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Technical note

A chemical deposition method to prepare circular planar ^{147}Pm sources for the measurement of particulate emission in air

J. Udhayakumar, Shyamala S. Gandhi, Manoj Kumar, Ashutosh Dash *

Radiopharmaceuticals Division, Bhabha Atomic Research Center, Trombay, Mumbai 400085, India

HIGHLIGHTS

- Preparation of circular planar ^{147}Pm source for dust monitors.
- Evaluation of efficiency of the process and product quality.
- Quality evaluation of the sources.

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ABSTRACT

This paper describes a method for preparing a circular planar source of 17 mm diameter containing approximately 400 kBq of ^{147}Pm employing a wet chemical deposition technique to be used in dust monitors. This manuscript described the overall process concept and experimental procedure. The technical feasibility, efficiency of the process and product quality has been evaluated. The quality of the prepared source in terms of nonleachability, uniform distribution of activity and stability, which are necessary attributes of a radioactive source were evaluated and found to be satisfactory.

1. Introduction

The technical and economic benefits of β^- gauge dust monitors for continuous monitoring of particulate concentration in air have been well recognized and their utility needs hardly to be reiterated (Courtney et al., 1982; Dresia and Spohr, 1971; Gotoh, 1992; Jaklevic et al., 1980). At the very heart of the dust monitor, is a radioactive source containing low energy pure β^- particle emitting radioisotope to provide a steady β radiation flux to measure the concentration of suspended particles exploiting the β-ray absorption attenuation technique. In order to tap the potential of β^- particle emitting radioactive source, a rod type ^{147}Pm source was successfully developed which consists of a cylindrical wire in which the activity was deposited on a small surface area of the tip (Kumar et al., 2011, 2012). Although the basic principle of β-particles attenuation remains unaltered, over the years dust monitor technology has undergone an impressive design evolution. Consequently, the radioactive source design has changed and circular planar ^{147}Pm sources are beginning to replace rod type ^{147}Pm sources for these applications. In this changing scenario, the source preparation strategies require a vision to produce latest design of sources with a range of activities adaptable to the existing and foreseeable need.

The request from a commercial dust monitor supplier for large numbers of circular planar ^{147}Pm sources housed in a holder compatible with the analyzer inspired us to develop an indigenous technology for the fabrication of such type of source. The radioactive source for this purpose consists of a circular planar active area of 17 mm diameter containing 400 ± 20 kBq of ^{147}Pm homogeneously distributed on one face and housed in a 22 mm diameter cylindrical aluminum source holder. In pursuit for an appropriate technique to deposit predicted quantity of ^{147}Pm homogeneously on a planar substrate with good adherence, the adaptability of chemical deposition technique seemed to be an appropriate choice owing to its proven effectiveness in making small area source (Kumar et al., 2012).

In this paper, the utility of the chemical deposition technique for the deposition of predicted quantities of ^{147}Pm onto one surface of a small circular copper substrate (17 mm diameter) and quality control of ^{147}Pm source to meet regulatory compliance,

* Corresponding author. Tel.: +91 22 25595372; fax: +91 22 25505151.
E-mail addresses: adash@barc.gov.in, adash1960@yahoo.com (A. Dash).

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have been reported. The overall process concept, experimental procedure and quality assurance of such a source have been described.

2. Experimental

2.1. Materials

^{147}Pm as promethium(III) chloride of specific activity ~18.5–25.9 GBq (500–700 Ci/g) was procured from M/s Tritec, Switzerland. Reagents such as boric acid, nickel sulfate, sulfuric acid, ammonium hydroxide as well as water, were of spectroscopic grade and were procured from BDH (India). Polystyrene granules used for coating were of analytical grade and procured from BDH (India). Metallic pure copper plate (99.99%) and platinum plate of high purity with material testing certificate, were procured from M/s Hindustan Platinum Ltd., India. The circular copper substrates used in this work were machined from a sheet of copper metal. The electrolytic solutions were prepared from ultrapure water (Millipore Milli Q system).

2.2. Instrumentation

Regulated power supply working in the range of 1–28 V, 0–2.5 A from Aplab Limited (Model no. L1282), India was used for electro-deposition of Ni on the copper substrate. Beta Radiation Survey Meter (PRM131A) of PLA Electro Appliance Pvt Ltd., India was used to measure the radiation dose on the surface of the source. Liquid scintillation measurements were performed using a low level liquid scintillation counter (Model: Tricarb 2100TR, Packard Instrument Co., USA) with Aquasafe 300 Plus scintillation cocktail (M/s Zinsser Analytic GmbH, Germany) and 22 ml polythene scintillation vials (Meridian, UK). AGFA film grade-G-7(AGFA India Pvt Ltd.) was used for autoradiography. Optical density measurements were carried out using OPTEL Transmission densitometer (Model No. 125. 3E NDT, LLC, USA). Cotton wool samples of Swipe test and water samples of Immersion test were counted in a G.M. counter (Model PNS-2, Electronic Enterprises (I) Pvt. Ltd., India).

