Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Development of small-scale electroplating system for Ni-63 electroplating onto Ni foil

Jin Joo Kim [a*], Sang Mu Choi [a], Kwang Jae Son [a], Jintae Hong [a]
[a]*Department of HANARO Utilization and Research, Korea Atomic Energy Research Institute,*
989-111 Daedeok-daero, Yuseong-gu, Daejeon, Korea
[*]*Corresponding author: jinjookim@kaeri.re.kr*

1. Introduction

Betavoltaic battery is a device that converts the decay energy of beta-emitting radioisotopes into electric energy. Ni-63 is pure betaemitter with a low energy spectrum and significantly long half-life of 100.1 years and thus is widely used as the power source of betavoltaic battery [1,2]. There are several methods for the formation of a Ni deposit onto a semiconductor such as electroplating, electroless plating, and chemical vapor deposition. Among them, the electroplating process is most commonly used for Ni deposition [3].

In this study, small-scale radioisotope electroplating system was designed and fabricated to perform electroplating with a small amount of plating buffer and minimum exposure of radioactive materials. These procedures and the manufactured electroplating device can be applied to radioactive Ni-63 electroplating for the fabrication of a betavoltaic battery.

2. Methods and Results

2.1 Design and fabrication of electroplating device

When using a conventional electroplating bath it must be used the plating buffer of about 200 milliliter to make a single sheet of Ni-63 foil. In this case, the radioactive waste discarded after electroplating is increasing, and specific activity of Ni-63 deposit is decreasing. To solve these problems, small-scale radioisotope electroplating system was designed and fabricated to perform electroplating with a small amount of plating buffer and minimum exposure of radioactive materials. A rendering image and drawing image of electroplating device are shown in Fig. 1.

2.2 Ni electroplating

The Ni coatings were deposited by DC electroplating at current densities of 5, 10, 15, 20, and 25 mA/cm^2. The basic composition of the bath was 0.2 M Ni and 25 g/l of boric acid (H_3BO_3). The composition and condition of Ni electroplating are shown in Table 1. The pH of the bath was adjusted to 4.0. A nickel foil with dimensions of 17 × 17 × 0.125 mm^3 was used as a cathode and a Pt-coated Ti mesh with dimensions of 10 × 10 × 1 mm^3 was used as an anode. A Ni foil with a high purity of 99.99 % was used as the substrate. The deposition time was adjusted to achieve an average thickness of 6 μm based on Faraday's law [4]. The microstructure of the coatings was studied through scanning electron microscopy (SEM).

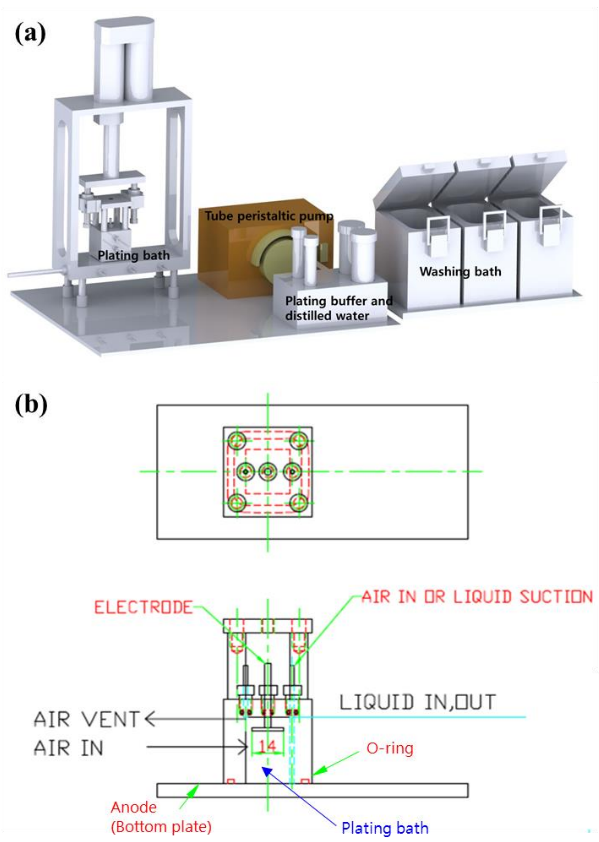

Fig. 1. A rendering image (a) and drawing image (b) of small-scale electroplating device.

