Supply of ^{70}Zn beam from 18-GHz ECRIS using the micro-oven

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In the 18-GHz electron cyclotron resonance ion source (ECRIS)[1], we have achieved the practical use of the micro-oven to supply high-intensity and stable ^{48}Ca beams for a long term.[2-4] In the process of the operational tests, we found that the temperature of our oven could be increased up to about 1000°C without damaging the oven. At that temperature, the vapor pressure of ZnO is expected to reach a level high enough to extract the Zn beam with adequate intensity. Therefore, we conducted the supply test of Zn beam using the micro-oven.

In contrast to the Ca beam, in which the Al powder is mixed to the CaO powder to reduce CaO, only the powder of ZnO was placed in the crucible because the vapor pressure of ZnO is sufficiently high. The hot liner[5], which plays an important role in reducing the material consumption rate when supplying the ^{48}Ca beam, is not used when supplying the ^{70}Zn beam because even if the oven current is increased, the beam intensity hits a peak at an inadequate level when installing the hot liner into the ECRIS.

When increasing the oven current gradually, the water evaporated first. By increasing the oven current, the production of the Zn beam was observed at the oven current lower than that at which the Ca beam was produced. This production seems to be due to the metallic Zn existing slightly in ZnO. The production of the Zn beam at this oven current was terminated after a short time. By further increasing the oven current, the production of the Zn beam was observed again at the oven current higher than that at which the Ca beam was produced.

The ^{70}Zn^{15+} beam produced by the micro-oven was first supplied for the experiment at the RIBF, from May to June 2014. The beam intensity at the exit of ECRIS and the oven current are shown in Fig. 1. As an example, the power applied to the oven for the oven current of 2.45 A (May 16 to May 19) is estimated to be 39 W. The RF power fed to the ECRIS was 550 W. During the experiment, the sudden increases in pressure in the ECRIS, followed by either the increase in beam intensity or runaway of the ECRIS, occurred several times. These phenomena seem to be due to the grain size of the ZnO (in this experiment, the material was prepared by chipping sintered ZnO rod. The grain size was up to about 1 mm in diameter). Assuming that a grain had a metallic Zn core and a ZnO shell, the inner pressure of the grain increases. The shell becomes thinner with the evaporation of ZnO and cracks at some point to cause a sudden increase in pressure in the ECRIS. This instability problem seems to be prevented by chipping the grains as fine as possible.

Because there was a break period ("CGS failure" in Fig. 1), the material was replaced just to be safe. The statuses of beam supply before and after the break are summarized in Table 1. The consumption rate all through the experiment was 0.14 mg/h.

Table 1. Status of beam supply.

	Before	After
Beam intensity [electric μA]	30	33
Amount of ZnO placed in the crucible [mg]	1007	835
Amount of ZnO consumed [mg]	59	22
Consumption rate of ZnO [mg/h]	0.16	0.10

The vapor pressures among Ca, Zn, and ZnO are in the following order: Zn > Ca > ZnO. In order to evaporate ZnO, an oven temperature higher than that for Ca is required. But after being decomposed into Zn and O by the plasma, a vapor pressure higher than that of Ca is obtained. Sufficiently low consumption rate without the hot liner seems to stem from the above relation of vapor pressures.

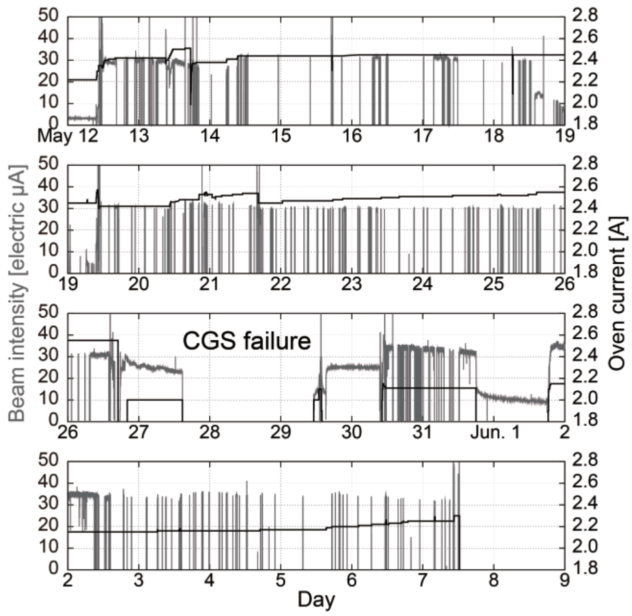

Fig. 1. Long-term supply of the ^{70}Zn beam for the experiment at the RIBF. The beam intensity for ^{70}Zn^{15+} (gray) and the oven current (black) are shown.

References
1) T. Nakagawa et al.: Nucl. Instrum. Methods B **226**, 392 (2004).
2) K. Ozeki et al.: RIKEN Accel. Prog. Rep. **46**, 128 (2013).
3) K. Ozeki et al.: Rev. Sci. Instrum. **85**, 02A924 (2014).
4) K. Ozeki et al.: Rev. Sci. Instrum. (*to be published*).
5) A. Efremov et al.: Rev. Sci. Instrum. **69**, 662 (1998).

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