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Properties of a Schottky-Barrier Transistor and the Carrier-Coupling Devices

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An MNP three-layer structure operates as a switch involving transistor, in which the metal (M) of the Schottky-barrier serves as a collector for the injected holes from the positively biased emitter(P), (Fig.1). By raising the collector bias voltage(V_{CB}), a switching occurs accompanied by a transistor characteristics. The static characteristics (grounded-base (N) connection) is shown in Fig.2.

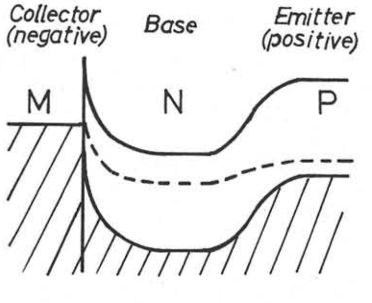


Fig.1 Energy diagram of a MNP device.

Injected minority carriers (holes) diffuse to accumulate in the depletion layer of the Schottky-barrier. The result is a barrier field raising until to reach the collector breakdown (turnover). The turnover voltage (V_{th}) can be reduced by injecting the minority carriers. Once electrons are injected due to the high field, they steers more holes into the depletion layer to accumulate as positive charges. Stimulating further emission of electrons, the net result is the negative resistance.

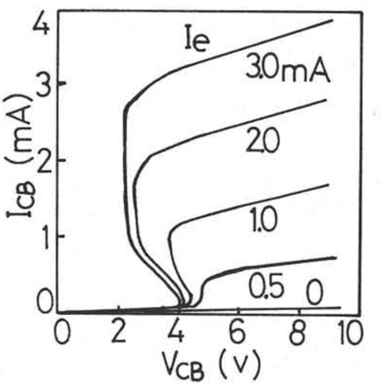


Fig.2 Static characteristics of a MNP device.

This positive feedback ceases at last when the barrier vanishes substantially, then the MNP element behaves like an UJT with a current gain.

A theory based on the above mechanism is developed which can account for the behavior of the Schottky-barrier transistor. As the theory assumes the existence of the neutral region where the incoming electrons are replaced by additional holes, a lower limit of the N-layer thickness for the initiation of the negative resistance should exist, which is given in Fig.3.

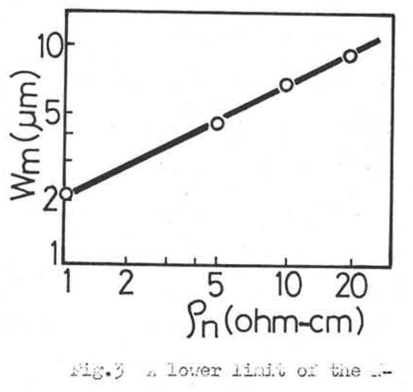


Fig.3 A lower limit of the N-layer thickness for the initiation of the negative resistance.

In Fig.4 are shown the temperature dependences of V_{th} and the sustaining voltage (V_s). At higher temperature tunnel emission prevails, V_{th} being constant.

In a MNP switching device, the effect of injecting minority carriers is enhanced by accumulation of the carriers so that the turnover voltage is very sensitive to the presence of the excess minority carriers. In fact, the diode has appreciable photo-sensitivity,[1] and can be switched on or off with a conventional LED. The

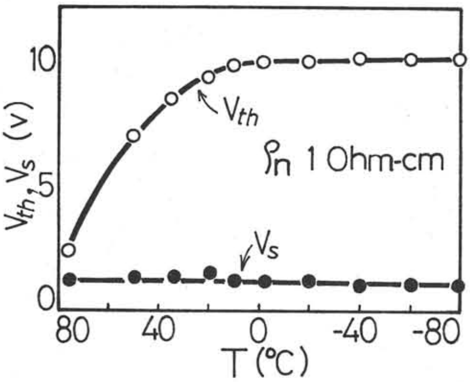


Fig.4 Temperature dependences of the turn-over and the sustaining voltages.

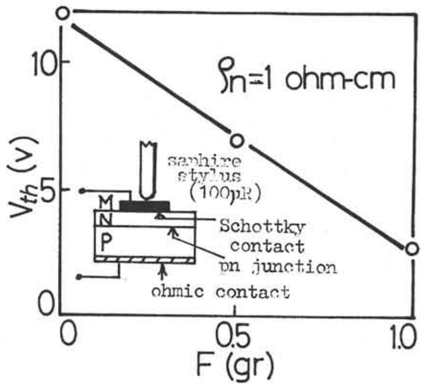
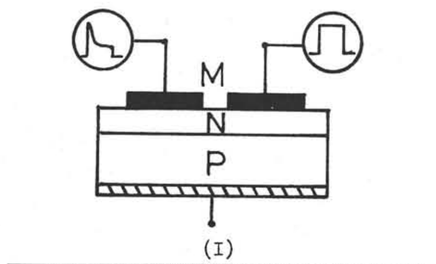


Fig.5 Stress-dependence of the turn-over voltage

turnover voltage is also reduced remarkably by applying pressure. Stress-dependence of V_{th} is shown in Fig.5.

In Fig.6 is shown a carrier-coupling effect between two adjacent elements formed on a common substrate. An element on the left is set in the "on" state and one at the right is biased a little below its turnover voltage. The latter remains in the "off" state so far as the two voltage pulses are separated in time.(a) If two pulses are made partially overlap the right element turns on.(b) This returns to its original "off" state if the left element is made turn off.(c) This coupling action is controllable utilizing additional electrodes in the vicinity of the elements. These effects can be explained by using the theory discussed above. The triggering sensitivity is also high, due to the lateral drift as well as the accumulating multiplication mechanism. By using MNP elements many possible applications are anticipated which perform functions similar to PCD.[2] The MNP element is very suitable for IC structure since its structure and manufacturing process are simple and the power dissipation is substantially small.



(I)

(a) (b) (c)

(II)

Fig.6 A carrier-coupling effect between two adjacent elements. (I) Schema of device structure. (II) Oscilloscope traces showing coupling effect. The upper traces are voltages of the left element, and the lower are the right. Scales: voltage 5V/div, time 1microsec/div.

References

1) for example, T.Yamamoto: Trans. IECE Japan, 53-C (1970) 881

2) T.Suzuki and Y.Mizushima: Proc. 3rd Conf. on Solid State Devices, Tokyo, (1971)