Performance of Silicon Betavoltaic Device by using a Ni-63 Radioisotope

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1. Introduction

Semiconductor betavoltaic converters use energy from radioisotope sources to generate electricity for remote applications requiring a long life power. Radioisotopes emitting β radiation such as Ni-63 and tritium (H-3) have been used as fuel for low power batteries. Significant advantages of a high energy density, the insensitivity to climates and a longer life than chemical batteries make them attractive candidates for nano-power sources. [1]

The betavoltaic effect is the generation of a potential due to a net positive charge flow of an electron-induced electron-hole production (EHP). Because the resulting current is from an n-type to a p-type semiconductor, the net power can be extracted. [2]

Hence, the objective of this study is to provide the feasibility of nuclear beta sources for supplying a power to realistic MEMS devices.

2. Preparation of the betavoltaic device

2.1 Fabrication of the silicon PN diode.

The betavoltaic device consists of a very thin thickness of impurity layer for the beta ray to reach the depletion region which is the area of EHP. Therefore the structure of this device has the n-type front surface which is contacted with Ni-63 beta source.

The technical considerations, to suppress the leakage of the generated electron and to form the contact layer structure for removing the additional mask during the ion implantation and to use the thin film metal layer process which is different from conventional fabrication process, were adopted in the manufacturing processes of this device.

The general structure of silicon PN diode is shown in the Figure 1 and the detailed dimension was described in the reference paper. [3].

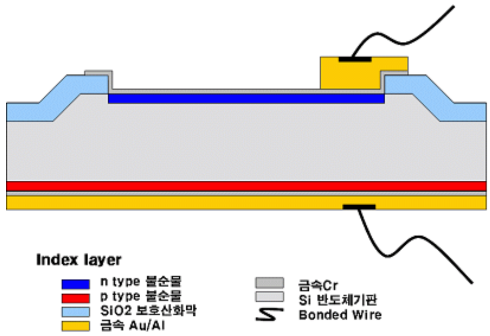

Figure 1 Internal structure of the Silicon betavoltaic device.

2.2 Package of the Silicon PN diode and Ni-63 radioisotope.

The silicon diode/isotope assembly was mounted onto a copper clad PCB which allowed electrical contact to the backside device via a conductive paste to the PCB. Electrical contact to the front side of the PN diode was made with a wire solder in Figure 2. After assembling, epoxy package was done by pouring the potting material (FP4450HP) and curing at 150℃ for 90 minutes.

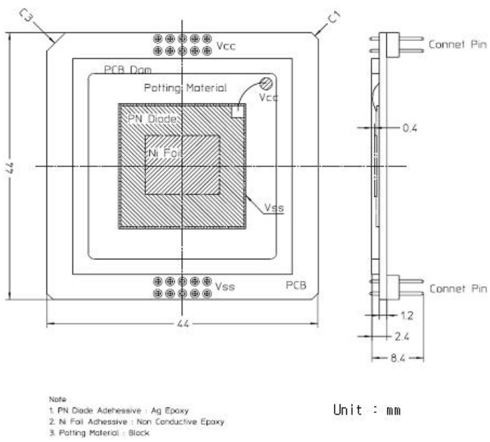

Figure 2 Drawing of Silicon PN Diode Package

3. I-V Test of the betavoltaic device

The current-voltage (I-V) measurements were made with a Semiconductor Parameter Analyzer (HP4155). The I-V characteristics of the Si PN diode were measured before and after Ni-63 irradiation in Fig. 3. The diode turn-on voltage as seen in the inset was approximate 0.2 V. The fourth quadrant of the I-V curve has been concerned as the photovoltaic device. This device exhibited a short circuit current (I_{sc}) of 74.7 nA and an open circuit voltage (V_{oc}) of 5 mV, and the maximal output power (P_{max}) is about 0.37 nW. This curve could lead to a fill factor of 0.5.

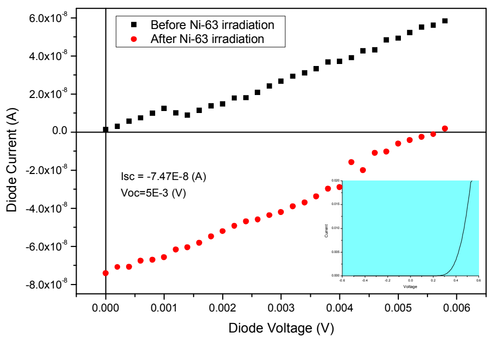

Figure 3 Test result of Si PN Diode before/after Ni-63 irradiation

The I-V characteristics of the packaged betavoltaic device under Ni-63 beta irradiation were shown in Fig. 4. This device exhibited a similar result.

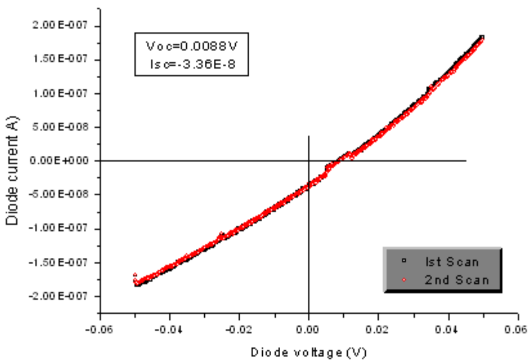

Figure 4 Test result of the packaged device under Ni-63 irradiation

For power on the order of 10 nW, it is possible to make a stack of this betavoltaic devices with high specific activity isotope layers between them, connected in series or parallel depending on the voltage requirements of the application.

4. CONCLUSIONS

Silicon PN diode and Ni-63 radioisotope was assembled in order to fabricate the betavoltaic device. This device was demonstrated to show a peak electrical power density of more than 0.15 nW/cm^2 using 10 mCi Ni-63 source. Radioisotope battery is expected to be applicable in the medical and military fields as a power source for MEMS application.

Acknowledgements

This work was supported as a part of nuclear basic research expansion program by the Korean Minister of Science and Technology.

References

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