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The use of polyimide foils to prevent contamination from self-sputtering of ^{252}Cf deposits in high-accuracy fission counting ☆

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Abstract

It is demonstrated that a thin polyimide foil can be employed to prevent contamination from the self-sputtering of a ^{252}Cf source under vacuum, with small energy loss of the emitted fission fragments, with very small effect on the efficiency of counting the fission fragments, and with a long lifetime of the plastic foils.

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1. Introduction

At the US National Institute of Standards and Technology (NIST), the standard neutron source NBS-I is used as the basis for calibration of the emission rate of all other isotopic neutron sources. The artifact standard NBS-I was most recently calibrated more than 40 years ago by a laborious procedure of only moderate accuracy, about 1% [1]. It is preferable, where possible to replace such an artifact standard with a standard based on a constant of nature. The average number of neutrons emitted per fission in ^{252}Cf, nubar-252, is a well-established natural constant that can be potentially employed to establish a standard source for neutron emission rate. The fission rate of a bare deposit of ^{252}Cf can be measured accurately by defined-solid-angle counting of fission fragments, and then multiplication by the constant nubar-252 gives the neutron emission rate of that source. The major difficulty with this approach is that under vacuum a ^{252}Cf source self-sputters and rapidly contaminates the surface barrier detector and every exposed surface of the defined-solid-angle counting apparatus. To prevent this sort of contamination, thin foils of polyimide may be used as barriers, covering the ^{252}Cf deposit. With thickness of 25–50 μg/cm^2, these foils are thin enough to pass fission fragments and alpha particles, with very little energy loss, while trapping the much less energetic sputtered particles. For the highest accuracy, the perturbation of the effective solid angle by the polyimide foils must be carefully determined. In this work, the magnitude of the perturbation is found by counting fission fragments with one or two foil barriers and then extrapolating to zero foil thickness. The extrapolation method is also tested on alpha particle counting with high-quality ^{239}Pu deposits. The percentage of energy loss and perturbation of counting efficiency is determined for both alpha particles and fission fragments. The purpose of this work was to evaluate the possible systematic error introduced by a polyimide foil barrier covering a ^{252}Cf deposit when using nubar-252 as a natural standard to recalibrate NBS-I.

2. Experimental procedure

In a previous report by Deneke et al. [2] it was shown by means of a blind comparison that the defined-solid-angle alpha counting techniques of NIST and the Institute for

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Reference Materials and Measurements (IRMM) agreed within about 0.05%, even in a most difficult case with a very complex alpha spectra and short-lived daughter activities. Fig. 1 shows the NIST defined-solid-angle counting apparatus that was employed in both the previous blind comparison and in the present work. In the blind test, most of the NIST work was done without polyimide foil covers, because self-sputtering is much less of a problem with actinides having low-spontaneous fission rates. In the present work, the count rate from the uncovered alpha deposit was observed, and then the observation was repeated with one or two polyimide foils covering the deposit. For a deposit that emits only alpha particles, but no fission fragments, it is possible to see whether the difference in the perturbation in changing from two foils to one foil (of roughly equal thickness) is about the same as the difference in the perturbation when changing from one foil to none. This extrapolation to zero cannot be tested directly with the ^{252}Cf deposit, because a test with no cover would immediately and permanently contaminate the expensive heavy-ion surface barrier detector with sputtered material. With the Cf deposit, only the difference between the perturbations with one and two foils was observed.

The polyimide foils employed in these tests were prepared at the IRMM in the manner reported by Stolarz and Van Gestel [3]. The foils labeled A2 and A3 that are used in this work were reported by IRMM to have areal densities of 39.1 and 37.5 μg/cm^2, respectively, as estimated by spectrophotometry. Fig. 2 shows one of these foils as mounted between a pair of aluminum rings.

Charged particle energy distributions and/or count rates were recorded using both a multichannel pulse-height analyzer (PHA) and a single channel analyzer (SCA).

For the ^{239}Pu alpha deposit, the alpha energy attenuation due to the polyimide foils is seen in the PHA spectra of Fig. 3, while Table 1 gives the SCA count rate perturbation results and summarizes the PHA energy attenuation data.

