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Recent Advances in the Plasma-Coupled Device

T.Suzuki, K.Kawarada, Y.Yamamoto, T.Shibata, H.Kodama and A.Tamama

Musashino Electrical Communication Laboratry

Nippon Telegraph and Telephone Public Corporation, Musashino, Tokyo

A plasma-coupled semiconductor device (PCD) has many interesting properties as a functional device. Many functions have, so far, been realized by using a plasma-coupled scheme.[1)~3)] In this paper, the results of the recent advances in the PCD are presented.

1. Logic operations : Basic structures for AND or OR logic are shown in Fig.1. The upper two elements act as the input elements, and logic outputs are derived from the lower element. The operation makes use of the effect that the degree of decreasing of the peak-point voltage of the output element when both input elements are "on" differs drastically from that when either is "on". Fig.2 shows two examples of the structure for NOT logic. In Fig.2(a), shielding effect of an ohmic gate against spreading of the electron-hole plasma, is used to realize a NOT operation. In the case of Fig.2(b), the no.3 element is continuously turned on. When the no.1 element turns on, the no.2 element turns on in prefernce to the no.4. The potential at the emitter of the latter decreases by the ohmic drop across the common resistor R_C, and the no.4 element remains in the "off" state. A half adder constructed from these logic elements, directly coupled through a silicon substrate, is shown in Fig.3. In Fig.4 are shown the oscilloscope traces indicating a half adder operation by two-phase clock signals.

2. A field-coupled regenerator : On constructing a logic circuit, it is often necessary to transfer the information to a distant point in a chip, or to a point in another chip. A regenerator circuit has been developed for this purpose, which makes use of a field-coupled effect. The basic configuration is shown in Fig.5, where P and Q are ohmic electrodes. When the A element is "on", the potential of the P electrode, V_{n+}, decreases, owing to the conductivity modulation around the collector region. This is shown in Fig.6. When P and Q are connected, this drop gives rise to decreasing of the peak-point voltage, V_p, of the B element, as shown in Fig.6. It is easily seen that the "on" or "off" state of the A element is transferred to the B element by applying appropriate biasing voltage.

By optimum design of the electrode configuration, it is possible to drive more than five elements by single P electrode. Fig.7 shows

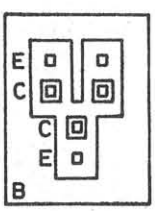

Fig.1

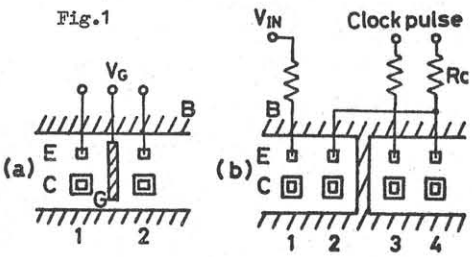

Fig.2

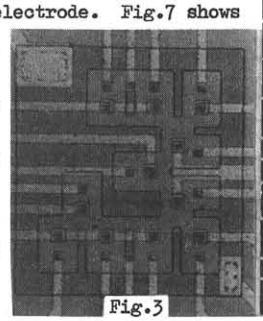

Fig.3

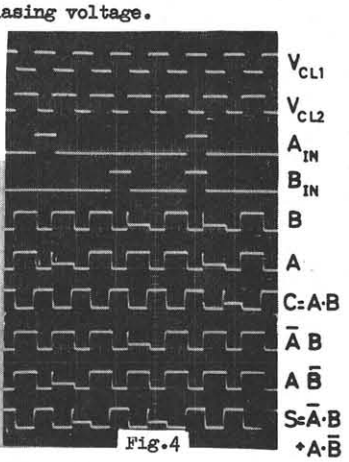

Fig.4

a plasma-coupled decimal ring-counter utilizing this field-coupled regenerator. An "on" state that arrives at the last stage returns to the initial stage by a field-coupled effect due to additional P and Q electrodes.

