Modification of septum electrode for RRC-EDC

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Electric deflection channel (EDC) is an important device to extract the circling ion beam in a cyclotron by using high-static electric field up to 10 MV/m. The circling beam and the extracting beam in the cyclotron are separated by a septum electrode, which is a thin ground electrode of the EDC and only the extracting beam is affected by the electric field and deflected. Because major beam loss in the cyclotron occurs on the septum electrode, the heat load restricts the maximum beam intensity accelerated by the cyclotron. Especially for the uranium beam acceleration at the RIBF, turn separation of the circling beam in the RIKEN ring cyclotron (RRC) is about 7 mm due to the low acceleration voltage and the short stopping range of ions in a material causes melting of the septum electrode, as happened in fiscal year 2012. Therefore, a new septum electrode for the RRC-EDC was introduced in order to improve the heat-load durability of the beam loss.

We fabricated the septum electrode with a V-cut entrance as shown in Fig. 1. The septum electrode was made of oxygen-free copper and divided into two pieces, the entrance side and the remainder, to facilitate the replacement of the damaged entrance side. Thickness of the beam-pass area on the septum electrode was 0.8 mm for the entrance side, 1.6 mm for the central part, and 5 mm for the exit. The cooling water pipes between the two pieces were connected by a VCR[1)] tube fitting. Ten points of E-type thermocouple devices were mounted on the septum electrode for thermal interlock.

Figure 2 shows the results of the 3D heat transfer calculation for the original and the new septum electrode assuming turbulent forced convective heat transfer by cooling water. The range of both plots is from 0 °C to 1100 °C. For the original septum electrode, which is a simple flat plate, the maximum temperature was about 850 °C assuming 4.0 mm(height)×0.8 mm(thickness)×0.05 mm(range) uniform distribution of 300 W heat load at the entrance, and assuming the heat transfer coefficient of 20000 W/(m^2·K) on the inside of cooling water pipe. On the other hand, the maximum temperature was reduced to 670 °C for the new septum electrode assuming 500 W uniform heat load for the same dimensions and same heat transfer coefficient. For both cases, the peripheral temperature was set to 25 °C. The original septum electrode was replaced by the new one, and the old driving motors for the RRC-EDC were also changed to new stepping motors. The modified RRC-EDC was used for the machine time from the winter of 2013, including the RIBF experiment. No failure was found on the new septum electrode with about 4.5 kW of $^{238}U^{35+}$ beam and 1.6 kW of ^{48}Ca beam.

In order to extend the capability for further intensity growth, we have started to develop a mass-less septum electrode by arranging numerous thin tungsten ribbons. A test piece of a 50-μm-thick tungsten ribbon was irradiated by varying the intensity of $^{238}U^{35+}$ beam with an energy of 10.7 MeV/u provided by the RRC in November 2014 to investigate the melting boundary. The tungsten ribbon melted at an intensity of about 50μA. The result will be compared with the heat transfer calculation and the prototype septum electrode will be fabricated.

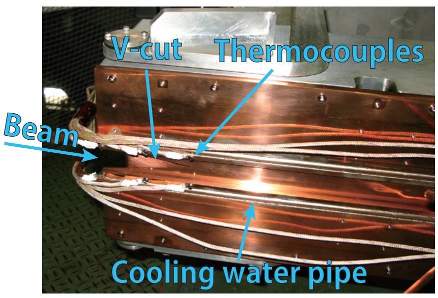

Fig. 1. New septum electrode with a V-cut entrance.

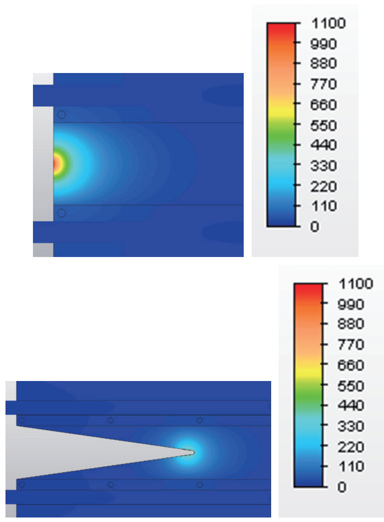

Fig. 2. Results of the 3D heat transfer calculation around the beam entrance side for the original (upper panel) and the new (lower panel) septum electrode.

References
1) Product of Swagelok Co.

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