Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Development and Production of Industrial Radioactive Sealed Sources at KAERI

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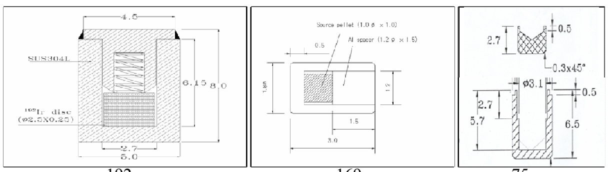
1. Introduction

Radioactive sealed sources in a variety of shapes, sizes and activity levels have been used for a wide range of applications in industry. Commercial applications are extended continuously with the development of the industries. ^{192}Ir is one of the most widely used for NDT application in Korea. The domestic market (including export) of ^{192}Ir for non-destructive testing was around 210 kCi in 2005 year[1]. Korea Atomic Energy Research Institute (KAERI) has developed different kind of sealed sources and commercially supplied by utilizing the HANARO and Radioisotope Production Facility (RIPF) since 2001. In order to improve the image quality in the lower range of steel thicknesses and to decrease radiation exposure of workers in the field of radiography, low energy gamma emitters such as ^{169}Yb and ^{75}Se are used. Recently, KAERI developed these radiation sources. For the quality and safety assurance of the sources, the ISO quality management system and the international safety standards were applied. In this paper, the design, fabrication, and characterization of the developed sources will be discussed.

2. Methods and Results

2.1. Design

Inner sources for ^{192}Ir, ^{169}Yb and ^{75}Se, are designed as shown in Fig. 1.



(a) ^{192}Ir (b) ^{169}Yb (c) ^{75}Se

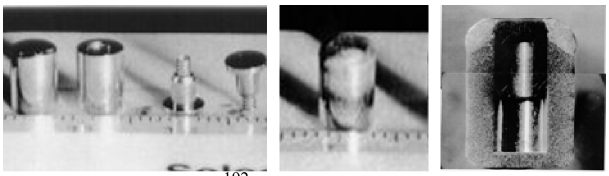
Fig. 1 Schematic drawings of inner source capsules

2.2. Fabrication of Inner Sources

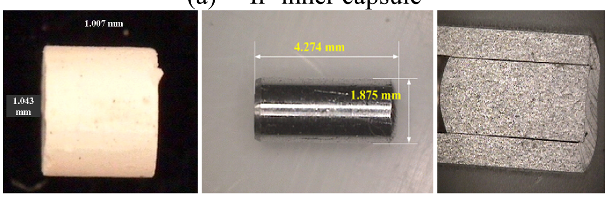
The inner source of ^{192}Ir consists of a plug, a capsule body, a spring, and irradiated discs. Fabrication process starts by picking up iridium discs, inserting it into the capsule body for piling up, fixing the inserted discs and welding of the capsule. Activity of the ^{192}Ir NDT sources can be easily adjusted in the range of 50 ~ 100 Ci by changing the number of discs [2].

^{169}Yb inner source developed at KAERI is a cylindrical pellet of Yb_2O_3 at the dimension of 1mm in diameter and 1mm in length. To fabricate this pellet, compacting equipment and a die have been developed. Various experiments were carried out to obtain the optimal compacting and sintering conditions. The best results could be achieved at the conditions of a 100 kg_f compaction and a 1150 ^oC sintering for three hours. The density of pellet is 6.0 mg/mm^3. The prepared pellet is put into aluminium capsule. For sealing, it is welded with a plug by using a laser welder.

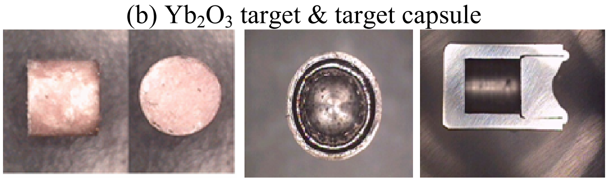
The target capsule of ^{75}Se source is consisted of a cylindrical SeO_2 pellet and a titanium capsule. The weight of SeO_2 pellet is 70 mg. Fabrication of SeO_2 pellet is similar to the process of making the Yb pellet. The optimal conditions are 100 kg_f of compacting and 120^{o}C of heating for 30 min. The prepared SeO_2 pellet is inserted in a titanium capsule, and this capsule is sealed by TIG welding. Photographs in Fig. 2 show the fabricated cores, the target shapes after welding, and the microscopic view of welding cross-section.



