B-3-5

Hot Carrier-Voltaic Effect in P-N Junction and Its Application to Electron Emitters and Light Detectors

M. Umeno, H. Hattori, T. Jimbo and Y. Sugito

Department of Electronics, Faculty of Engineering, Nagoya University
Chikusa-ku, Nagoya 464, Japan

When a p-n junction of a semiconductor (with band gap energy E_g) is illuminated by intense light beam (with its photon energy $h\nu$) in a condition of $E_g > h\nu$ such as in Ge p-n junction illuminated by Q-switched CO_2 laser, an electromotive force is induced across the p-n junction with the polarity opposite to an ordinary photovoltaic effect such as a solar cell.[1] Such an anomalous photovoltaic phenomenon has been discussed with many photovoltaic mechanisms, and it has been explained as an optically excited hot carrier-voltaic effect by studying the induced voltage across the p-n junction due to hot carriers excited in electric field parallel to the p-n junction plane.[2] In this report, such a new voltaic effect in p-n junction due to hot carriers in electric field is presented with the anomalous photovoltaic effect, and useful applications to high-efficiency electron emitters and high-sensitivity light detectors are proposed.

Anomalous Photovoltaic Effect

When a CO_2 laser beam illuminates the p-n junction of Ge, an electromotive force is induced with p-side negative and n-side positive in opposite to ordinary photovoltaic effect, as shown in Fig.1(a). The electrons in n-side and the holes in p-side are excited optically, as shown in Fig.1(b). These excited carriers correspond to be in the forward bias. Then, the electrons travel into p-side and the holes into n-side, inducing the anomalous voltage. The same phenomena are expected by exciting carriers in electric field in place of the optical excitation.

Hot Carrier-Voltaic Effect

When pulse electric field is applied in parallel to the p-n junction plane, electrons and holes are accelerated and become warm or hot without lattice heating. Some of such hot carriers travel to the another p or n side with crossing the junction plane through scattering by phonons, inducing the electromotive force with the same polarity as the anomalous photovoltage, as shown in Fig.2(a). Such experiments have been done by using rods of n- or p-type Ge with a p-n junction at its center, as shown in Fig.2(b). The induced voltages are shown in Fig.3 as a function of applied electric field. The voltage V_{N-P} induced between p-n junction and ohmic contact is very sensitive to the departure from thermally equilibrium velocity distribution.

Applications to Electron Emitters and Light Detectors

Using the hot carrier-induced vertical current effect in a p-type semiconductor

surface with n-type inversion layer with small surface potential, efficient cold cathod can be proposed, as shown in Fig.4. In such devices, the joule heating in the thin inversion layer with 20∿100Å may be weak because of heat sink effect in large bulk semiconductor continued from the surface, and negative electron affinity-like surface deposited with Cs is very efficient.

Also, in addition to the above mentioned device, when its surface in vacuum can be illumined by light, high sensitive photo-detector may be obtained. Especially, its devices are useful in infrared region and we may get an infrared photo-multipliers which have not been set up until now.

These efficient devices will be discussed in details with theoretical estimates of hot carrier-voltaic effect in p-n junction and surface inversion layer.

1). Hattori, Umeno et al.; Meeting Rec. Phys. Soc. Japan, '75-4/5, '75-10/11, '76-4/7.
2). Umeno, Hattori, Sugito; Meeting Rec. Phys. Soc. Japan, '76-4/5.

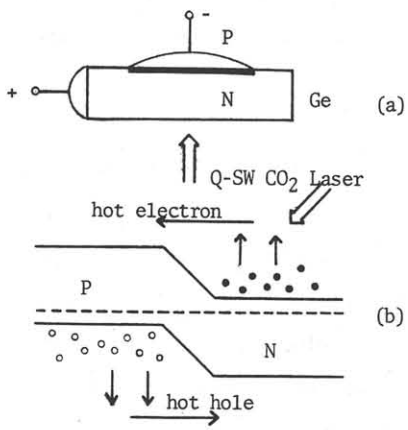

Fig. 1

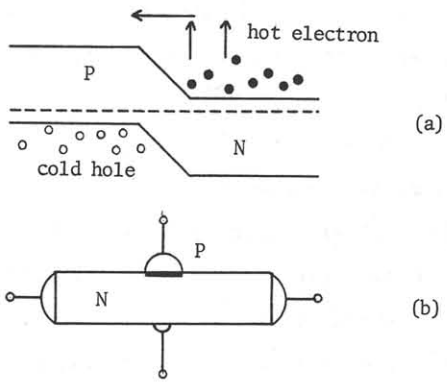

Fig. 2

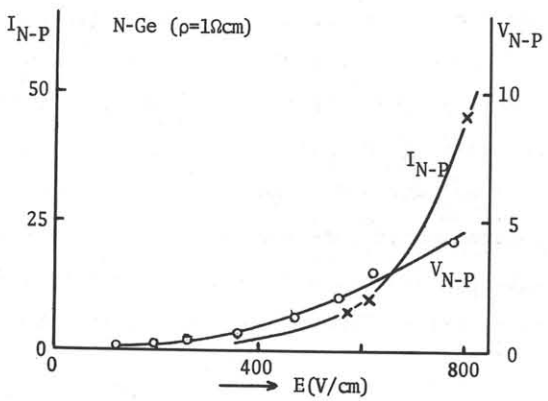

Fig. 3

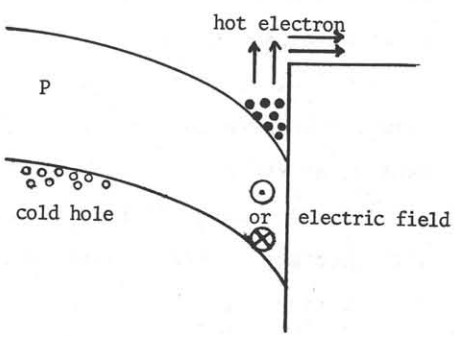

Fig. 4