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PRODUCTION OF A SQUARE GEOMETRY AMERICIUM STANDARD SOURCE FOR USE WITH PHOTODIODES

Priscila Costa[1], Bianca Geraldo[1], Marcus P. Raele[1], Júlio T. Marumo[1], Roberto Vicente[1], Guilherme S. Zahn[1] and Frederico A. Genezini[1]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
priscila3.costa@usp.br
fredzini@ipen.br

ABSTRACT

In the development of a thermal neutron detector using a square photodiode and a thin boron film, a radioactive calibration source with the same geometry was needed. An americium-243 standard source was produced by electrodeposition aiming at the calibration of a PIN-type silicon photodiode with a detection area of 10 x 10 mm^2. To produce the samples two tests were performed. In the first test, a square stainless steel plate (10 x 10 mm^2) was fixed on the surface of the conventional plate, which was removed after deposition. To reduce the loss of activity of the source, in the second test nail polish was applied on the silver plate leaving only an area of 10 x 10 mm^2 without varnish coating. Once the electrodeposition process was completed, the activity concentration measurement was performed by alpha particle spectrometry. The first method presented a lower activity when compared to the total activity of Am-243 added initially. For the second method, the total activity was concetrated in the exposed square region (without nail polish).The results showed that it is possible to obtain a square geometry source; furthermore, the surrounding nail polish was not contaminated by ^{243}Am. The comparison of these two approaches indicated that the second method was more efficient as it was possible to concentrate all the americium activity in the delimitated square area.

1. INTRODUCTION

A thermal neutron detector based on enriched boron film and a photodiode is under development at Nuclear and Energy Research Institute (IPEN). The nuclear reaction between boron and thermal neutrons produces a lithium recoil nucleus and an alpha particle that will be detected by a silicon photodiode.

Photodiode operation parameters, such as, the signal-noise ratio, sensitivity to alpha particle and counting efficiency need be studied for neutron detector characterization. To verify the response of this device to alpha particles a standard source of americium is used for calibration.

Alpha sources can be obtained using several techniques, such as [1-4]: electro-spraying, electrodepositing, magneto hydrodynamic, electrolytic deposition, spontaneous deposition, micro-precipitation, direct evaporation, vacuum sublimation, drying of a liquid drop directly deposited on a substrate, electrostatic deposition etc.

Electrodeposition is a commonly used method for the preparation of sources for an alpha-spectrometry, due to the advantages offered by this method, such as [3-4]: it is simple,

inexpensive equipment produces a very thin deposit, has high deposition yields (99.8%) and high qualities of the sources obtained.

The electrodeposition, in general, produces calibration sources with active areas in circular geometry. As the silicon photodiode geometry used for the neutron detector has a square active area (10 x 10 mm^2), and boron will be deposited on the whole surface of the sensitive area of the photodiode, to perform an accurate calibration it is interesting to use a source with the same geometry. For this purpose, the aim of this work is to obtain a square planar standard americium source produced by electrodeposition.

2. METHODS AND MATERIALS

In Fig 1 a simplified scheme of the electrodeposition setup is shown, in which a plate is positioned over the base, before the cell is docked. Inside the cell, a standard solution of Am-243 with known activity is dissolved in an electrolytic solution and the ions are deposited on a cathode (source holder) where an electric current passes, so the calibration sources are produced.