2.3. Electrodeposition of Ni

The schematic diagram illustrating the electrochemical set-up used for the deposition nickel on a circular copper substrate is shown in Fig. 1. One side of the circular substrate and the peripheral area not required for deposition were blocked by coating with Araldite, an epoxy resin nonconductive adhesive paste. For electrical connection, rods of the same material were welded at the top edge of the circular sheet and held by metallic vice. A circular platinum foil of equal area was used as the anode. The electrodes were positioned face to face, separated 10 mm apart and immersed in the electrolyte. Electrodeposition of Ni on the one surface of the circular copper substrate was carried out galvanostatically using modified Watt type bath following the reported procedure (Dash et al., 2011; Kumar et al., 2009). After electrodeposition, the copper substrates were washed thoroughly with double distilled water and ethanol, and then dried in a current of dry air to a constant weight. These were stored in sealed containers until use.

2.4. Preparation of the source

Each Ni electrodeposited copper disc was kept in a beaker. The pH of the feed solution was maintained at 4–6 with the addition of 1 M NaOH. About 1 mL of the ^{147}Pm feed solution containing ~125 kBq of ^{147}Pm was pipetted out and added to a solution containing $SmCl_3$ at a concentration of 300 μg of Sm/mL

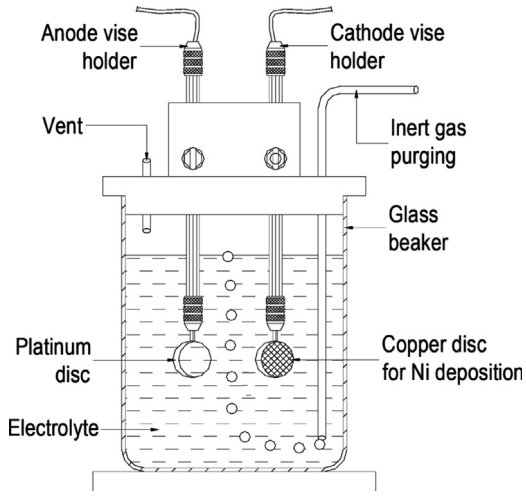

Fig. 1. Schematic of set-up for the electrodeposition of Ni on the circular copper substrate.

in a 25 mL capacity beaker. Since there is no stable isotope of ^{147}Pm in nature, Sm was used as the inactive carrier, owing to their very similar chemical properties (Kumar et al., 2012). The resulting solution was evaporated to dryness and reconstituted with 1 mL of HCl solution maintained at pH~4. The Ni electrodeposited circular copper was kept in contact with the ^{147}Pm/Sm solution for 5 min after which it was taken out with the help of a forceps, washed and dried under an infrared lamp. The radioactivity content of the ^{147}Pm solution was measured before and after deposition by liquid scintillation counting using suitable aliquot of the sample. Subsequently the active area of the sources was coated with polystyrene by the dip–pull method (Kumar et al., 2011).

2.5. Assay of deposited ^{147}Pm activity in the source

The radioactivity assay procedure adapted for each ^{147}Pm source consists of two stages for activity confirmation. In the first step, the total electrolyte activity strength was assayed by liquid scintillation counting by drawing suitable aliquots before and after the deposition. The amount of ^{147}Pm deposited on the matrix was calculated from the knowledge of these two. In the second step, dose rate of each source was individually measured and activity content was assessed from the relation between activity and dose rate.

2.6. Quality control

The ^{147}Pm source was tested for leachable activity as per reported procedures (Kumar et al., 2011; Udhayakumar et al., 2012). The distribution of ^{147}Pm activity on the source was examined by autoradiography (Dash et al., 2011; Saxena et al., 2012). Swipe test and leakage test of the prepared ^{147}Pm sources were performed as per the reported method (Kumar et al., 2011).

2.7. Source assembly in a circular holder

Each circular holder consists of an aluminum 'cylinder', with a flat bottom for nesting the circular source (Fig. 2). The flat bottom has a hole and a groove that will nest the source. There is a machined depression at the bottom of holder to mount the source in place. The holder is threaded on the inside edge to accommodate a matching cap. A circular cap threaded on the outside edge that matches the internal diameter of the holder was used to enclose the source. The cap can be used to turn in either direction. The cap can be rotated in a clockwise direction to screw into the holder. The active area of the source is