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Study on the Production of Seed Core for Brachytherapy

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1. Introduction

Brachytherapy known as internal radiotherapy with sealed source core is growing attention as an effective treatment for prostate and eye cancers. It can minimize the radioactive damage for nearby healthy tissues and organs owing to concentrating radiation on the specific tumor with low dose. In addition, there is the added advantage of having a lower complication rate after treatment. Generally, ^{103}Pd, ^{131}Cs and ^{125}I has used as radionuclides for the brachytherapy source. Among them, ^{125}I is mainly used in terms of cost, half- life and energy. Radioactive ^{125}I can be produced by bombarding neutrons on ^{125}Xe and decays to ^{125}Te while emitting 27 and 31 keV X-rays and a 35 keV γ-ray with a half-life of 59.4 days.

An ^{125}I seed is composed of an inner source core adsorbing ^{125}I and an outer shell capsule made from the compatible titanium. The seed has a cylindrical shape of 4.5 mm (l) × 0.8 mm (∅) and is implanted permanently into body. The material and design of the active source core vary greatly by the manufacturer and the diverse approaches have been reported for many years. The Korea Atomic Energy Research Institute (KAERI) has been used the rod-shape as the design of core and previously reported a bare ceramic rod [1] and an Ag+Al_2O_3 rod [2]. Recently, the effect of the various intermediates (N_3^-, CO_3^{2-}, $C_2O_4^{2-}$, AsO_4^{3-}, Cl^- and PO_4^{3-}) using each set of 10 silver(Ag) rods were reported and the novel iodide adsorption technique using phosphate was developed [3].

In this research, the mass production of the source cores on the basis of this method using 100 Ag rods were performed and compared with previous results using 10 rods. Finally, leachability test of the finished source cores was performed.

2. Experiments

2.1 Materials

A silver rod (Ag, purity 99.9%) was obtained from Hee Sung Steel Co., Ltd., Korea. Sodium iodide (NaI) was obtained from Sigma Aldrich Co., LLC., USA as a cold iodide. ^{131}I with a half-life of 8.02 days is produced at HANARO and used as a tracer instead of ^{125}I. All other chemicals used in this work are at least ACS reagent grade.

2.2 Condition of experiments

The washing and surface etching conditions are like below. First, Ag rods in water were sonicated for 3 minutes, and then rinsing with ethanol. The surface etching was performed with 3 M HNO_3. Ag rods were placed in flask with 3 M HNO_3 and gently shaken at 70 ℃ until the color of the surface became a lusterless light-grey color.

To introduce the reaction-intermediate, phosphate, Ag rods and hydrogen peroxide (H_2O_2) as oxidant were reacted in PO_4^{3-} solution for 24hr. The washing and rinsing procedure were performed twice with H_2O and acetone, respectively [3]. Another set of rods was treated with chloride (Cl^-), as reported in the literature [4].

Each set of 10 and 100 rods was immersed in 0.5 and 5 ml of 0.01 M sodium hydroxide (NaOH) solution containing non-radioactive iodide (^{127}I) and ^{131}I (half-life 8.02 days) as the tracer instead of ^{125}I, respectively. The radioactivities of the non-radioactive iodide were equivalent to 1850 MBq (50 mCi) and 14800 MBq (400 mCi) in cases using 10 rods and 100 rods, respectively. The vials were rotated with a roll mixer at the speed of 200 rpm for 24 hours at room temperature. The solution was then removed, and the rods were washed with a saline solution and deionized water.

2.3 Measurement of the activity

For the analysis of the adsorbed quantity of iodide, the activities of the rods were measured individually by the HPGe detector (ORTEC Inc. GEM 20P4-70).

2.4 Leachability test

For the leachability test, 5 rods adsorbed with ^{131}I were selected randomly and placed individually in 1 ml of deionized water at room temperature. Then, the activities of the 0.5 ml of the solution were measured.

3. Results

3.1 Profiles of Surface-modified Ag rods

Figure 1 shows the profiles of the etched and surface-modified Ag rods. While the color of the Cl^--base rods had dark grey without luster, only the PO_4^{3-}-based rods retained glossy silver color.

