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Study of seed layer effect in nuclear battery with P-N diode junction

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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 amps, is generated in devices [2]. If a radioisotope (RI) with a long halflife (over 50 years) is used, a lifetime of a power source is extended as long as halflife time of RI. Some special applications require long-lived compact power sources. These include space equipment, sensors in remote locations (space, underground, etc.), and implantable medical devices. Conventionally, these sources rely on converting chemical energy to electricity. This means they require a large storage of chemical ''fuel'' since the amount of energy released per reaction is small. The nuclear battery is a novel solution to solve the power needs of these applications. For the ^{63}Ni beta-source we used, the half-life is 100.2 years. Hence, the power sources we describe could extend a system's operating life by several decades or even a century, during which time the system could gain learned behavior without worrying about the power turning off. Radioactive thin-film-based power sources also have energy density orders of magnitude higher than chemical-reaction-based energy sources. In this study, we fabricate nuclear battery using ^{63}Ni source with diode junction, and studied seed layer effect for optimization of structure of p-n junction.

2. Experimental Technique

Ni layers with thickness of 200, 500, and 1000 Å, on the single trench P-N absorber were prepared by an e-beam deposition, which is seed layer for electroplating 63Ni of beta-voltaic source. The electroplating was carried out by two-step processes such as preparation of ionic solution including 63Ni, and coating processes on the seed layer. The basic composition of the bath was 0.2 M Ni, 25 g/l boric acid (H3BO3). Ni metal powders were dissolved in mixed HCl and distilled water. Boric acid is used in nickel plating solutions for buffering purposes. The pH of the bath was adjusted to 4.0 ± 0.2 by addition of drops of KOH (1 N). The electroplating of Ni on the seed layer was carried out at current density of 10 and 20 mA/cm^2.

3. Results and discussion

Ni seed layer on p-n diode with area dimension of 4 mm× 4mm as anode materials. The deposition time was adjusted to achieve an average thickness of 3 μm based on the Faraday's law. The optimum thickness of ^{63}Ni on the seed layer was about 2 μm, which was determined by analysis of self-shielding effect of beta-ray(β-ray) as shown in Fig. 1.

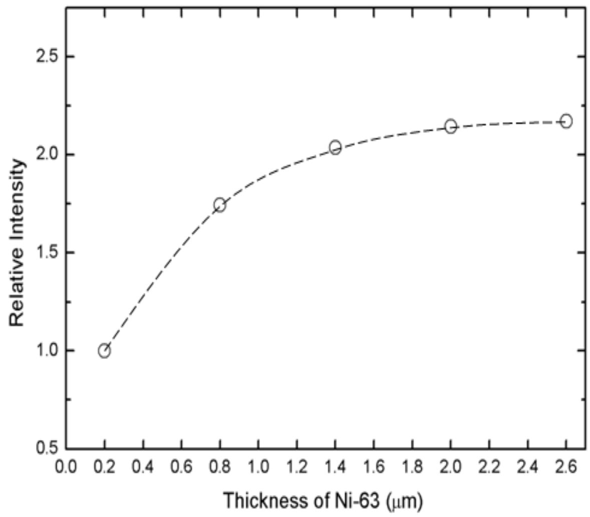
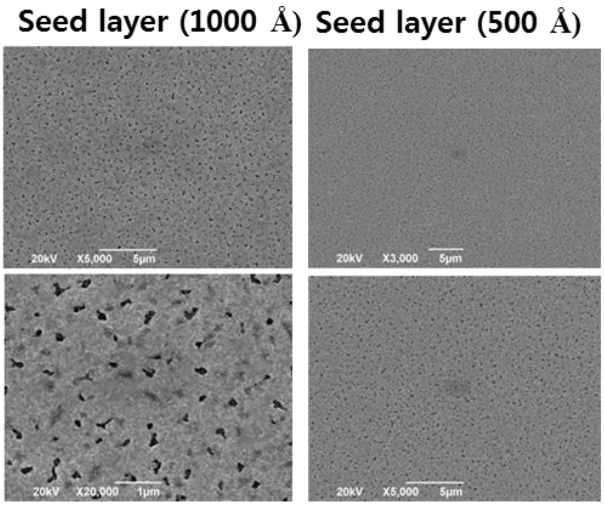
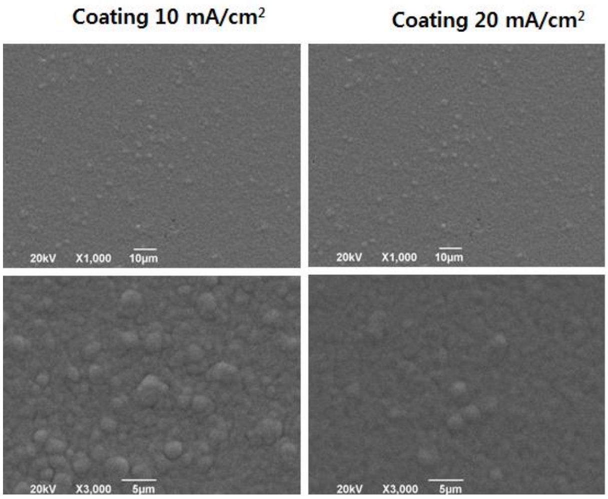


