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Electroplated Ni on the PN Junction Semiconductor

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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) at the cathode surface. Radioactive thin-film-based power sources also have energy density orders of magnitude higher than chemical-reaction-based energy sources. In this study, Ni particles were coated on single trenched PN absorber. For electro deposition of Ni-63, the seed layer should be coated on the PN junction. We determined optimum seed layer for electroplating.

2. Experimental Technique

Nickel (Ni) coatings were deposited by DC electroplating at current densities of 10, 20, 30, 40 and 50 mA/cm^2. The basic composition of the bath was 0.2 M Ni and 25 g/l of boric acid (H_3BO_3). A nickel sheet of 99.99 % purity with dimensions of 10×20×0.125 mm^3 was used as a cathode (substrate) and a Pt-coated Ti mesh with dimensions of 25×135×1 mm^3 as an anode. The deposition time was adjusted to achieve an average thickness of 3 μm based on Faraday's law [3]. The microstructure of the coatings was studied by scanning electron microscopy (SEM) and X-ray diffraction (XRD). XRD investigations were carried out using a Philips X'Pert-Pro instrument operated at 40 kV and 30 mA with CuKa radiation (k = 1.5418 Å).

3. Results and discussion

Ni seed layers with thickness of 200, 500, and 1,000 Å were observed by scanning electron microscopy (SEM). In Fig. 1, the SEM images for Ni coated PN junction semiconductor (pH 4, 3 μm) at a Ni seed layer of 500Å were displayed. The nonhomogeneous surface of the seed layer with thickness 200 Å was measured. The Ti-Ni seed layer was coated with poor dispersion on the P-N junction. Otherwise, the thicker thickness of seed layer than 500 Å was well coated with fully covered by Ti-Ni.

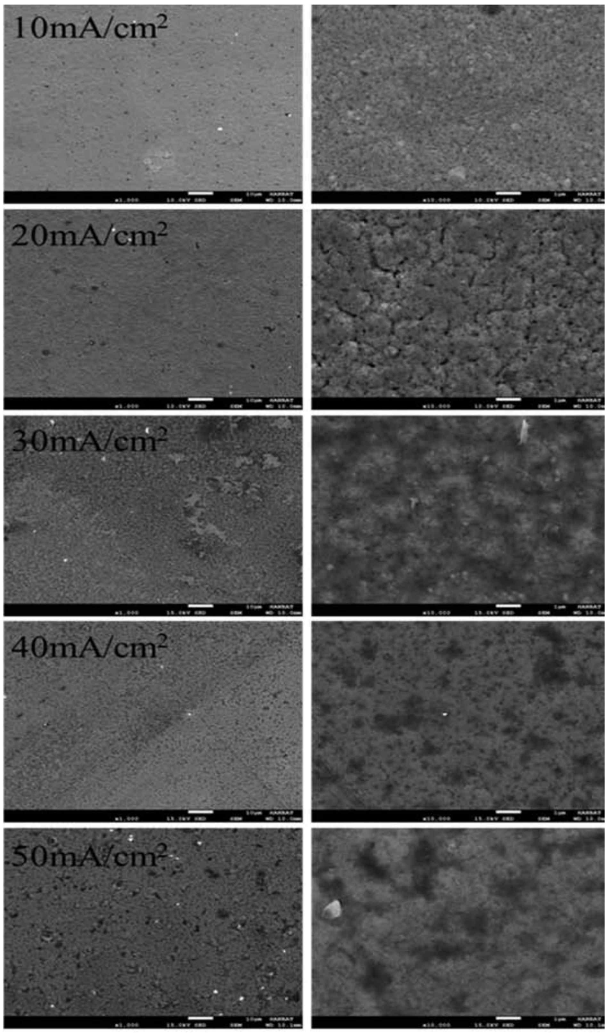

Fig. 1. SEM images for Ni coated PN junction semiconductor (pH 4, 3 μm) at a Ni seed layer of 500Å.

Fig. 2 show the SEM images for Ni coated PN junction semiconductor (pH 4, 3 μm) at a Ni seed layer of 1000 Å. The thicker thickness of seed layer than 1000 Å was also well coated with fully covered by Ti-Ni. So, the seed layers with thickness of 500 Å and 1000 Å were applied to beta voltaic battery.