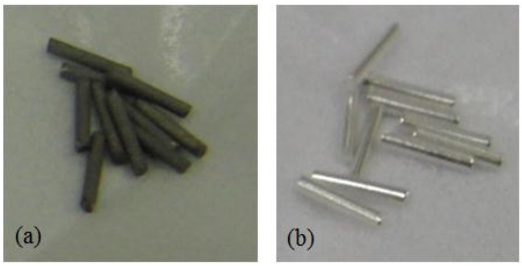

Figure 1. Profiles of Ag rod treated with Cl^-(a) and PO_4^{3-}(b).

3.2 Comparison of adsorbed iodide on Ag rods

The amounts of adsorbed iodide on 10 and 100 Ag rods are shown in Figure 2.

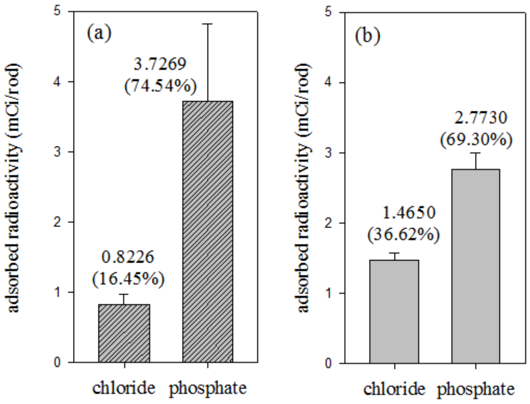

Figure 2. Measured radioactivity of equivalent ^{125}I on Ag rods.
(a) Iodine adsorption activities when 10 rods were used. Solution activity: 185 MBq/rod (5 mCi/rod)
(b) Iodine adsorption activities when 100 rods were used. Solution activity: 148 MBq/rod (4 mCi/rod)

In case of using 10 rods, PO_4^{3-}-based rods show the 4.5 times higher iodine exchange rate than Cl^--based rods. In case of Cl^-, the exchange reactions can be explained in terms of K_{sp} value. But the exchange reaction with iodine and PO_4^{3-} cannot be explained by this theory. The mechanism of this reaction can be explained by a distortion effect [3].

To prepare the mass production, 100 rods were used. The 100 PO_4^{3-}-based rods adsorbed (102.60 MBq (2.7730 mCi)), ~70% from the contact solution with equivalent of 148 MBq/rod (4 mCi/rod).

Figure 3 shows the adsorption activity distribution charts of the 100 Ag rods. The number of rods having an average of ± 5% activities was 55, which is over half. To obtain a dense distribution of the rod activity and the higher obtainment, it is very important to uniformly produce the rods having a fixed length of 3 mm (l). For the mass production, various cutting tools have been being studied.

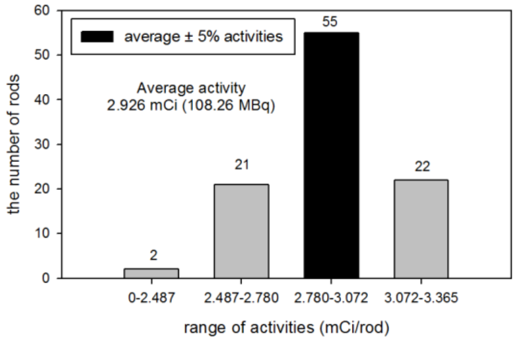

Figure 3. Distribution charts for the adsorbed activities of 100 Ag rods.

3.4 Leachability test

As a quality assurance of the sources, a leachability test before encapsulation for checking leached iodine from rods should be carried out. In this report, a leachability test was performed by randomly choosing 5 Cl^--based and PO_4^{3-}-based rods, respectively [5]. When H_2O was used, the obtained results show that the iodine from the surface of the rods leached 0.06% and 0.23%, respectively. From these results, it could be found that PO_4^{3-}-based Ag rods firmly adsorb iodide and show a safer and more stable state in the aqueous solution. In the case of leached iodide from rods, a leak test after encapsulation is a very essential part and is in progress now.

4. Conclusions

^{125}I source core made from phosphate-based Ag rod is more advantageous than other methods in terms of iodine adsorption yield, stability and the rate of generating radio-waste. From the leachability test, seed core by this method shows robust adsorption between Ag rods and iodide. In conclusion, we suggest that this method is a good direction for the preparation of ^{125}I seeds using for prostate and eye cancer treatment.

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