Identification of Pu isotopes by measurement of Q-value with cryogenic detector

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Introduction

Cryogenic detectors using heat generation below 1 K have become an attractive alternative because of their outstanding energy resolution [1, 2, 3]. Significant improvement in gamma spectroscopy has been achieved with high resolution transition edge sensors (TESs) for nuclear material analysis [4]. In alpha spectroscopy, superior resolution to that of conventional detectors has been also demonstrated [5, 6]. Since all the deposited energy can be converted into thermal energy by surrounding a radioactive source with metal foil [7], alpha energy can be measured without any correction for self-attenuation. Accompanying electrons, x-rays, and/or ɣ-rays are also converted into thermal energy. Thus measurement of alpha decay in 4π geometry returns the Q value, the total decay energy, independent of decay branches without loss of energy and count, enabling Q spectroscopy.

Experipental setup

Fig. 1 shows the experimental setup of the absorber and the sensor together with a Superconducting Quantum Interference Device (SQUID). The sample preparation procedures were divided into two parts. The first part was the construction of a 4π metal absorber. A small amount of a solution mainly containing ^{239}Pu and ^{240}Pu was dropped onto a piece of gold foil. Foil were made with thickness of 30 μm After the solution was dried, leaving a deposition of radionuclides, the foil was folded in order to cover the radioactive material. It was then diffusion-welded at 400 °C for 16 hours in an argon atmosphere. The resulting thicknesses were 60 μm. The welded sandwich was cut to 1.4×0.9 ㎟.

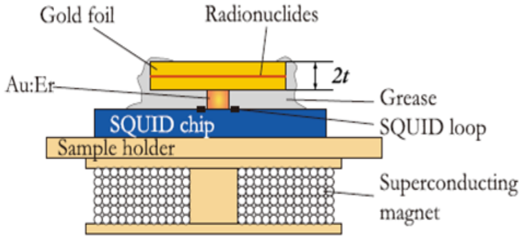

Figure 1. Cross-sectional view of the experiment

The next procedures were to establish an MMC setup. A hole less than 10 μm in diameter was punched in the middle of the gold rectangular slab using a high-power pulse laser. A Au:Er disk 40 μm in diameter and 30 μm in height was wedge-bonded over the hole on one side of the slab. When the sample was viewed from the other side, the hole indicated the position of the Au:Er sensor. A gradiometric SQUID susceptometer with two 50 μm figure-8-shaped pickup loops [8] was used to measure the magnetization change of the paramagnetic sensor. The rectangular slab was placed on the SQUID chip (1.55×2.08×0.625 ㎜^{3}) in such a way as to align the sensor in one of the pickup loops using a long-focal-length microscope. A small superconducting magnet was placed under the sample holder to magnetize the erbium ions in the Au:Er sensor. The concentration of enriched ^{166}Er in the Au:Er was 800 ppm [9]. The experimental setup was cooled with a dilution refrigerator.

Result

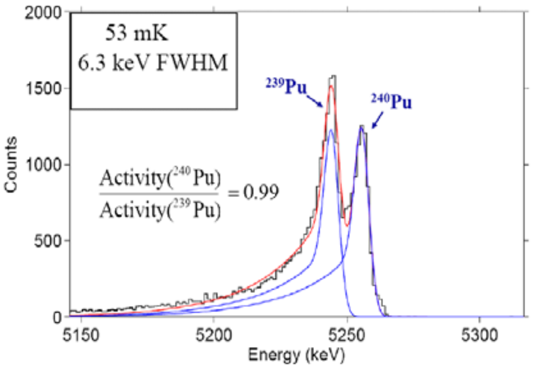

Figure 2. Spectrum of Pu isotopes

We established Q spectroscopy, a novel method for the study of alpha decay, by combining 4π detection scheme with a low temperature microcalorimeter. A 4π metal absorber guarantees absolute measurement of radioactivity without energy loss in the source and absorber. As a clear demonstration of Q spectroscopy, The mixed Pu isotope source enclosed by thin gold foil was measured below 100 mK. Its resulting energy spectrum with 6.3 keV FWHM is shown in Figure 2.

Conclusion

The recent results of KRISS show that Q-spectroscopy using a cryogenic detector is a useful tool to assay nuclear materials. Q-spectroscopy is expected to overcome the drawbacks of conventional detection techniques and to introduce novel techniques in nuclear metrology.

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