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Short Research Article

Development of production technology of ^{125}I seed for brachytherapy†

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Introduction

Radioisotopes have been employed in various industrial, medical, environmental, and advanced scientific fields. Commercial applications are extended continuously with the development of the industries. The Korea Atomic Energy Research Institute (KAERI), which operates a research reactor (HANARO) is the sole production organization of radioisotopes (RI) in Korea. Currently, KAERI has interest in the development of radioisotopes for medical applications[1] because the medical demand is growing fast, and the supplies heavily rely on imports. During the last decade, brachytherapy has emerged as a novel treatment method for localized eye and prostate cancer. Brachytherapy employs radionuclides that emit principally low-energy gamma rays. It occupies a recognized place in the radiation therapy modality. The radionuclide ^{125}I is primarily chosen for this purpose. Radioactive ^{125}I can be produced by bombarding neutrons on ^{125}Xe. ^{125}I decays via an electron capture to the first excited state of ^{125}Te with a half-life of 59.4 days. Subsequently, the decay proceeds principally by an internal conversion resulting in the emission of 27 and 31 keV X-rays and 35 keV γ-ray emissions. ^{125}I sources for the purpose of brachytherapy are fabricated in the form of seeds, 4.5 mm long and 0.8 mm in diameter. In this study, an ^{125}I brachytherapy source in a seed form was developed for the treatment of the prostate cancer. The source has its dimension in 4.5 mm length and 0.8 mm diameter. ^{125}I solution was produced by the bombardment of neutrons on ^{124}Xe in the HANARO.[2,3] The matrixes were examined as confinement media of ^{125}I in the seeds. Such materials are silver rods, ceramic rods containing silver powder, and $AgNO_3$-treated ceramic rods. Adsorption/absorption of ^{125}I was carried out in ^{125}I solution at various conditions. To encapsulate the rods in titanium tubes, a laser welding technique and a micro-positioning system were developed. An optimal welding condition was determined for the sealing of titanium tube without a plug. Seven welding parameters were determined through the Taguchi experiments and the analysis of welding characteristics. An average melted length of the tubes could be predicted from results of this analysis. For the quality assurance of the welded parts, the titanium tubes were thoroughly tested and inspected. The welded ends showed good appearance and cross-section without any defects. This technology will be further developed to set up an automated commercial production system.

Results and discussion

For the ^{125}I brachytherapy seed, a carrying media consisting of Al_2O_3 and silver nano powder is developed. In this material, approximately 15 wt% of Ag is contained. The porosity of the material is approximately 10%. To test the adsorption performance of the ^{125}I carrying media, each rod is contacted with a solution of 50 µl containing 5 mCi of ^{125}I. The adsorption capacity is more than 95% after 4 h. At the same condition, the adsorption capacity of the bare silver rod is below 20%.

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In order to develop the welding technique for the fabrication of the ^{125}I seeds, a precise welding assembly system that adopts a rotating welder was built. Two welding methods for sealing the iodine-absorbed media were tested. For the first technique, titanium capsules are designed and manufactured by using a precision abrasive machining. Dummy capsules are fabricated manually to demonstrate the feasibility of the proposed design. Since the cap is too small to fabricate precisely, it requires a relatively high cost to produce the capsule elements. Hence, a direct welding method, which irradiates the laser beam directly to the edge of a titanium tube, is developed.[4] When the edge of a small titanium tube is irradiated by an Nd:YAG laser beam, it is melted down to the proper length, coalesced, and sealed. Accurate control of the melting length of the tube edge is the most important parameter when producing sound sealings. The effects of the laser welding parameters on the melting length are analyzed and optimized by the Taguchi and regression analysis methods. The pulse width and focal position among the welding parameters have the greatest effect on the S/N ratio of the melting length. Optimum welding conditions are obtained at 0.86 ms of the pulse width and 3.19–3.35 mm of the focal position in the scope of the experiments. The optimum welding conditions are finally derived by using Taguchi method. To confirm the estimated results, repeated experiments are performed with 3.3 mm of the focal position, and the average melting length is measured as 1.33 mm which agrees well with the estimated value.

Several seeds of ^{125}I were prepared to have activities of approximately 5 mCi. To test the uniformity of these ^{125}I seeds, dosimetric properties were measured for the radial and longitudinal directions. It shows below 10% in longitudinal distribution and 4.5% in radial distribution. Self-shielding effect of the rods and the titanium tube were measured. The rate is 22% by the rod and 21% by the titanium tube.

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