

# Method for preparing ultra-thin sources for low-energy particle spectrometry

H. Kikunaga,<sup>\*1,\*2</sup> H. Haba,<sup>\*1</sup> and J. Kanaya<sup>\*1</sup>

Generally, internal conversion electrons originate from the K shell. If the decay energy of a nuclear isomer is less than the binding energy of an inner-shell electron, the emission of an electron from the shell is forbidden, in which case the isomer interacts with outer-shell electrons. As a result, the probability of internal conversion is affected by the outer-shell electron state, namely the chemical state. Examples of this type of nuclides are  $^{99}\text{Tc}^m$  (2.17 keV) and  $^{229}\text{Th}^m$  (7.6 eV). The goal of our research is to measure such low-energy internal conversion electrons of various chemical states. For high-resolution energy spectrometry, it is necessary to prepare radionuclides as a thin source. In this report, we attempt to prepare an ultra-thin source using the Self-assembled Molecular (SAM) technique. The performance of the SAM substrate was investigated through radio-tracer experiments.

RIKEN Ag-based multi-isotope tracers and single-isotope tracers were used for the experiments. The multi-tracers were produced by irradiation of a Ag metal plate with a  $^{14}\text{N}$  ion beam accelerated by the RIKEN Ring Cyclotron. Ag target material was removed by a precipitation method with the use of hydrochloric acid. Single-isotope tracers were prepared using the AVF cyclotron at CYRIC, Tohoku University.

The procedure for the preparation of SAM substrates was similar to that described in Ref<sup>1)</sup>. An Al plate 25 mm in diameter was polished and rinsed with distilled water. After drying, the Al plate was treated with 1 vol.% 3-aminopropyltriethoxysilane (APTES) in absolute toluene through chemical vapor deposition in a self-made PTFE cell at 100 °C for 2 h; subsequently, it was rinsed with methanol and absolute toluene. Phosphonation of the terminal amino groups of APTES was performed with phosphoryl chloride and  $\gamma$ -collidine in absolute acetonitrile, and the sample was then rinsed with absolute acetonitrile and distilled water. The coupling of the SAM substrate and radionuclides was carried out in an aqueous solution or an isopropyl alcohol solution.

The bound radionuclides were assayed by  $\gamma$ -ray spectrometry with an HPGe semiconductor detector. A  $\gamma$ -ray spectrum of a multitracer-SAM sample is shown in Fig. 1. The  $\gamma$ -peaks of  $^{46}\text{Sc}$ ,  $^{54}\text{Mn}$ ,  $^{65}\text{Zn}$ ,  $^{75}\text{Se}$ ,  $^{83}\text{Rb}$ ,  $^{85}\text{Sr}$ ,  $^{88}\text{Zr}$ ,  $^{88}\text{Y}$ ,  $^{101}\text{Rh}$ , and  $^{102}\text{Rh}^m$  are observed in the spectrum. By comparison of  $\gamma$ -peak counts of each nuclide, we found that the yield of nuclides with oxidation

states +3 and +4 is relatively high. On the other hand,  $^{22}\text{Na}$  and  $^{57}\text{Co}$  were not detected, although these nuclides were included in the multi-tracer solution. This tendency was found regardless of the reaction solvent to be combined with radionuclides.

To confirm the uniformity of the SAM source, the  $\alpha$  source was prepared with  $^{241}\text{Am}$  tracer and subjected to autoradiography. A photograph taken using an imaging plate is shown in Fig. 2. The deviation of  $\alpha$  activity is observed at the upper-left part of the image. This deviation probably originates from fine scratches on the Al plate. With the exception of this part, the  $\alpha$  activity is spread uniformly over the entire SAM substrate. Although there are still some problems, the present method will provide us with a reliable ultra-thin source after some improvements.

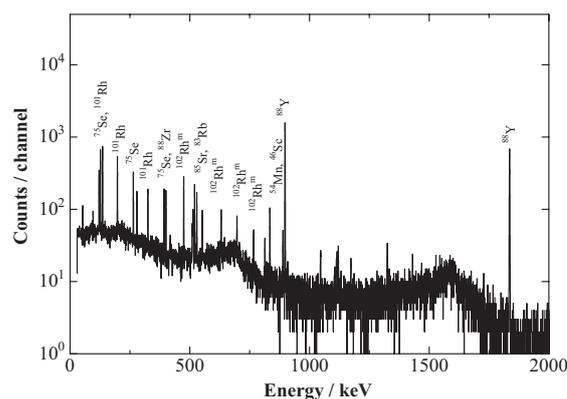


Fig. 1. An example of a  $\gamma$ -ray spectrum of a multitracer-SAM sample.

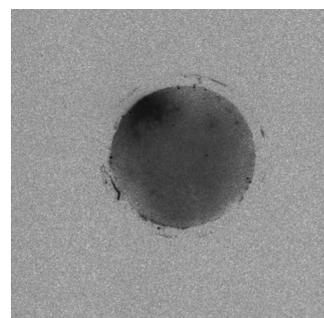


Fig. 2. Photographic image of a  $^{241}\text{Am}$ -SAM sample taken using an imaging plate.

<sup>\*1</sup> RIKEN Nishina Center

<sup>\*2</sup> Research Center for Electron Photon Science, Tohoku University

## References

- 1) A. Shida et al.: Surf. Coat. Technol. **169-170**, 686 (2003).