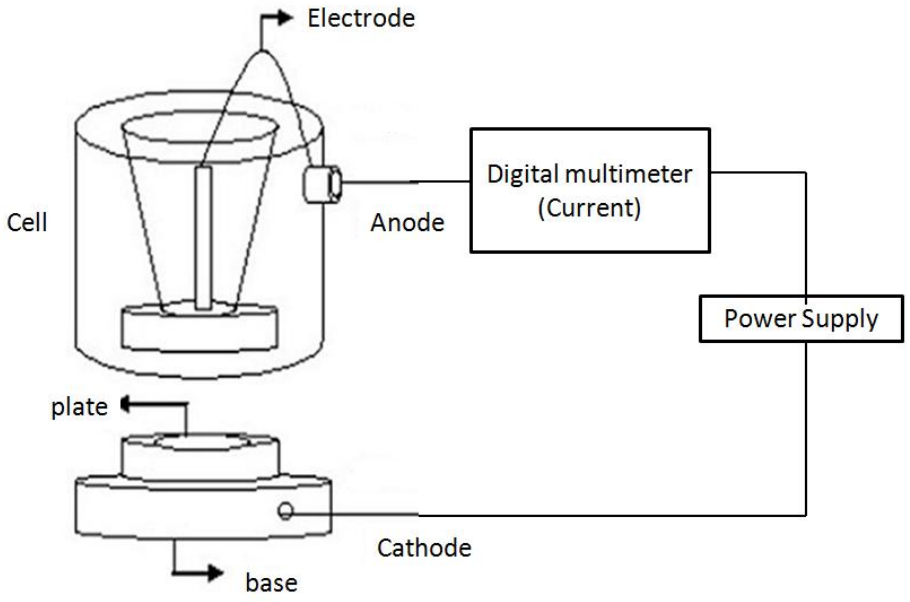

Figure 1: Simplified scheme of the electrodeposition setup [5]

The electrolytic solution [6], consists of ammonium sulfate 0.8 $mol.L^{-1}$ and sulfuric acid 3 $mol.L^{-1}$, with the pH adjusted to 1.2-2.8 with sulfuric acid 3 $mol.L^{-1}$ and ammonium hydroxide 28%, using thymol blue 0.1% as indicator. An aliquot with known activity concentration of the alpha particle-emitting radionuclide (Am-243) was evaporated and the salts were dissolved in an electrolytic solution for electrodeposition. Two americium radioactive sources with different activity concentration values were used; for test #1 the solution had 105.92 $Bq.mL^{-}1$ (certificate 68L01) and for test #2 it had 0.026844 $Bq.mL^{-1}$

(certificate 120L15). For test #2, as four sources were produced, it was interesting to use a lower activity, avoiding the generation of excessive radioactive waste during the experiment.

The electrodeposition was performed at a constant voltage of 7.5 V for 60 minutes in an acrylic cell with platinum anode and brass cathode for electric contact. A silver plate of 2.5 cm diameter was placed on the cathode, where the radionuclide was deposited. Once the electrodeposition process for these plates was completed, the activity concentration was quantified by alpha particle spectrometry (Alpha Analyst- Canberra).

In order to obtain a square geometry americium standard source two tests were performed:

- Test 1: a square piece of stainless steel with square geometry (10 x 10 mm^2) was fixed on the surface of the conventional plate (Fig 2);
- Test 2: different nail polish (white, red, transparent) was applied on the silver plate (Fig 2) leaving only an area of 10 x 10 mm^2 without varnish.

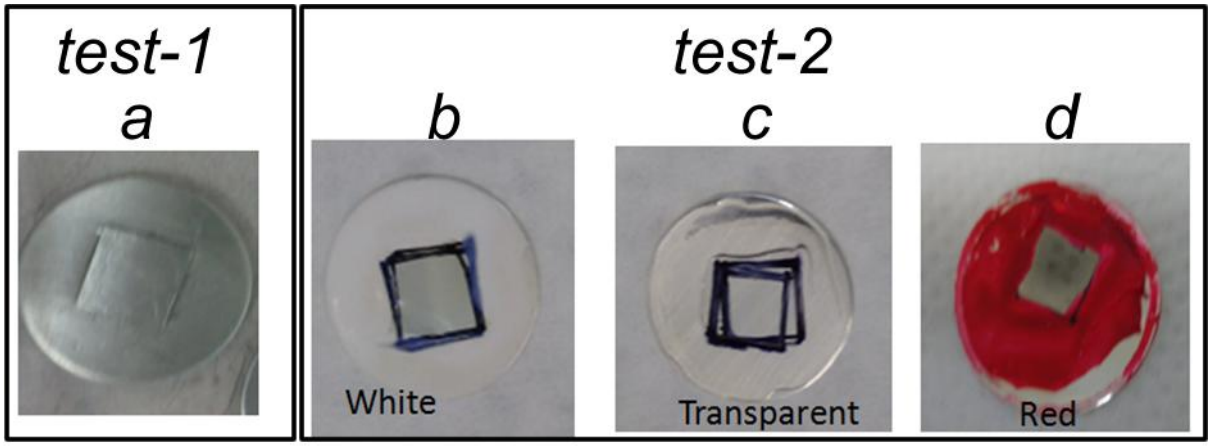

Figure 2: Stainless steel square plate over the regular support (a), and silver plates with varnishes (b, c and d)

The red nail polish that was used is from brand Gio Antonelli, and the color is commercially called “creamily anxiety”. White (“creamily white”) and transparent (colorless) polishes are from Impala. During preparation of the silver plate a support (Fig 3) that has the same dimensions of the photodiode was used for marking the region of interest with a thin tip marker. The nail polish was then applied twice in each plate and left to dry for at least one hour. After the electrodeposition process the nail polish was removed with cotton swabs using acetone, only around the region without americium deposition.

