Mass measurements of neutron-rich nuclei around $A = 112$ with ZD-MRTOF-MS system

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The ZeroDegree-MRTOF (ZD-MRTOF) system combined with a gas catcher cell with radio-frequency ion guide method has been developed at the downstream of ZeroDegree spectrometer in RIKEN Nishina Center.[1)] An online test for this system was performed with fission reactions symbiotically with the in-beam γ-ray spectroscopy experiments[2)] at the end of 2020. The reaction products after the second target at the focal plane F8 were selected and guided by the ZeroDegree spectrometer, then they were captured by the gas cell and transported to the MRTOF for precise mass measurement. We measured more than 70 masses in total, and in this work, we concentrated on the masses in the range of neutron-rich isotopes $A = 111$–113.

In Fig. 1, an example of the TOF spectra obtained from the experiments is shown. In the spectra, it can be seen that the beam's ions and their β-decay products were observed. To fit the peaks in the spectra, a Gaussian function coupled with two exponential tails[3)] was employed during the data analysis process. The definition of the fitting function is shown in Eq. (1),

$$f(t) = A \cdot \begin{cases} \exp(\frac{\Delta_{\rm L}(2t-2t_{\rm c}+\Delta_{\rm L})}{2\sigma^2}) & t \le t_{\rm L} \\ \exp(\frac{-(t-t_{\rm c})^2}{2\sigma^2}) & t_{\rm L} < t < t_{\rm R} \\ \exp(\frac{\Delta_{\rm R}(-2t+2t_{\rm c}+\Delta_{\rm R})}{2\sigma^2}) & t \ge t_{\rm R} \end{cases} \quad (1)$$

where A and t_c are the amplitude and maximum position of this function, σ is the width of the central Gaussian part, t_L ($t_L = t_c - \Delta_{\rm L}$) and t_R ($t_R = t_c + \Delta_{\rm R}$) are the transition points of the left and right side of the Gaussian function, where the Gaussian function smoothly changes to an exponential function. The function value and its first derivative are continuous at the transition points. Compared to Gaussian and exponential-Gaussian hybrid functions, the accuracy of fitting results can be significantly improved[4)] using the function described in Eq. (1). We can calculate the ion mass accurately after measuring the ions' exact time-of-flight.

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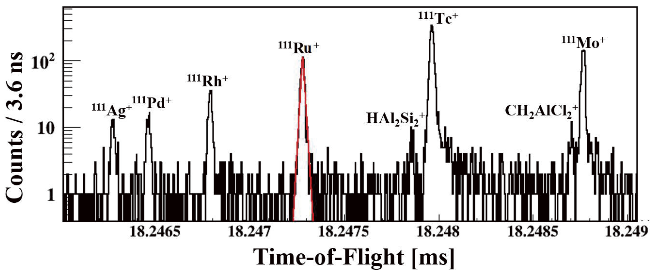

Fig. 1. An example of TOF spectrum at $A = 111$ with radioactive ions and stable molecules. The red line indicates the fit function defined in Eq. (1).

In this work, we measured 15 masses of radioactive neutron-rich nuclei ^{111,113}Ag, ^{111,113}Rh, $^{111\text{–}113}$Pd, $^{111\text{–}113}$Ru, and ^{111,112}Mo (see in Fig. 2). Compared with the mass values listed in AME2020, an excellent agreement between our results and previously reported values has been observed. The mass measurement of ^{113}Ru was improved, and the ^{112}Mo mass was measured for the first time. Based on our results, we investigated the double neutron separation energy (S_{2n}) and empirical neutrons shell gap (δ_{2n}), and the results will be presented in a future publication.

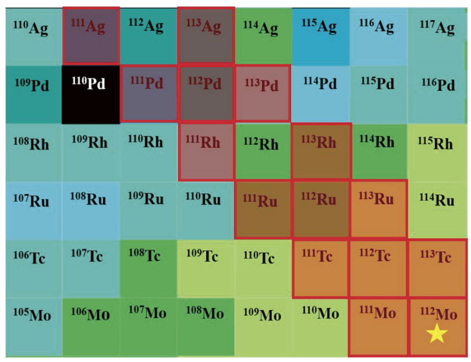

Fig. 2. Nuclei chart $A \sim 110$, nuclei measured with ZD-MRTOF are in red square, and the new mass is marked with a star.

References

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