(a) ^{192}Ir inner capsule



(b) Yb_2O_3 target & target capsule



(c) SeO_2 target and target capsule

Fig.2 Photographs of inner capsule of sealed sources

2.3. Target preparation and Neutron Irradiation

^{192}Ir active cores for the source fabrication were prepared by the (n,γ) reaction in HANARO. In order to reduce the influence of neutron self-shielding[3, 4] during the irradiation, thin discs are arrayed in a suitable geometry by using a specially designed irradiation capsule. The maximum number of iridium discs loaded in one irradiation capsule is 440, and the fabricated capsules are irradiated for 1-2 operation cycles in CT, IR, or OR holes, in which the flux density are of $2 \sim 5 \times 10^{14}$ n/cm$^2 \cdot$ sec. The physical sizes of used iridium targets are 2.5 ~ 3.0 mm diameter and 0.25 mm thickness. After irradiation radioactivity of disc is about 9-19Ci/ea. Several pellets of enriched Yb_2O_3 are loaded in a irradiation capsule, and the fabricated capsule is irradiated for one operation cycles in CT, IR or OR holes. After the irradiation, it has approximately 7 Ci of activity. In case of ^{75}Se source, the irradiation yield was calculated for a target of ^{74}Se at 100% enrichment. It was evaluated that 80 Ci of ^{75}Se source could be produced in CT hole of HANARO reactor by 80 days irradiation.

2.4. Fabrication of Assembly

To make ^{192}Ir and ^{169}Yb source assemblies, a inner capsule is enclosed in a outer capsule made of SUS-304L stainless steel for double sealing. Equipment has been developed to handle the irradiated iridium discs and to weld the capsules. The double-sealed ^{192}Ir source capsule is connected to a flexible cable to make the final source assembly. Severe safety tests are applied to the ^{192}Ir, ^{169}Yb, and ^{75}Se source capsules according to the international safety standards. The titanium inner capsule containing inactive SeO_2 pellet is inserted to outer capsule made of stainless steel. This double-sealed capsule is connected to make the source assembly. Fig. 3 shows the assemblies fabricated with inner sources of ^{192}Ir, ^{169}Yb, and ^{75}Se.

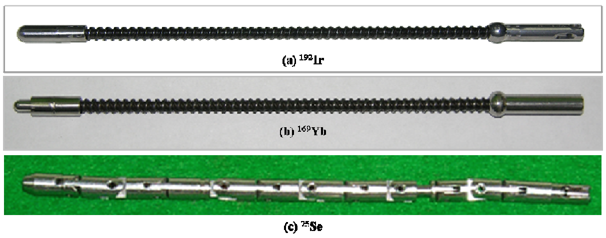


Fig. 3 Photography of source assembly

2.5. Quality Control

For the safety assurance of the developed sources, the welded joints and capsule of the sources are thoroughly tested and inspected in accordance with the international safety standards such as ANSI N542-1977, ANSI N43.9-1991 and ISO 2919-1999(E). Through these tests, the integrity and leak tightness of the sealed source capsules and assemblies developed at KAERI were verified. For commercial supply of the sealed radiation sources, KAERI obtained the ISO 9002 certification in 2000 and established the quality management system of the sealed source products as well as manufacturing process. ^{192}Ir radiographic sealed source capsules comprise the special form radioactive material according to the IAEA and domestic regulations.

4. Conclusion

As an ongoing effort to develop radiation sealed sources for industrial applications, KAERI has developed ^{192}Ir, ^{169}Yb, ^{75}Se sealed sources for NDT. To assure the safety, safe tests were carried out for the capsules by following the ISO2919 standard. These sources show satisfactory properties of safety and mechanical aspects. The ^{192}Ir sealed source capsules comprise special form radioactive material according to the IAEA and domestic regulations. For the quality assurance of these final products, ISO quality management system was introduced in 2000. ^{169}Yb sealed sources are developed by using Yb_2O_3 pellets. To produce the pellets, optimal compacting and sintering conditions are determined experimentally. Source holders for ^{169}Yb are designed and fabricated. An assembly with active source holder was prepared the quality test was performed. ^{75}Se sealed sources are developed by using natural SeO_2 pellets. For commercial production, enriched $^{74}SeO_2$ pellets and high flux reactor ($>10^{15}$ n/cm$^2\cdot$sec) could be needed.

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