 10 mm and an electrically suppressed Faraday cup are also placed in it. The beam size on the target was approximately 3 mm with the slit. The target material was a carbon foil with a thickness of approximately 300 μg/cm^2.

The experiment with ^{105}Pd has been conducted prior to that with ^{107}Pd. The typical beam current is between 10 and 20 nA for ^{105}Pd. Two implantation samples were prepared in order to detect the transmutation of ^{105}Pd: one is for the analysis with deuteron irradiation, and the other is for the analysis without the irradiation.

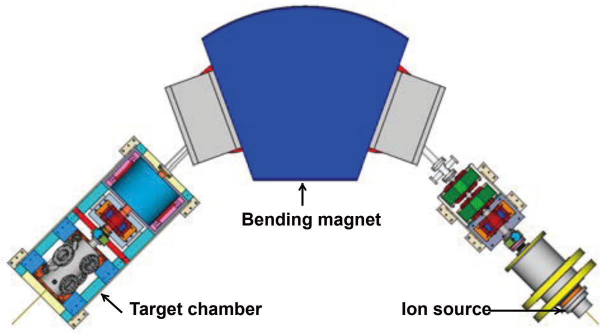

Fig. 1. Implantation beam line for ^{107}Pd concentration.

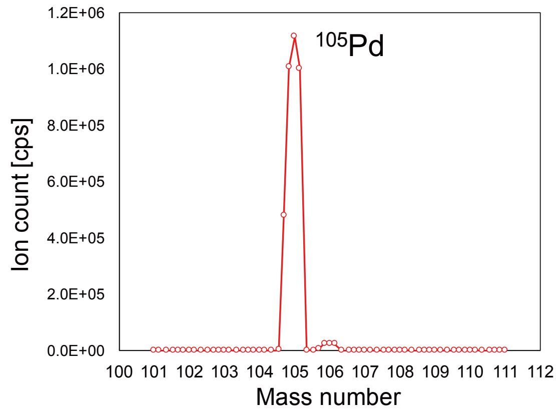

Fig. 2. ICP-MS results of the implantation sample. The vertical axis shows the number of ions detected by ICP-MS, and the horizontal axis shows the mass number of ions.

After the implantation, palladium was extracted from the target foil by reverse aqua regia and perchlolic acid, and investigated by ICP-MS. Figure 2 shows the results of ICP-MS. ^{105}Pd was successfully concentrated up to approximately 98% and separated from other palladium isotopes.

Implantation samples will be irradiated by deuteron produced by AVF Ring Cyclotron at RIKEN RIBF in the future and the isotopic ratio of palladium will be measured by thermal ionization mass spectrometry.

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References

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