Electroplating Ni-63 metal ions in chloride bath on the Cu-plate

Kwon Mo Yoo, Young Rang Uhm*, Kwang Jae Son, Keun Yung Park
Radioisotope Research Division, Korea Atomic Energy Research Institute (KAERI), Daejeon 305-353, Korea
*Corresponding author: uyrang@kaeri.re.kr

1. Introduction

Recently, a radioisotope as a 'fuel' has been concentrated, because it is 'burned' at the rate of the isotope's half-life [1]. In other words, given a half-life of 100 years, a nuclear battery would still produce half of its initial starting power after 100 years. A speck of a radioisotope such as nickel-63, for example, contains enough energy to power a nano-nuclear battery for decades, and to do so safely [2].
Ni-63, a beta radiation source, is prepared by electrical deposition of radioactive Ni-63 ions on a thin non-radioactive nickel foil. Ni-63 plating is similar to other electroplating processes that employ soluble metal anodes. The nickel plating solution described by Watts in 1916 eventually replaced all other strategies in use up to that time [3]. Charged Ni ions are formed by sulfate, sulfamate, chloride, and a Watts bath [4]. However, charged Ni-63 ions are formed by dissolving metal Ni-63. Specifically, it requires the passage of direct current (DC) between two electrodes that are immersed in a conductive, aqueous solution of nickel salts. The flow of a DC causes one of the electrodes (the anode) to dissolve and the other electrode (the cathode) to become covered with nickel. The nickel in the solution is present in the form of divalent positively charged ions (Ni^{2+}). When the current flows, the positive ions react with two electrons ($2e^-$) and are converted into metallic nickel (Ni^0) at the cathode surface. In the present study, we optimize and established process for the electroplating Ni-63 on Cu-plate.

2. Experimental Technique

2.1 Preparation of ionic solution including Ni-63
Ni metal powders of 4 g with Ni-63 were dissolved in a mixture of 45 ml HCl and 5 ml distilled water for 2 hours at 80℃ until Ni powders were dissolved. H_3BO_3 of 8 g and saccharin of 0.67 g were added in 100 ml DI water, and mixed with Ni-dissolved solution. Finally, 135 ml DI water and 18 g KOH were added. The pH level was optimized as to be pH 4.0 at previous study.[5] The microstructure of the coatings was studied by scanning electron microscope (SEM).

2.2 Electroplating of Ni-63
The proposed prototype for the synthesis can be applied to the electroplating radioactive Ni-63. Fig. 1 shows the photographs of the glove box and plating bath in hot cell. The 2D dimension of the substrate and thickness of the coating layer were 4 × 10 cm^2 and 3 ㎛. The specific radioactivity for the starting material of Ni natural powder(purity 99.9 %, High purity chem. Co.), which was irradiated by neutron (flux: 4.2×10^{13} $n/cm^2/s$) at HANARO, was about 4 mCi.

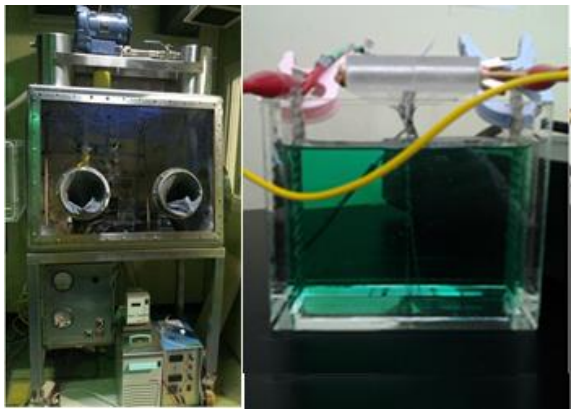

Fig.1 The photographs of the glove box and plating bath in hot cell (Bank-2, HANARO Reactor in KAERI).

3. Results and discussion

To established coating condition of Ni-63, non-radioactive metal Ni particles was dissolved in acid solution and electroplated on the Ni sheet. The nickel plating process is used extensively for decorative, engineering and electroforming purposes because the appearance and other properties of electrodeposited nickel can be varied over wide ranges by controlling the composition and the operating parameters of the plating solution. The deposition time was adjusted to achieve an average thickness of 6 μm based on the Faraday's law [6] as below;

$$\mathbf{T\ (cm)} = \frac{\mathbf{t \times I \times MW}}{\mathbf{\rho \times valance \times faraday\ constant \times A}} \qquad (1)$$

