Study on fabrication of a prototype betavoltaic battery using Ni-63

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1. Introduction

A betavoltaic battery that converts the decay energy of beta-emitting radioisotopes into electricity is characterized by specialized properties such as a long service lifetime, high energy density, easy small-scale fabrication, and minimum maintenance requirements. It is widely used in low-power applications such as medical devices, micro robots, sensors for monitoring, and power sources for MEMS (microelectromechanical system) because it can operate effectively under extreme environmental conditions. Radioisotope Ni-63, a pure beta emitter, has a low energy spectrum of 17.4 KeV and significantly long half-life of 100.1 years. For this reason, Ni-63 is suitable for the energy source of a betavoltaic battery.

In this study, a prototype betavoltaic battery was fabricated using a Ni-63 sealed source and SiC semiconductors. Ni-63 was electroplated onto Ni foil for manufacturing a Ni-63 sealed source using a small-scale electroplating device, and the radioactivity of the fabricated single Ni-63 foil is about 25 mCi/cm^2. It was bonded to a SiC semiconductor, and a short circuit current (I_{sc}) and open circuit voltage (V_{oc}) were then investigated. The unit cells were arrayed 4 × 4 in two PCB. The power output of a betavoltaic battery unit cell was measured at about 6 nW. A whole prototype betavoltaic battery's power output was measured at 145 nW.

2. Methods and Results

2.1 Ni-63 Electroplating

The Ni-63 was obtained from POLATOM in Poland, and its specific activity was 12 Ci/g. The Ni-63 electroplating was conducted at current density of 15 mA/cm^2 using manufactured small-scale electroplating device. The basic composition of the bath was 0.05 M Ni-63 (in 0.5M HCl) and 0.4 M boric acid. The pH of the bath was adjusted to 4.0. The composition and condition of Ni-63 electroplating are shown in Table 1. 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.

Table I: Composition and condition of Ni electroplating

Bath composition	
$^{63}NiCl_2$ in HCl	0.05M
H_3BO_3	0.4 M
NaCl	0.7 M
Saccharin	0.00829 M
Tween 20	0.5 %
Bath condition	
Temperature	40 °C
Deposition time	1758 sec
Substrate dimension	1 × 1 cm^2
Current density	15 mA/cm^2
Cathode	Ni foil
Anode	Pt-coated Ti mesh
pH	4.0

Figure 1 presents images for electrodeposited Ni-63 on the Ni foil at current densities of 15 mA/cm^2. The thickness of the Ni-coated Ni foil was estimated 2.5 ~ 3.0 μm, and the size of single foil is 4 × 4 mm^2. The radioactivity of the fabricated single Ni-63 foil is about 25 mCi/cm^2.

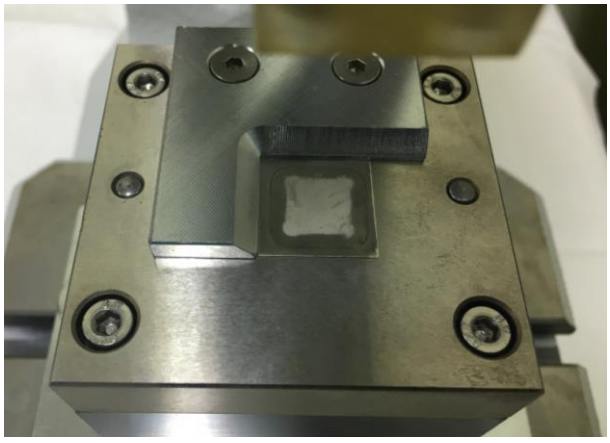

Fig. 1. Images for electrodeposited Ni-63 on the Ni foil at current densities of 15 mA/cm^2.

2.2 Fabrication of prototype betavoltaic battery

The unit cells were arranged in 4 × 4 on two PCB, and the total arranged Ni-63 foil was 32 pieces. A short circuit current and an open circuit voltage of all the unit cells were measured so that power outputs of two PCB are similar. The demonstration of the Ni-63 mounted

SiC shows a short circuit current of 3.7 nA and an open circuit voltage of 2 V resulting a conversion efficiency of 7.9% and power output of 7.4 nW.

Figure 2 presents images for the prototype betavoltaic battery using Ni-63 and SiC semiconductors. The result shows a short circuit current of 49 nA, an open circuit voltage of 3 V, and the power output of prototype battery using 32 pieces of Ni-63 foil was 145 nW. In further study, power output improvement with arraying and the stacking of bigger unit cells will be conducted.

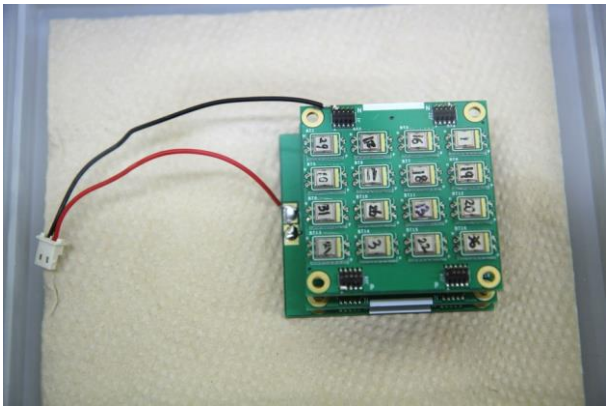

Fig. 2. Prototype of betavoltaic battery using Ni-63 and SiC semiconductors.

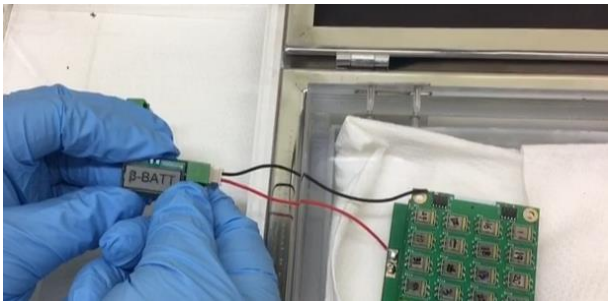

Fig. 3. LED test using prototype betavoltaic battery.

3. Conclusions

The prototype betavoltaic battery was fabricated using a Ni-63 sealed source and SiC semiconductors. The radioactivity of the fabricated single Ni-63 foil is about 25 mCi/cm^2. The unit cells were arrayed 4 × 4 in two PCB. The power output of unit cell was measured at about 6 nW. A whole prototype betavoltaic battery's power output was measured at 145 nW.

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