Lead-ion beam production using high temperature oven of RIKEN 28-GHz superconducting electron resonance ion source[†]

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At the RIKEN Radioactive Isotope Beam Factory (RIBF),[1)] one of the major future research objectives is the study of unstable nuclear structures in high-mass-number regions, particularly in the proton-rich Pb region. To produce a primary beam of Pb ions, which are solid metal at room temperature, the Pb must first be vaporized and fed into the plasma in the ion source. A high-temperature oven (HTO), capable of heating up to approximately 2000°C, was previously developed within the superconducting electron cyclotron resonance ion source (SC-ECRIS)[2)] for producing the ion beams from high-melting materials such as uranium oxide (UO_2) and metallic vanadium.[3)] The HTO is practically used to provide stable high-intensity beams of these metal ions for experiments at the RIBF. This study investigates whether HTO, originally developed to vaporize high-melting-point materials, can be used to stably generate ion beams of Pb with a low melting point of 327°C.

As the first step, an off-line test bench was set up, and metallic Pb powder was heated in the HTO to test the generation of Pb vapor. The Pb vaporization rate, equivalent to the consumption rate of the Pb metal sample as a function of time, was measured by varying the heating power of the HTO. The consumption rate was calculated by measuring the difference in the Pb sample's weight in the crucible before and after evaporation into the vacuum at a constant rate for a certain time. Figure 1 shows the Pb consumption rate as a function of the HTO heating power $P_{\rm HTO}$. As shown in Fig. 1, the consumption, or evaporation, increased exponentially from $P_{\rm HTO} \sim 170$ W. In this heating power range, the HTO system was fully controllable. For example, in the case of uranium beam production as an example, an ion beam of uranium with a charge state of 35+ on the order of 10 particle μA can be generated at a UO_2 consumption rate of approximately 5 mg/h using the HTO. These results suggest that the HTO system can produce sufficient Pb beams for future research conducted at the RIKEN RIBF.

Figure 2 shows the mass-to-charge-ratio (M/Q) spectrum of ion beams extracted from the SC-ECRIS (R28G-K),[2)] at extraction voltage $V_{\rm ext} = 10.0$ kV. In the figure, Pb ions with charge states from 14 to 33 are clearly produced, as indicated by red dashed lines, and each of these peaks primarily contains the Pb isotopes of the mass numbers 206, 207 and 208. The values of $P_{\rm HTO} = 125$ W did not completely match between the off-line and actual ion source tests owing to differences in the crucible temperature. These discrepancies were caused by differences in cooling water flow rates and differences in the resistances of heating parts including contact resistance between crucible and electrodes. At that stage, the Pb beam could not be fully optimized because a method for removing toxic Pb contamination on the plasma chamber walls had not yet been sufficiently developed. The first step of the Pb vapor production test was successfully completed; however, the long-term stable supply test of Pb, which could not be completed due to time constraints, will be conducted in the future.

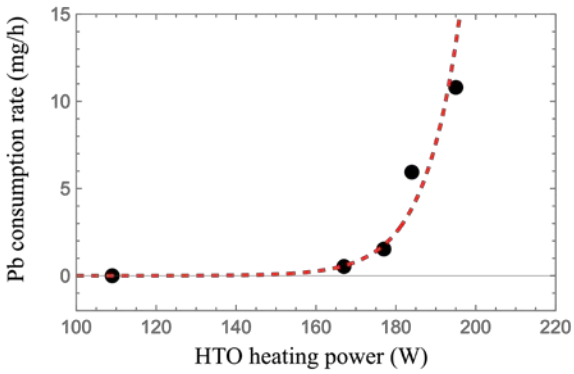

Fig. 1. Pb consumption rate obtained by varying the HTO heating power using the off-line test bench.

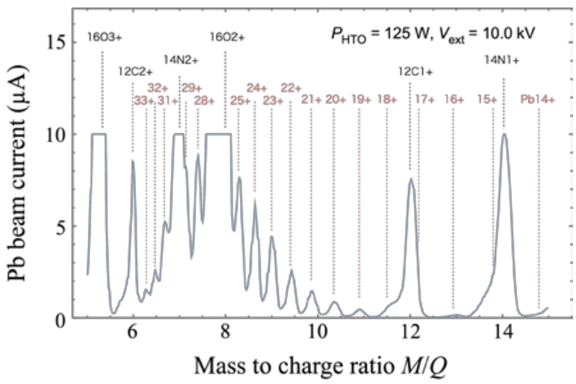

Fig. 2. Pb ions in M/Q spectrum together with the C, N, and O ions generated from residual gases in the ECRIS.

References
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