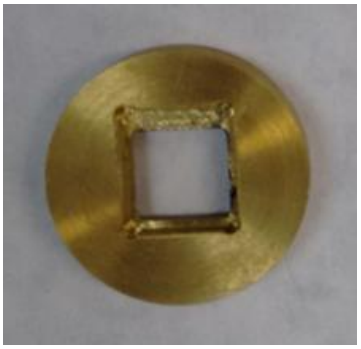

Figure 3: Support to mark the area of interest in the silver plate

3. RESULTS AND DISCUSSION

In Fig 4 the source obtained in test #1 is shown. It is possible to note that the total activity is dispersed all over the surface of the plate, with only part of the americium deposited in the square region. This process results in a loss of activity, as in this case only the square region would be used. During test #1, the electrodepoistion the current was of 1.2 A.

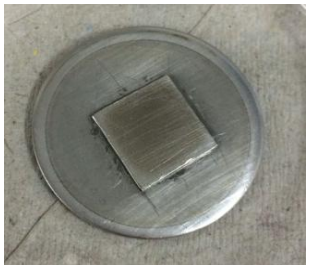

Figure 4: Americium electrodeposition stainless steel source

In test #2 red nail polish was used, but it was possible to observe that this color, when mixed with the electrolytic solution, made it difficult to adjust the pH. As an alternative, white and transparent nail polishes were tested. However, when the plate was painted with transparent nail polish, it was not possible to carry out the electrodeposition process, because during a preliminary water leakage test, some of the water leaked.

The process of electrodeposition on the red nail polish plate was performed with a current of 0.6 A (Fig 5); later, part of the red nail polish was removed, avoiding the removal of the deposited americium, in order to verify if the americium deposition occurred in the red nail polish. The quantification of plates with and without nail polish was performed by alpha spectrometry for 184321 seconds, and the results are shown in Fig 6.

Figure 5: Americium electrodeposited source with and without red nail polish

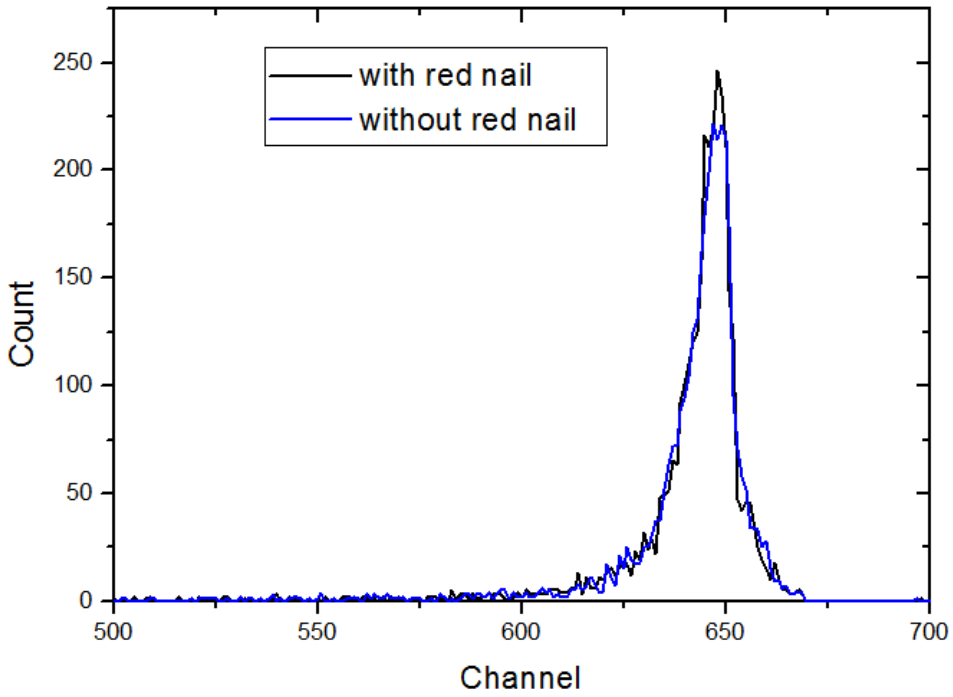

Figure 6: Spectra of the americium source with and without the red nail polish.

The net area of the peak obtained with the source with red nail polish is 3289 ± 60 counts, while for the source without red nail polish it is 3277 ± 60 counts. These results show that there was not any deposition in the nail polish area; this insures that the deposition of the total activity is concentrated in the square region.

