# Superheavy element research at RIKEN Nishina Center

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The study of the heaviest nuclei (elements) by using heavy-ion beams is one of the most important research subjects. When the RIKEN Ring Cyclotron (RRC) was being constructed in 1985, Dr. Kosuke Morita designed and constructed the Gas-filled-type Recoil Ion Separator (GARIS) as the first large-scale experimental equipment in the experimental hall E1. New isotopes, $^{195}$At, $^{196}$Rn, $^{197}$Rn, $^{199}$Fr, and $^{200}$Fr, were discovered using RRC and GARIS.

In 2000, the RIBF project was started, and GARIS was relocated from the E1 room to the energy-upgraded RIKEN Linear Accelerator (RILAC) facility by adding CSM accelerators in order to start a full-scale experiment to search for new elements. With the technical developments of both the accelerator/ion source and the experimental setups, the experimental system had the highest possibility in the world of providing the heaviest elements. First, follow-up experiments conducted by the preceding research group, Gesellschaft fur Schwerionenforschung (GSI), were performed. In these experiments, elements 108, 110, 111, and 112 were produced with the highest production rate to date. The experiment aimed at discovering the 113th element was started in 2003 by using the $^{209}$Bi($^{70}$Zn, n)$^{278}$113 reaction. Three decay chains originating from $^{278}$113 were successfully observed in 2004,[1] 2005,[2] and 2012.[3] Furthermore, a connection to the known isotopes $^{266}$Bh and $^{262}$Db was established using the $^{248}$Cm($^{23}$Na, 5n)$^{266}$Bh reaction in 2009. The prolonged experimental effort for $^{278}$113 was concluded in Oct. 2012. The three decay chains of $^{278}$113 are presented in Fig. 1.

IUPAC finally decided to give our research group the right to name and determine the symbol for the element 113 in Dec. 2015. We proposed the name Nihonium with the symbol Nh. The name and symbol were finally accepted by IUPAC in Nov. 2016. Figure 2 shows the group members who participated in the naming meeting.

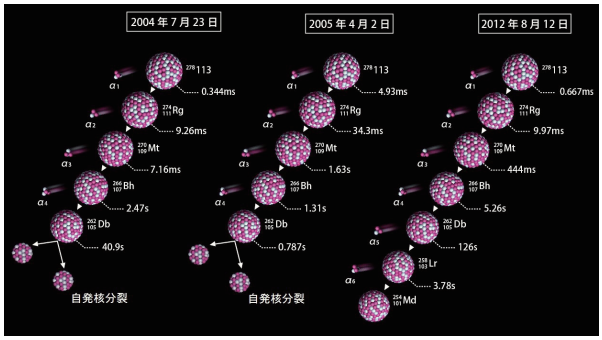


Fig. 1. Decay chains related to $^{278}$113. The first two decay chains consist of four alpha decays and end with the spontaneous fission of $^{262}$Db. The third decay chain consists of six alpha decays and is connected to $^{254}$Md.

Fig. 2. Research group members after the conclusion of the naming meeting of the element 113.

Aiming to discover further new elements, a new Gas-filled Recoil Ion Separator (GARIS-II) for asymmetric reaction such as hot fusion reaction was developed. GARIS-II has a large angular acceptance (18.5 msr) and short path length. The transmission of GARIS-II is 1.7 times higher than that of the present GARIS. New element search using the hot fusion reaction will be started in the near future at RIKEN Nishina Center.

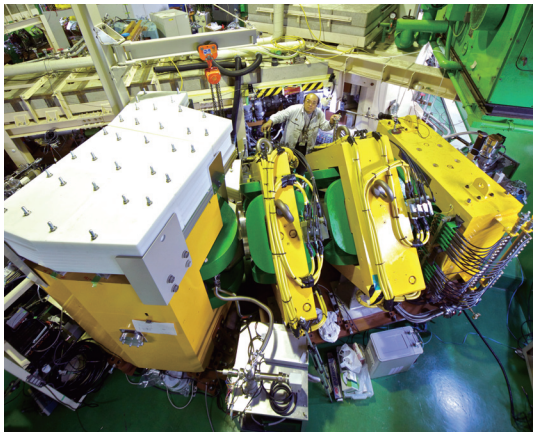

Fig. 3. Photograph of the GARIS-II separator. The separator has a Q-D-Q-Q-D configuration.

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References
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2) K. Morita et al., J. Phys. Soc. Jpn. **76**, 045001 (2007).
3) K. Morita et al., J. Phys. Soc. Jpn. **81**, 103201 (2012).