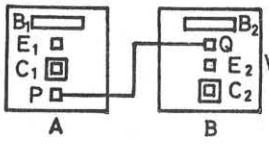

Fig.5

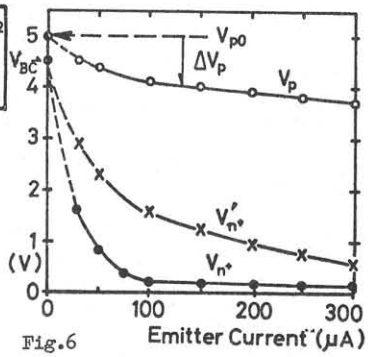

Fig.6

3. Storage-mode operation for high sensitive imaging :

A PCD optical imaging device follows two approaches. One is a self-scanning system, in which negative resistance elements in the PCD array are used as photosensors. In the other system, an array of photosensors is attached to the PCD scanning switch circuit. In either case, an imaging operation with the highest sensitivity is obtained by employing a storage mode. The equivalent circuit of the H-type PCD element with a "hook" structure is expressed as in Fig.8. The storage-mode operation is realized by utilizing the equivalent phototransistor structure. For a storage-mode operation, the voltage bias across the base and the collector electrodes are removed during a time interval T. At the final terminal of the storage time, an instantaneous current flows through R_{BE} and R_{EC} and makes the peak-point voltage decrease for a moment, as shown in Fig.9. A sufficiently large C_{BH}/C_{HC} is desired for an efficient storage-mode operation. Fig.10 shows the variation of the peak-point voltage ΔV_p vs. storage time T for various illumination intensity. Additional capacitance is attached to C_{BH} by using metal-oxide-substrate structure.

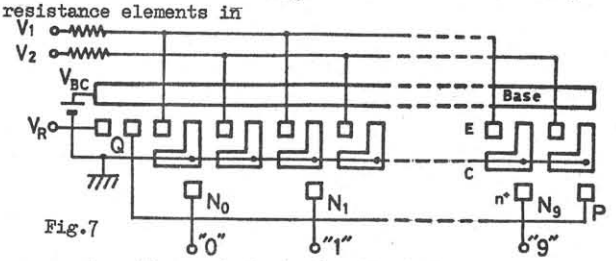

Fig.7

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References

1) T.Suzuki and Y.Mizushima: Proc. 3rd CSSD Japan (1971) Japan Soc.Appl.Phys.Tokyo (1972) 40

2) T.Suzuki and Y.Mizushima: Digest of Techinical Papers ISSCC (1972) 28

3) K.Kawarada, Y.Yamamoto, K.Yano and T.Suzuki: Proc. 4th CSSD Japan (1972) Japan Soc.Appl.Phys.Tokyo (1973) 187

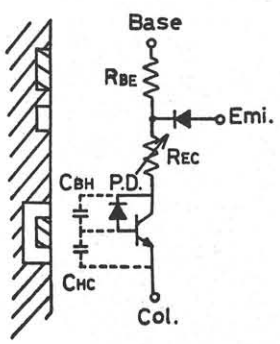

Fig.8

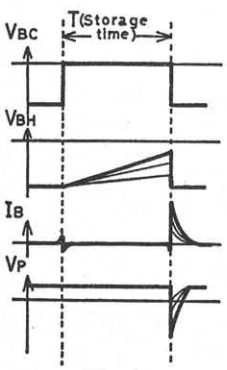

Fig.9

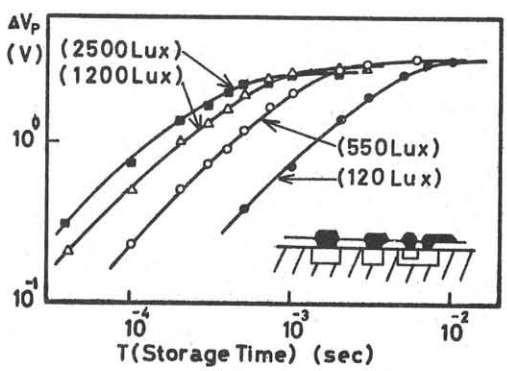

Fig.10