A Low-Background Room-Temperature Semiconductor Detection System for the Analysis of Strontium-90 in Seawater

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Strontium-90 (Sr-90) is a fission product primarily released through anthropogenic nuclear activities. It has a relatively long half-life of approximately 28.8 years and is characterized by the emission of high-energy beta particles without accompanying gamma rays. Due to its chemical similarity to calcium, Sr-90 is readily accumulates in bones, where it causes prolonged internal exposure. This physicochemical characteristic makes Sr-90 a significant radiological hazard, as it can lead to serious health effects such as bone cancer and leukemia. Moreover, given its anthropogenic origin, Sr-90 serves as a key indicator for monitoring nuclear activities and assessing radiological contamination.

Due to its high solubility, Sr-90 remains dissolved in seawater and moves with ocean currents. Its concentration in seawater is typically very low, averaging around 1 mBq/L, making its detection particularly challenging. To measure such low levels, both chemical separation techniques and high-sensitive detectors are required. The sensitivity of a detection system is generally evaluated in terms of the minimum detectable activity (MDA), and achieving a lower MDA requires both a low background count rate and high geometric efficiency.

In this study, we developed a detection system based on a PIPS (Passivated Implanted Planar Silicon) detector (Cf. Figure 1). The PIPS is a room-temperature semiconductor detector that operates without any cooling devices. It offers several advantages, including low leakage current, a stable entrance window, and a thin dead layer of approximately 50 nm. The detection system consists of the PIPS detector, signal processing and acquisition electronics, a 10-cm lead and 2-cm copper shield to block ambient radiation, and a veto detector that rejects cosmic-ray-induced background via anti-coincidence counting. The target nuclide is Yttrium-90 (Y-90), chemically separated from a Sr-90/Y-90 equilibrium sample. The Y-90 is precipitated as $Y(OH)_3$ by pH adjustment and subsequently deposited onto a GF/F filter. The filter sample is attached directly to the detector surface to maximize detection efficiency.

The performance of the detection system was quantitatively evaluated through background and spiked sample experiments. Without any shielding, the background count rate was relatively high at approximately 39.38 counts per minute (cpm), but it was significantly reduced to less than one-tenth of the initial value, reaching 3.61 cpm by applying the lead shield and anti-coincidence counting. The detection efficiency, evaluated using a 5-Bq spiked sample, was approximately 43.4%. Assuming a sample mass of 50 kg, a chemical recovery rate of 90%, and a measurement time of 1 hour, the MDA was estimated to be approximately 0.99 mBq/L. This result demonstrates the feasibility of applying this system to practical seawater analysis.

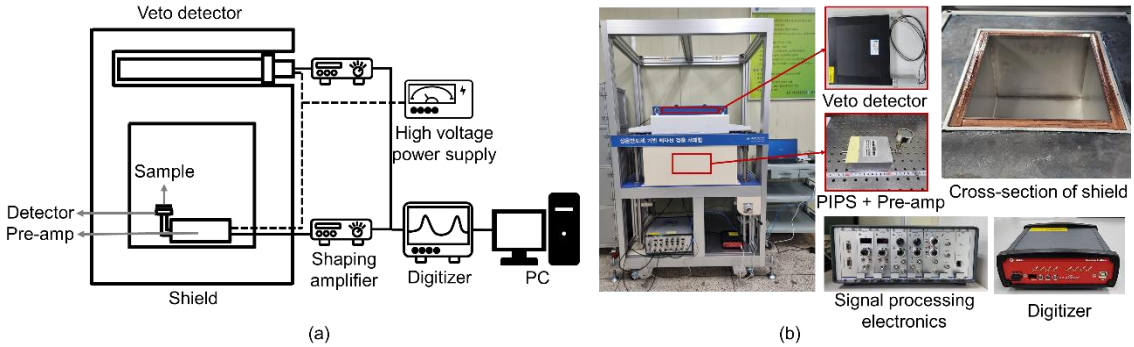

Figure 1. (a) Schematic and (b) photograph of detection system.