Double side electroplating for applying beta voltaic with sandwich structure

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1. Introduction

Radioisotope batteries derive their energy from the spontaneous decay of radionuclides, as distinguished from nuclear fission energy created in reactor power systems. To apply power source, devices with small volume convert radioactive decay into electricity to provide high energy densities for several decades, where harvestable energy is unavailable [1]. As a result, a variety of nuclear-based small-scale power sources have been developed with varying degrees of success and maturity. A nuclear battery with diode junction is a device that converts nuclear radiation directly to electric power [2]. The mechanism of a nuclear battery is same as the P–N junction diode for solar cell application. The photovoltaic is operated by converted photons to electrical energy in the junction. In betavoltaic battery, beta particles are collected and converted to electrical energy as similar principle as photovoltaic. A very low current, order of nano or micro amperes, is generated in devices [2-3]. The difference of the short circuit current between the pre-deposition and post deposition of Ni-63 was found to be 5 nA. This value is very low to apply device junction. So, we suggest betavoltaic with sandwich structure, as shown in Fig. 1. To fabricate betavoltaic, Ni-63 should be coated on the double side of substrate. In the present study, we optimize and established process for the electroplating Ni-63 on double side on the Cu-plate.

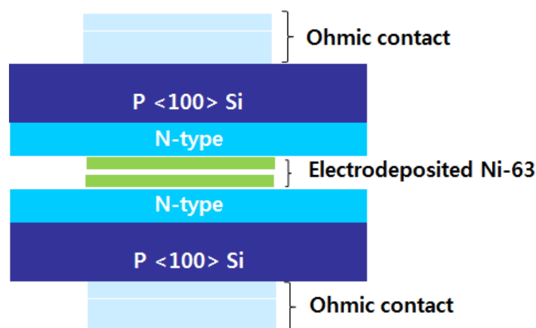

Fig.1 Betavoltic battery with sandwich structure

2. Experimental Technique

2.1 Preparation of ionic solution of en-riched Ni

Ni metal powders of 4 g with Ni 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.[4] The microstructure of the coatings was studied by scanning electron microscope (SEM).

2.2 Electroplating of Ni

The proposed prototype for the synthesis can be applied to the electroplating Ni. Fig. 2 shows the photographs of the plating bath for the double side.

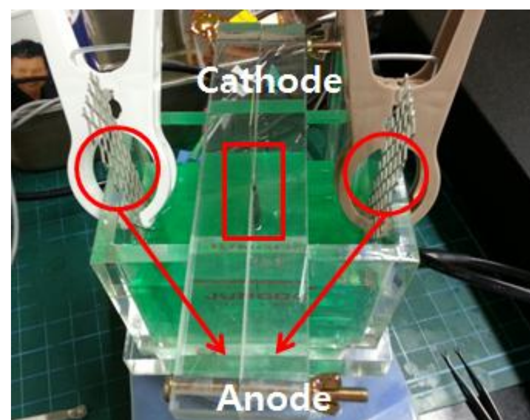

Fig. 2. photograph of the plating bath for the double side.

3. Results and discussion

To established coating condition of Ni, 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 [5] as below;

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

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 6 μm of thickness was determined as 1,757 s at current density 20 mA/cm^2. Estimated time to be 6 μm of thickness was increased to 2,342 s at current density of 15 mA/cm^2.

Fig. 3 show the results of scanning electron microscopy (SEM) for the Ni coated Cu plate at the current density of 20 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 prototype for electroplating radioactive Ni-63 has been established.

