Ni-63 electroplating for random number generators

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1. Introduction

A true random number generator (TRNG) based on radioactive isotopes generates random numbers by directly utilizing the probabilistic characteristics of radioactive decay, unlike commercial random number generators that rely on algorithms. Specifically, by detecting particles emitted during radioactive isotope decay, it can obtain physically unpredictable signals[1,2]. Using alpha or gamma rays carries the risk of detector damage due to their high energy. Therefore, employing low-energy beta rays enables the creation of highly reliable and long-lived TRNGs.

When constructing a TRNG using beta nuclides, large quantities of radioactive isotopes are not required; instead, a source measuring only a few millimeters is sufficient. Electroplating is the most effective method for this purpose, but several precautions must be considered when electroplating RI. First, an insoluble anode must be used to exclude the possibility of natural nickel plating and ensure primarily Ni-63 is deposited. Second, since radioactive isotopes are expensive, a small plating bath must be used to achieve a relatively high radioactive isotope concentration [3]. Third, the amount of radioactive waste generated after plating must be minimized to ensure manageability.

Small plating tanks experience a rapid decrease in nickel concentration during plating, preventing multiple production runs. Agitation is difficult, making it easy for bubbles to remain trapped within the tank. These residual bubbles can cause pinholes, leading to quality degradation issues. Therefore, an optimization process is necessary to manage Ni ions in the plating solution and adjust temperature and current density to maximize utilization of the limited Ni-63.

This study applied the conditions established for cold forming to Nickel-63 in the fabrication of a small plating tank for radioactive isotopes, enabling consistent quality in the electroplating process.

2. Methods and Results

The electroplating system was built around a small plating tank we fabricated ourselves, and we evaluated the plating results by varying several parameters. We assessed whether the plating was uniform through visual inspection and evaluated the plating thickness using changes in deposition weight.

2.1 Electroplating system

The electroplating system is shown in Figure 1. An air filter was installed around the small plating tank to remove hydrogen and chlorine generated during plating. Containers were provided for the plating solution, cleaning solution, and waste liquid. A filter was installed to remove insoluble impurities generated during plating. A heater was placed on the floor to regulate the temperature of the plating solution, and a thermometer was installed on the wall. During plating, pumps 1 and 2 circulate the plating solution to remove impurities and achieve ion concentration equilibrium.

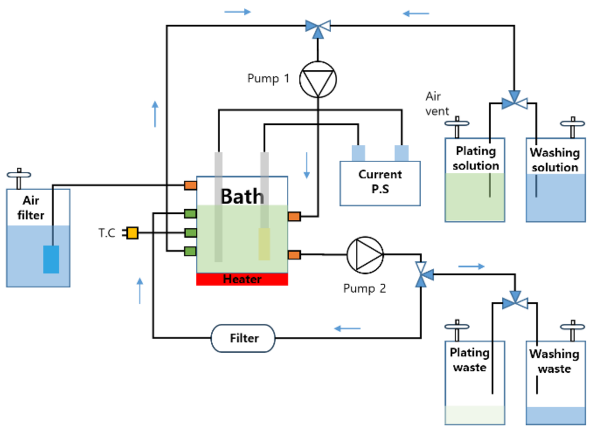

Fig. 1. Small plating system for radioactive isotope electroplating.

2.2 Materials

The reagents purchased for the plating solution included Nickel-63 (ORNL), nickel chloride hexahydrate (97%, SAMCHUN), boric acid (99.5%, SAMCHUN), HCl (37%, MERK), and ammonia solution (28%, JUNSEI). The equipment used for plating included a power source (KEYSIGHT, E36223A) and a peristaltic pump (Masterflex, Reglo ICC Pump).

2.3 Ni-63 electroplating

The results of electroplating using Ni-63 are presented in Figure 2. The plating solution concentration was 0.1 M, and the pH was adjusted to 4 using HCl and NH_4OH. The current was 48 mA, the plating time was 20 minutes, and the plating solution temperature was maintained at 45℃. For samples 1 and

4, pH control issues prevented obtaining clean plating results. However, samples 2 and 3 yielded uniform plating results, except for some pitting. The deposition amounts were 7.2 mg on average for samples 1 and 4, and 4.3 mg for samples 2 and 3. Samples 1 and 4 were plated with impurities due to abnormal pH during plating, resulting in a plating yield of 7.2 mg. Samples 2 and 3 were plated with the pH accurately adjusted, yielding an average plating result of 4.3 mg.

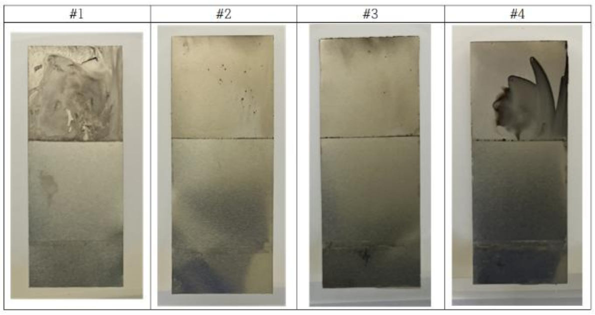

Fig. 2. Ni-63 electroplating results at 40°C and 40 mA.

3. Conclusions

Due to the characteristics of the small plating tank and Ni-63, the plating conditions differ from conventional methods, so a new type of small plating tank was proposed. The plating conditions were set to 40°C and 40 mA by adjusting factors such as temperature and current. The result of plating Ni-63 showed that 4.3 m was plated when the plating was free of impurities.

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