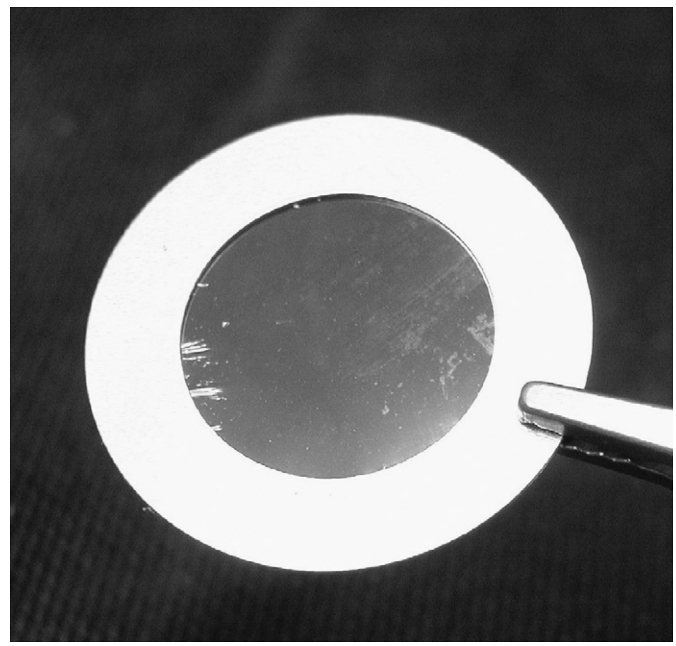

Fig. 2. Polyimide foil mounted between two aluminum rings, with inside diameter of 25 mm and outside diameter of 40 mm.

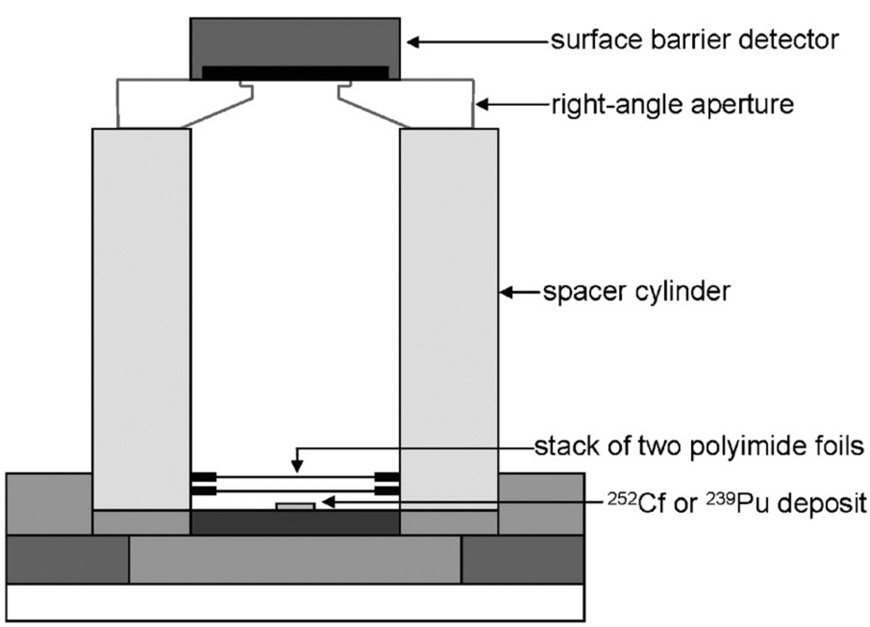

Fig. 1. Diagram of the defined-solid-angle charged-particle counting apparatus (surrounding vacuum chamber not shown). The spacer cylinder and the polyimide foil supports have penetrations to permit evacuation of the air in the vacuum vessel without creating large pressure differences across the foils. The two foils covering the deposit are mounted a few millimeters above the actinide deposit, never touching it or each other. The solid-angle-defining right-angle aperture edge is 81.369 mm above the deposit.