Fig. 1 Thickness dependent of self-shielding effect for ^{63}Ni on the p-n diode

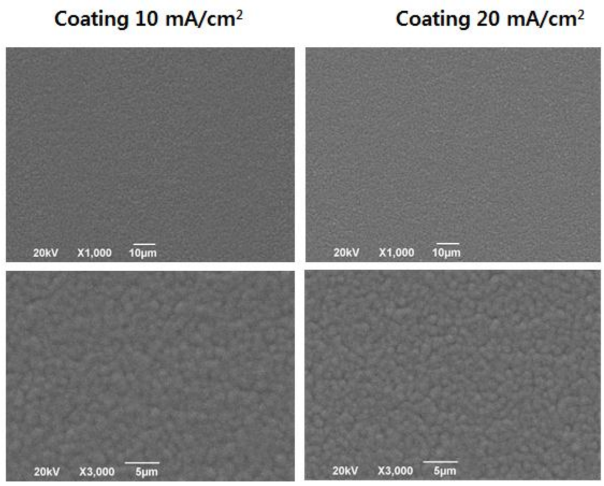
To establish the coating conditions for 63Ni on P-N absorber, non-radioactive metal Ni particles are dissolved in an acid solution and electroplated on a Ni seed layer. The prototype for electroplating radioactive 63Ni on the single trench P-N absorber with seed layer has been established. The experimental results showed that increasing the current density had a considerable effect on the average grain size of the deposits. The conductivity and the uniformity of the seed layer are enhanced, as thickness is increased. The electroplating was failed on the seed layer with thickness of 200 Å due to very high resistivity of e-beam deposit layer.



(a)



(b)



(c)

Fig. 2 SEM images for (a) the seed layer with thickness of 500 and 1000 Å , and electroplated Ni layer on seed layer with thickness of (b) 500 and (c) 1000 Å

However, it was confirmed that the thick seed layer plays a role of increasing self-shielding of β-ray from the photo-voltaic measurement (I-V curves) by using e-beam with energy of 30 keV. To fabricate effective β-voltaic battery, the thickness of seed layer about 500 Å have been determined in the view of both preventing self-shielding β-ray and increasing conductivity on the surface. Fig. 2(a), 2(b) and 2(c) represent the results of scanning electron microscopy (SEM) for the seed layer and electroplated Ni layer on p-n diode. The particles on the Ni sheet were formed as spherical shape. The average size of particles was observed as independent on the current density. The corss section images for electroplated Ni on p-n diode is displayed in Fig. 3.

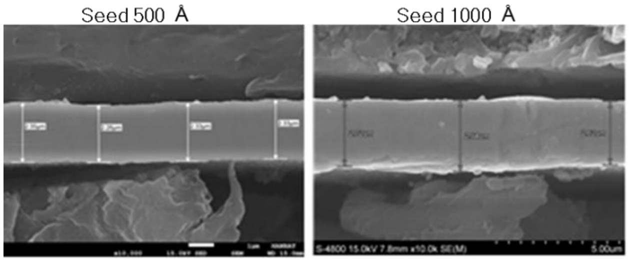


Fig. 3 SEM images for cross section for Ni layer on seed layer with thickness of 500 and 1000 Å

Conclusion

Ni seed layers with thickness of 200, 500, and 1000 Å were deposited by an e-beam irradiation on the single trench P-N absorber in beta voltaic battery. The experimental results showed that increasing the current density had a considerable effect on the average grain size of the deposits. Self-shielding of β-ray from measuring photo-voltaic (I-V curves) is significantly increase, as the thickness of the seed layer become thick.

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