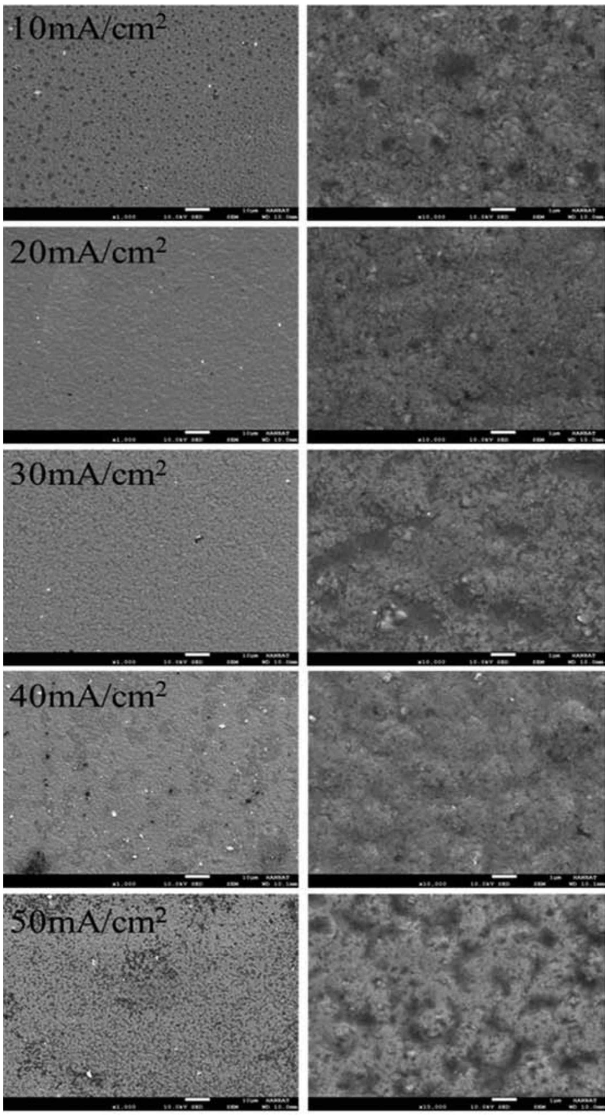

Fig. 2. SEM images for Ni coated PN junction semiconductor (pH 4, 3 μm) at a Ni seed layer of 1000Å.

Both the conductivity and the uniformity of the seed layer are improved, as the thickness of deposit layer is increased. So, the smoothness of the coated layer was gradually progress, as the thickness of seed layer is increased. However, the penetration depth of the beta particles relates to the junction depth and depletion region width. The penetration depth of the particles in the silicon device was reported at Katz-Penfold range equation [5]. This equation considers only the density of the materials and energy of particles. From the equation, the maximum range of the average beta particles energy from Ni-63 into silicon is 2.2 μm. We have modeled the energy deposition as a function of the depth in the silicon using the Geant4 Monte Carlo code. The seed layer thickness strongly attenuates the low energy beta particles. The essentially zero response for the total thickness of 2 μm of Ni-63 and seed layer indicates that the self-shielding effect. According to the self-shielding and covering of the surface, the thickness of the seed layer was determined at 500 Å.

4. Conclusions

Nickel (Ni) electroplating was implemented by using a metal Ni powder in order to establish a Ni-63 plating condition on the PN junction semiconductor needed for production of betavoltaic battery. PN junction semiconductors with a Ni seed layer of 500 and 1000 Å were coated with Ni at current density from 10 to 50 mA cm^2. The surface roughness and average grain size of Ni deposits were investigated by XRD and SEM techniques. The roughness of Ni deposit was increased as the current density was increased, and decreased as the thickness of Ni seed layer was increased. The results showed that the optimum surface shape was obtained at a current density of 10 mA cm^2 in seed layer with thickness of 500 Å, 20 mA cm^2 of 1000 Å. Also, pure Ni deposit was well coated on a PN junction semiconductor without any oxide forms. Using the line width of (111) in XRD peak, the average grain size of the Ni thick firm was measured. The results showed that the average grain size was increased as the thickness of seed layer was increased..

Acknowledgement

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