THE RADIOISOTOPIC BATTERY BASED ON RADIO-VOLTAIC EFFECT

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The radio-voltaic effect is investigated to be applied radioisotopic batteries in this work. The collection rates of the electron-hole pairs are 94 percent for the alpha particles emitted by $^{239}$Pu source and 65 percent for the beta particles emitted by $^{90}$Sr-$^{90}$Y source. The maximum energy conversion efficiency got by the silicon element is about 16%. A prototype radioisotopic battery with $^{147}$Pm beta sources is constructed. Its maximum short-circuit current and off voltage are about 2μA and 190 mV respectively. The experimental data suggest that the life of the prototype battery may be more than three years.

Radioisotopic battery is a power generating device utilizing decay energy of radioisotopes. It is a maintenance-free power supply with long life, high energy density and high reliability. The thermo-electric and thermionic radioisotopic batteries are now used widely in the space travel, satellites and artificial heart pacer by developed countries. But the efficiency of these batteries with thermal conversion mechanism is usually lower than eight percent. Therefore, the investigations of new high efficiency conversion mechanism are very attractive and important.

There are about ten methods which may be used to convert the radioisotopic decay energy into electric power. These methods include two types—the direct and indirect. Radio-voltaic effect is one of the direct conversion mechanisms for the transfer of radioisotopic decay energy to the electric power. Its theoretic efficiency limit is about 40 percent. But since the restriction of the quality of semiconductors and techniques, the efficiency of this mechanism could not be developed before 1980. Nowadays, there are much more semiconductors than early times and the new semiconductor techiques have been invented, thus, the efficiency of the radio-voltaic effect could be greatly improved.

Principle of the radio-voltaic effect

There is a inner potential barrier in any semiconductor PN junction, therefore, the free charge carriers (electron-hole pairs) induced by the radiation of radioisotopic decay are separated by the barrier to create a radio-voltaic macropotential, then the carriers are collected and output as electric current. This processes is defined as radio-voltaic effect to compare with the photo-voltaic effect.
Because the average ionization energy for the generation of an electron-hole pair depends on the kinds of semiconductors and the electron-hole pairs are normally recombined very quickly, thus, the quality of radioisotopic battery is decided by the characters of the semiconductor elements. For example, the average ionization energy for silicon is 3.62 eV per electron-hole pair in room temperature, and the maximum output voltage is about 700 mV, so that, the theoretic energy conversion limit of the silicon element with a single PN junction is about 19.4%. However, the practical efficiency depends in essence on the diffusion lengths or life of the carriers and the amount of the energy deposited in the barrier layer. So that, the long diffusion length, long life of the carriers, thick barrier layer with high inner field intensity and low defect generation rate are needed for the suitable semiconductor element. But there are still some conflicts among different factors which must be solved in experiments and techniques.

Experimental

Some experimental approaches are being investigated in our laboratory. Semiconductor elements are successfully used to convert the decay energy of radioisotopes into electric power. It is explained as follows.

1 Material and PN junctions

Because the energy conversion efficiency of semiconductor elements depends on the average ionization energy, the absorption rate of the particle energy deposited in the potential barrier layer and the collection rate of the electron-hole pairs ionized by the particles, the silicon PN junction with a wide potential barrier is applied to absorb the total energy of particles, and at the same time, the life and diffusion length of the electron-hole pairs in the element is prolonged to be almost one mini second and about one meter respectively by using of the special semiconductor material. The elements with double and three PN junctions are also applied to improved its inner field intensity.

2 The energy conversion properties of elements

2.1 Collection rate of the electron-hole pairs in the element

The collection rate of the electron-hole pairs in the element is determined with the energy spectrum analysis method. The collection rate of the electron-hole pairs got without applied voltage is 94 percent for the alpha particles emitted by $^{238}$Pu source (Fig. 1) and 85 percent for the beta particles emitted by $^{90}$Sr-$^{90}$Y source (Fig. 2).

2.2 The relationship between short-circuit current and input power

The relation of short-circuit current and input power is direct ratio in theory,

$$I = P \theta / \epsilon$$

where, $I$: electric current; $P$: input power; $\theta$: collection rate of carriers; $\epsilon$: average ionization energy.