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Adsorption of iodide on silver rods for ^{125}I seed preparation

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1. Introduction

Recently, the rate of prostate cancer is increasing rapidly in Korea. Brachytherapy using ^{125}I seeds has drawn attention as one of the treatment options for this type of cancer. ^{125}I is a radionuclide, which emits 27 keV and 31 keV X-rays as well as 35 keV γ-ray with a half-life of 59.4 days. This radioisotope is produced by the bombardment of neutrons on the ^{124}Xe target, and it decays via electron capture to ^{125}Te. The brachytherapy sources are fabricated as seeds and implanted permanently to the prostate. The seed consists of a titanium capsule as a shell with the dimension of 0.8 mm in external diameter, 0.05 mm in wall thickness and 4.5 mm in length. A silver (Ag) rod with a dimension of 3 mm in length and 0.5 mm in diameter is used as the radioactive core after adsorption of ^{125}I. The loaded rod is inserted to the titanium tube which of ends are welded for complete isolation. The silver rod also acts as an X-ray marker to visualize by X-ray imaging [1] and determine the location of seeds in the prostate. Currently, the supply of ^{125}I seeds depends only on imports. Hence, national research and development are needed for local production. This research work is carried out to find the optimum conditions in the preparation of the radioactive core, more specifically in the adsorption of iodide on the silver rods.

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 characteristics of iodide adsorption are studied for cases of the method of surface treatment for a silver rod and the contact concentration of iodide.

To investigate the effect of the surface treatment on the adsorption, we performed experiments with three variables : surface etching, use of oxidant, and use of various substituents.

Ag rods were placed in the water and sonicated for 3 minutes, and then washed with ethanol. The surface etching was performed with 5 ml of 3 M HNO_3. Ag rods were placed in erlenmeyer flask with 3 M HNO_3 and shaked at 70℃ until the color of surface became lusterless light-grey color.

Several substituents which were used in this work are chloride (Cl^-) [2], azide (N_3^-), carbonate (CO_3^{2-}), oxalate ($C_2O_4^{2-}$) and arsenate (AsO_4^{3-}). Sodium chlorate ($NaClO_3$) and hydrogen peroxide (H_2O_2) were used as oxidants, which were added during substitution process. The washed or etched Ag rods were reacted in substituent solution for 62hr and washed twice with H_2O and acetone.

Such rods, either pretreated or not, were soaked in an iodide solution traced with ^{131}I and stirred by using a roll mixer for 24 hours. Ten Ag rods were used for each 0.5 ml of the contact solution. The equivalent concentration of the iodide solution is 100 mCi/ml as ^{125}I for each contact sample.

2.3 Measurement of the activity

For the analysis of adsorbed quantity of iodide, the radioactivities of ^{131}I on three randomly selected rods were measured after the reaction by using the gamma spectroscopy.

3. Results

3.1 Color of pretreated Ag rods

The untreated Ag rods were lustrous, while the etched ones were lusterless light-grey. The colors of rods treated with Cl^-, N_3^- and AsO_4^{3-} were lusterless dark-grey, dark-grey and reddish brown, respectively.

3.2 The effect of various substituents

The results using various substituents are shown in Table 1. When the substituents are used, the adsorbed radioactivities are 0.3466 mCi/rod at minimum, and 1.6922 mCi/ml at maximum, while that of the etched (no substitution) rods is 0.3006 mCi/rod. The best case is by the treatment of $C_2O_4^{2-}$, and the loading quantity is

1.6922 mCi/rod. This case is five times higher than the etched rods and two times higher than Cl^-.

Table 1. Measured radioactivity of equivalent ^{125}I on Ag rods affected by different substituents

Surface treatment	adsorbed radioactivity (mCi/rod)
etched	0.3006
Cl^-	0.8226
N_3^-	0.3466
CO_3^{2-}	0.8150
$C_2O_4^{2-}$	1.6922
AsO_4^{3-}	0.4408

3.3 The effect of etching process and oxidant addition

Table 2 shows the relationship between the etching process and the adsorbed amount of ^{125}I (equivalent quantity) on a rod. It is noticed that the etching process can make the absorption of iodide more effective as the surface area is increasing. Also, the effect of the oxidant addition during the substitution on the loaded quantity is shown. If the oxidant is added, the adsorbed radioactivities are higher in most of the cases. That is because the surface of Ag rods is more effectively substituted.

Table 2. Measured radioactivity of equivalent ^{125}I on Ag rods by different treatment

substituent	adsorbed radioactivity (mCi/rod)			
	washing	washing	etching	etching
	no oxidant	oxidant	no oxidant	oxidant
Cl^-	-	1.17	-	0.79
N_3^-	0.18	1.16	0.34	0.94
CO_3^{2-}	0.20	0.63	0.66	0.55
$C_2O_4^{2-}$	0.37	2.13	1.27	2.44
AsO_4^{3-}	0.14	2.71	0.50	2.43

3.4 The effect of concentration of iodide

Table 3 shows the effect of iodide concentration on the contact solution on the loaded amounts. The higher concentration of iodide is used, the adsorbed activity is higher.

Table 3. Measured radioactivity of equivalent ^{125}I on Ag rods at different iodide concentrations (10 rods/0.5 ml)

Surface treatment	concentration (mCi/ml)	adsorbed radioactivity (mCi/rod)			
		1st	2nd	3rd	average
etched	40	0.25	0.25	0.25	0.25
	100	0.29	0.29	0.32	0.30
	200	0.32	0.33	0.31	0.32

4. Conclusions

Silver is a good source core for the ^{125}I seed because it strongly adsorbs iodide and acts as an X-ray marker. By this study of the surface pretreatment, it is noticed that the treatment of oxalate ($C_2O_4^{2-}$) on the rod surface can provide the best adsorption condition for the iodide. Also, the etching process and the use of oxidant during the substitution can make higher loading of iodide because it increases the surface area.

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