Preparation of an ^{225}Ac source for ^{221}Fr EDM measurement

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The origin of the matter-dominant universe is one of the greatest mysteries in modern physics. It is considered that the violation of the charge conjugate and parity symmetry (CP violation) is needed to explain the mystery.[1] The existence of the electric dipole moment (EDM) of elementary particles could lead to the discovery of the source of CP violation and the prospects of new physics beyond the standard model of particle physics.

Francium (Fr), which is the heaviest alkali element, has a large enhancement factor of about 10^3 for the electron EDM.[2] In addition, ^{221}Fr is sensitive to the nuclear EDM. We aim to extract the nuclear EDM by comparing it with the ^{210}Fr EDM, which is sensitive to the electron EDM.

In this paper, we report the preparation of an ^{225}Ac source to obtain the ^{221}Fr recoiling from it. ^{221}Fr, which is produced from the alpha decay of ^{225}Ac with a half-life of 10 days, is convenient to conduct the EDM experiment without accelerator operation. We used an electrodeposition method to fix ^{225}Ac firmly on a plate. To obtain sufficient statistics for EDM measurements, we aimed to develop a source of 10 MBq or higher.

Figure 1 shows an overview of the cell used for the electrodeposition experiment. A Pt plate ($0.1 \times 15 \times 15$ mm^3) on a water-cooled Ti block is used as a cathode, and a Pt rod (1-mm diameter) stuck into the solution is used as an anode applied with +1 kV. Silicon rubber with a hole of 5 mm diameter functions as an electrode seal, and we can obtain an active target area as we arranged.

Before preparing the Ac source, the best condition of the electrodeposition was determined using Y, which is chemically similar to Ac. The Y sample we prepared included ^{88}Y, which has a long half-life of 106.6 days and emits γ rays with energies of 898 and 1836 keV that can be detected using a germanium semiconductor detector. By dividing the amount of Y electrodeposited on the Pt plate by that used for electrodeposition, we could determine the electrodeposition yields. ^{88}Y was produced by irradiating a ^{nat}SrO target with a 24-MeV deuteron beam for 4 h at the AVF cyclotron. The beam current was 3 μA. The target included 157.9 mg of ^{nat}SrO and was pressed into a disc of 10-mm diameter at 1.6 t for 5 min. After the irradiation, ^{88}Y was chemically isolated from the target by extraction chromatography using an Ln resin (particle size: 100–150 μm) filled in a column (internal diameter: φ5 mm, height: 50 mm).

This purified ^{88}Y was mixed with stable ^{89}Y and dissolved in 1 mL of 0.01 M HNO_3. 10 μL of the solution was mixed with 2 mL 2-propanol for electrodeposition. The number of Y atoms in the mixed solution was the same as that of 1-MBq ^{225}Ac.

Figure 2 shows the time dependence of the electrodeposition yield. At an applied voltage of +1 kV and at room temperature, the yields increased with time from ~15% at 10 min to ~100% at 40 min. We could visually observe the target layer on the Pt plate.

We purchased ^{225}Ac and attempted the electrodeposition with the optimized condition which achieved the highest yield. As a result, a maximum yield of 77.9% was achieved for the ^{225}Ac source of 20.4(6) MBq. A sufficient dose was achieved, but the difference in yields between Y and Ac may be due to subtle differences in chemical properties. The ^{225}Ac used in this research was supplied by the U.S. Department of Energy Isotope Program managed by the Office of Isotope R&D and Production.

The development of the experimental apparatus to trap ^{221}Fr from the ^{225}Ac source and measure the EDM is now in progress.

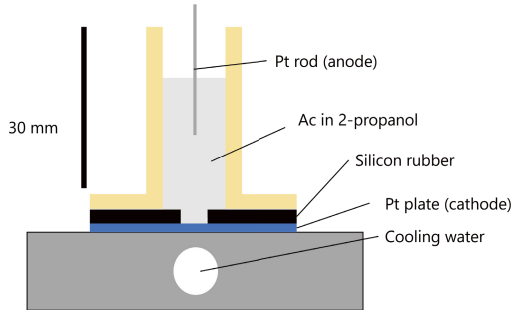

Fig. 1. Overview of the cell for Ac electrodeposition.

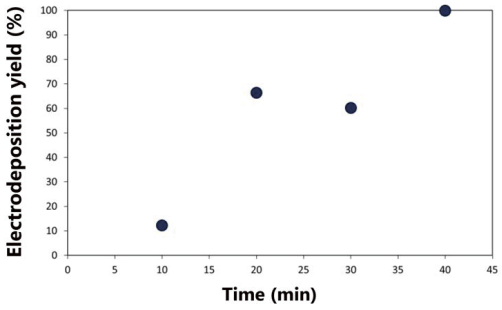

Fig. 2. Time dependence of the electrodeposition yields of Y at an applied voltage of +1 kV.

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References

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