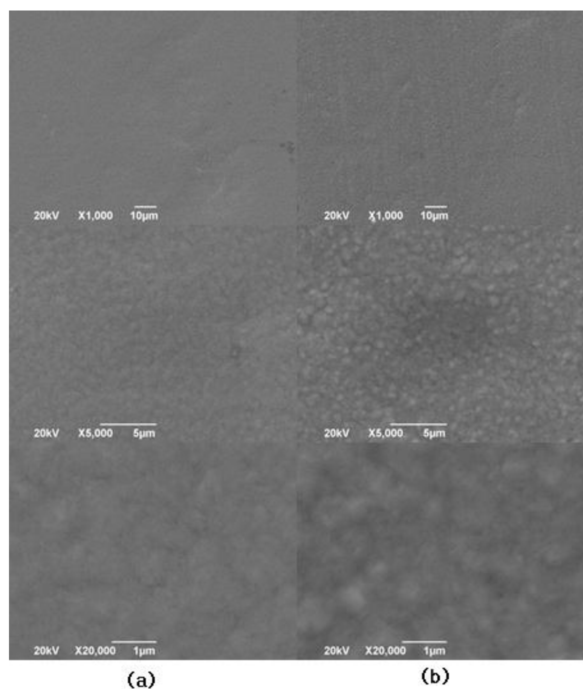

Fig. 3. SEM image for electrodeposited Ni on Cu plate at current density of (a) 15 and (b) 20 mA/cm^2

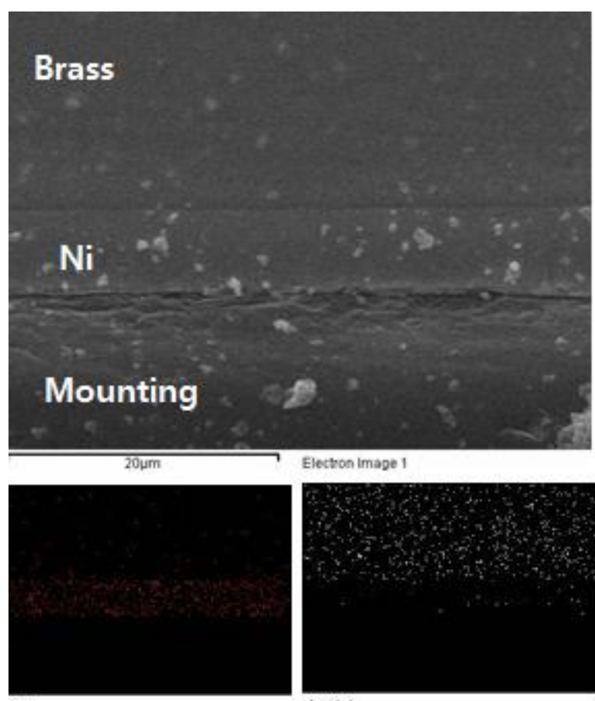

Fig. 4. SEM image for cross section and EDS mapping of the electrodeposited Ni on Cu plate at current density of 20 mA/cm^2

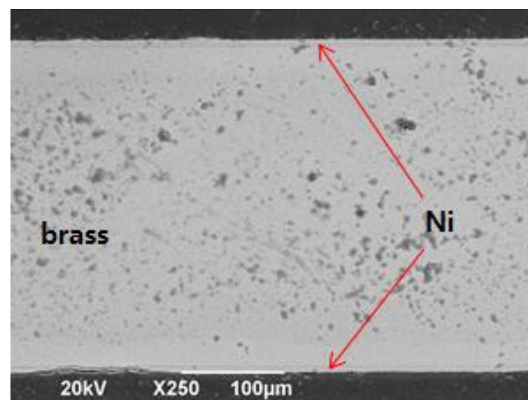

Fig. 5. SEM image for cross section of the electrodeposited Ni on double side of Cu plate at current density of 20 mA/cm^2

The thickness of Ni layer on Cu substrate is well matched as theoretical thickness. The thickness of Ni layer was 5.73 μm for deposited on Cu plate at current density of 20 mA/cm^2. However, the thickness of the Ni-layer was increased to 6.07 μm for deposited on Cu plate at current density of 15 mA/cm^2. The low current density affect to good morphologies of coating layer.

4. Conclusions

Nanocrystalline nickel (Ni) coatings were synthesized by DC electro deposition at a current density of 15 and 20 mA/cm^2. To fabricate betavoltaic, Ni-63 should be coated on the double side of substrate. The bath was primarily composed of 0.2 M Ni ions, prepared by dissolving Ni metal particles in HCl. The prototype for electroplating radioactive Ni-63 on double side has been established.

Acknowledgement
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References

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