For white nail polish, the current ranged from 0.6 A to 1.16 A. Fig 7 shows the americium sources with white nail polish.

Figure 7: Americium electrodeposited sources: "white 1", "white 2" and "white 3"

The comparison of the americium spectra obtained in test #2 is shown in Fig 8. For white 1, white 2 and white 3, the spectra acquisition time was 200040 s.

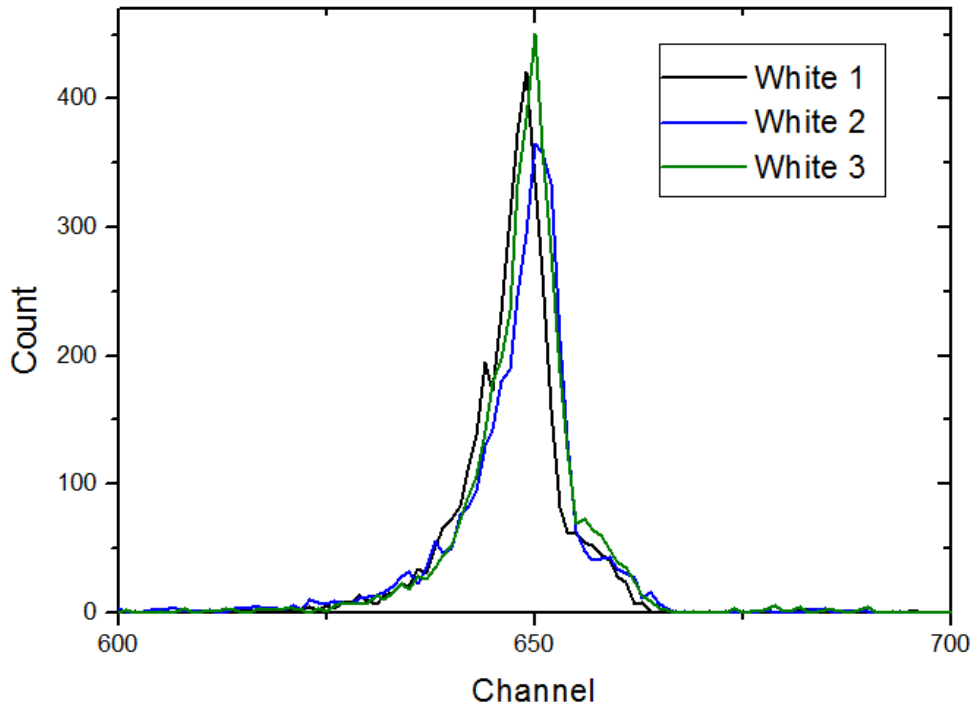

Figure 8: Comparison of experimental alpha spectra of americium sources obtained using white nail polish

In Tab 1 a comparison between net count rates obtained for the americium sources produced using nail polish is shown. The net count rates were all compatible within uncertainties, for red, white 1 and white 2 sources. The white 3 source presented a higher counting value, which can be explained by the fact that the same process was not guaranteed for demarcation of the deposition region, and also that during measurements on the spectrometer different chambers were used, so the source-detector alignment distance was not fixed.

Table 1: Comparison between net peak count rates of americium source produced using nail polish.

Source	Net Count Rate (cps)
With red	0.0179 ± 0.0003
Without red	0.0178 ± 0.0003
White 1	0.0179 ± 0.0003
White 2	0.0176 ± 0.0003
White 3	0.0194 ± 0.0003

4. CONCLUSION

A square area americium source can be produced by either of the two methods tested. In test #1, though, a part of the concentrated activity was removed, decreasing the final activity of the source because only the square would be used as source and the rest of the plate that contains the Am-243 will need to be treated as radioactive waste.

In test #2 the use of nail polish allowed obtaining a square area deposition of the radioactive source. Americium wasn't detected in the polish, showing that all the activity is concentrated in the square area of the plate. Using white nail polish proved to be more interesting due to the fact that during eletrocdeposition process this polish didn't affect the pH of the electrodepostion solution. Finally, the results showed that the use of nail polish improved the production of square americium sources, as the activity was all deposited in the square region.

The detector source alignment during alpha spectrometry was compromised because, even using the support of the (Fig 3), the deposition was not only in the center as it ended up surpassing the delimited region (Fig 5). Therefore it will be necessary to use another method to demarcate this region and thus ensure this alignment. In spite of this, the method of test 2 proved to be preferable because it concentrated all activity in the square region.

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