where: T is thickness to be deposited, t is the time of deposition, I is current, MW and ρ are molecular weight and density of Ni, and A is area of film. Estimated time to be 5 μm of thickness was determined as 977 s at current density 15 mA/cm^2. The thickness of Ni layer on Cu substrate is well matched as theoretical thickness. The thickness of Ni layer was 4.76 μm for deposited on Ni and Cu plate, respectively. Fig. 2 represents the results of scanning electron microscopy (SEM) for the Ni coated Cu plate, t at the current density of 15 mA/cm^2. The results showed that the average grain sizes were 30 nm, and 40 nm for Ni coating on Cu plates. Figs. 2(a), and 2(b) depicted SEM images for electrodeposited Ni on Cu sheet at current density at 15, and 20 mA/cm^2, respectively. The particles on the Ni sheet were formed as spherical shape. The non-

radioactive Ni ions dissolved bath was coated on the electroplated Ni layer for sealing radio-active Ni-63. Fig. 3 represents the results of a SEM image for the electrodeposited Ni with double layers. The coated upper layer was carried out by using commercial chloride bath. The prototype for electroplating radioactive Ni-63 has been established.

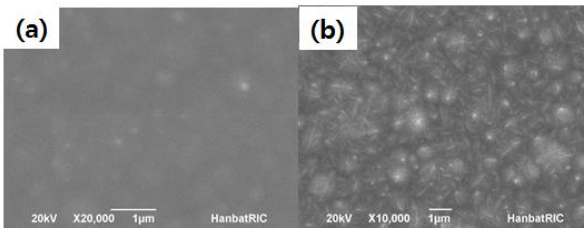

Fig. 2. SEM images for electrodeposited Ni on Cu sheet at current density of (a) 15 mA/cm^2, and (b) 20 mA/cm^2.

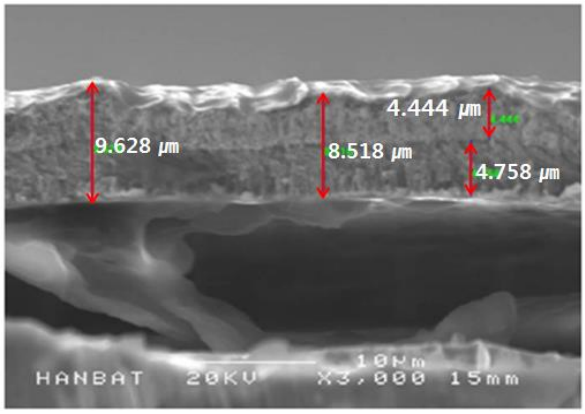

Fig. 3. SEM image for electrodeposited Ni on Ni coated Cu plate at current density of 15 mA/cm^2.

The prototype of electroplating Ni-63 in the glove box in a hot cell (Bank-2, HANARO Reactor in KAERI) was summarized as follows:

1. The first step for preparing ionic solution including Ni-63
   - 1.1 Preparation of the mixed solution: HCl (45 ml) and DI water (5 ml)
   - 1.2 Input Ni powders (4 g) with Ni-63 to (1.1)
   - 1.3 Refluxing for 2 h at 80 ℃ until Ni powders were dissolved
   - 1.4 Preparing H_3BO_3 (8 g), and saccharin (0.67 g) dissolved DI water (100 ml)
   - 1.5 Input Ni dissolved solution (1.3) to buffer solution (1.4)
   - 1.6 Input DI water (135 ml), and KOH (18 g) to (1.5)

2. The 2nd step for electroplating Ni-63
   - 2.1 Preparation of substrate, hot cell (or beaker), and electrodes
   - 2.2 Input prepared ionic solution (1.6) to plating cell
   - 2.3 Electroplating Ni-63 at currnt density of 15 mA/cm^2.

The specific radioactivity of the electroplated Ni including Ni-63 was estimated to be about 0.01 mCi. The accurate measurement for the specific radioactivity electroplated Ni-63 will be carried out in a future study. Fig. 4 displays the photograph of the electroplated Ni-63 with dimension and thickness of 4 × 10 cm^2, and 3 μm, respectively.

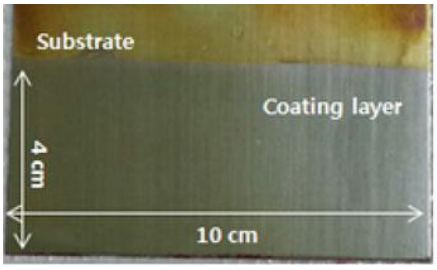

Fig. 4. The photograph of the electroplated Ni-63 on the Cu plate. The thickness of coated layer is to be 3 μm.

4. Conclusions

Nanocrystalline nickel (Ni) coatings were synthesized by DC electro deposition at a current density of 15 mA/cm^2. The bath was primarily composed of 0.2 M Ni ions, prepared by dissolving Ni-63 metal particles in HCl. The prototype for electroplating radioactive Ni-63 has been established. The electroplating was carried out by two-step processes such as preparation of ionic solution including Ni-63, and coating processes on the substrate.

Acknowledgement

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References

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