Table I: Composition and condition of Ni electroplating

Bath composition	
$NiCl_2$	0.2 M
H_3BO_3	0.4 M
NaCl	0.7 M
Saccharin	0.00829 M
Tween 20	0.5 %
Bath condition	
Temperature	40 °C
Substrate dimension	1 × 1 cm^2
Current density	5 ~ 25 mA/cm^2
Cathode	Ni foil
Anode	Pt-coated Ti mesh
pH	4

Ni deposits were produced with pH 4 at room temperature. Figure 2(a-e) presents SEM images for electrodeposited Ni on the Ni foil at current densities of 5, 10, 15, 20, and 25 mA/cm^2, respectively. There were no flaws on the deposit surface except at 5 and 25 mA/cm^2. The Ni coating layer had a crack at a current density of 5 and 25 mA/cm^2 because the current density is too high or too low. This means that the electroplating using of Ni onto the Ni foil was possible at a current density from 10 to 20 mA/cm^2. Figure 3 shows that the SEM images for thickness of the Ni-coated Ni foil at current density of 10 and 20 mA/cm^2.

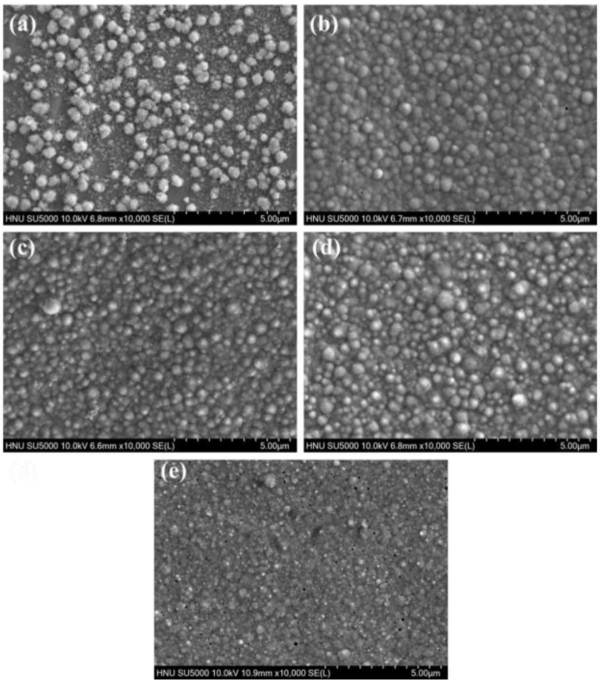

Fig. 2. Surface morphology of the Ni deposits onto Ni foil at the current density of (a) 5, (b) 10, (c) 15, (d) 20, and (e) 25 mA/cm^2.

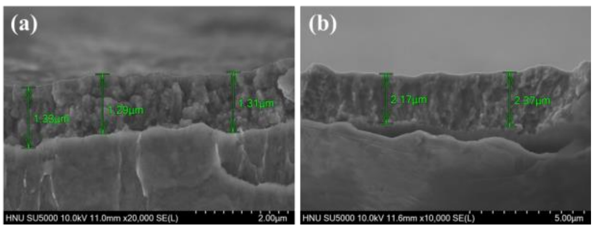

Fig. 3. SEM images for thickness of the Ni-coated Ni foil at current density of (a) 10 and (b) 20 mA/cm^2.

3. Conclusions

In this study, an electroplating system for small-scale Ni electroplating was designed and manufactured. The process for the fabrication of a Ni-63 foil as the energy source of a betavoltaic battery was developed using the minimum concentration of Ni. These procedures and the manufactured electroplating device can be applied to radioactive Ni-63 electroplating for the fabrication of a betavoltaic battery.

Acknowledgement

This work is supported by the National Strategic R&D Program for Industrial Technology (10043868), funded by the Ministry of Trade, Industry and Energy (MOTIE).

REFERENCES

[1] George Di Bari, Nickel Plating, ASM Handbook, Volume 5, Surface Engineering, published by ASM International, Materials Park, OH 44073, p 201, 1994.

[2] A. Thomas., Nuclear Batteries: Types and Possible Uses, Nucleonics, Vol. 13, No. 11, p. 129-133,1955.

[3] F. H. Ruddy, A. R. Dulloo, J. G. Seidel, F. W, Hantz, and L. R. Grobmyer, Nuclear Reactor Power Monitoring Using Silicon Carbide Semiconductor Radiation Detectors, Nuclear Technology, Vol.140, p. 198, 2002.

[4] R. Orinakova, A. Turonova, M.G. Kladekova, R.M. Smith, Recent developments in the electrodeposition of nickel and some nickel-based alloys. J. Appl. Electrochem. Vol. 36, p. 957–972, 2006.