Development of a new ^{225}Ac source for ^{221}Fr EDM measurement

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The origin of the matter dominated universe is one of profound mysteries in modern physics. According to the Sakharov conditions,[1] the violation of the combined symmetry of charge conjugation and parity (CP violation) is required to explain the mystery. The electric dipole moment (EDM) of elementary particles, if it exists, is expected to lead to the discovery of CP violation sources, and may also lead to prospects for new physics beyond the Standard Model of particle physics. The francium (Fr) atom is known to have a sensitivity to the electron EDM with an enhancement factor of approximately 10^3.[2] ^{221}Fr may also have a sensitivity to the Schiff moment arising from nucleon and nuclei EDM. We are aiming to extract these by comparing the EDM with the ^{210}Fr EDM, which has a sensitivity only to the electron EDM.

Actinium-225 (^{225}Ac), which generates ^{221}Fr through the α-decay, has been widely used as a source of ^{221}Fr.[3] In this paper, we report a new method to efficiently neutralize and decelerate ^{221}Fr atoms arising from the α-decay of ^{225}Ac at approximately 100 keV.

Figure 1 shows a schematic of the new method, where, by covering the ^{225}Ac electrodeposition source with a thin film of yttrium (Y), we were able to stop the ^{221}Fr atoms with an energy of approximately 100 keV in the film. ^{225}Ac is electrodeposited on a circular Pt plate with radius 5-mm. To create the Y film on the source, a negative high voltage is applied to the Y plate in an argon (Ar) atmosphere. Then, Ar ions generated by glow discharge from the cathode accelerated by the electric field sputter the Y atoms, which accumulate on the source. A thickness of more than 30-nm of the Y film is expected to stop most of the ^{221}Fr atoms produced by the α-decay in the Y film. By heating the source, ^{221}Fr in the Y film can be thermally diffused, and the ^{221}Fr that reaches the surface are desorbed from the surface. Most of the ^{221}Fr are expected to be desorbed as neutral atoms, since the work function of Y is lower than the first ionization potential of ^{221}Fr.

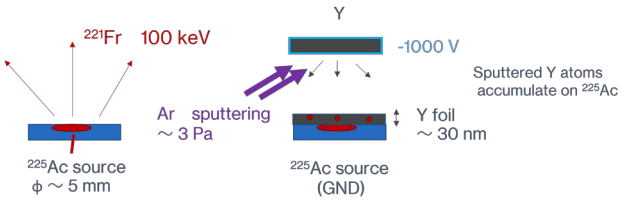

Fig. 1. Schematic of the new method for ^{221}Fr source.

In this new method, more ^{221}Fr atoms can be captured in the Y foil that in the conventional source4) when the ^{225}Ac dose with the same, and the efficiency of ^{221}Fr desorption form the Y foil surface by heating is also expected to be higher, because dominated the Y surface has low impurities and no oxide film is formed as long as it is sealed in a vacuum.

Based on this method, we sputtered Y and created the Y film on the ^{225}Ac source. The daughter nuclei of ^{225}Ac emitted from the source were captured by a catcher facing the source. The α decays were measured by a silicon semiconductor detector (SSD) before and after sputtering.

Figure 2 shows results obtained before and after the sputtering procedure. The three peaks measured before sputtering, as shown in Fig. 2(a), correspond to α-particle energies of ^{221}Fr, ^{217}At, and ^{213}Po, from left to right, respectively. As the sputtering time increased, the counts gradually decreased, and after approximately half a day of sputtering, the peak of ^{221}Fr almost disappeared. This result strongly suggests that ^{221}Fr, initially generated from the source at an energy of approximately 100 keV, were stopped in the Y film.

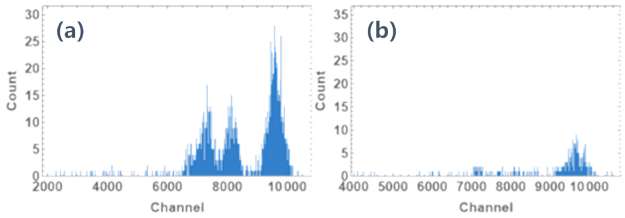

Fig. 2. The number of α-particles from the daughter nuclei of ^{225}Ac as measured by SSD. The horizontal axis shows the channel number corresponding to the α-particle energy. The measured α-particles of the daughter nuclei emitted from the source (a) after one hour of sputtering and (b) after half a day of sputtering.

We also confirmed that approximately 42% of the ^{221}Fr atoms in the source were extracted as neutral atoms by heating the source at approximately 1300 K for 20 seconds.

The apparatuses for trapping ^{221}Fr and measuring EDM are currently under development.

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