6-2

New Modes of Operation in Plasma-Coupled Devices

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A plasma-coupled semiconductor device (PCD) has been proposed, and its basic operations as a shift register, as a logic device and as an optical imaging device have been reported.[1] The results of further experiments will be presented here, to demonstrate the feasibility of the plasma-coupled concept for wider applications without complicated IC structures.

1. Active line (Active pulse delaying line)

In PCD, the information is regeneratively transferred as an "on" or "off" state of a current-controlled negative resistance element. There exists a delay in plasma coupling process, which depends on the distance between elements, and the drift or diffusion velocity of the plasma. Utilizing these characteristics, PCD array can be operated as an active line (Fig.1).

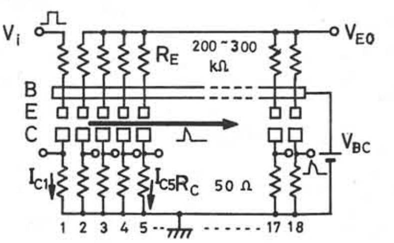

Fig.1 Active line of 18-Elements PCD.

Fig.3 shows the current pulses of every third element in PCD array in active line operation with the spacings of 30 μ between elements. All the elements are biased under monostable condition with stable "off" state. The current pulse injected to the first element is transferred at successive elements and reaches to the end of the array. The time τ_t which is needed to trigger the next element is varied by the emitter bias voltage V_{EO} (Fig.2), and the total transfer time is varied from 0.65 μsec to 1.1 μsec in this device. Maximum triggering time is obtained when V_{EO} is equated to the reduced peak voltage V_{P1}.

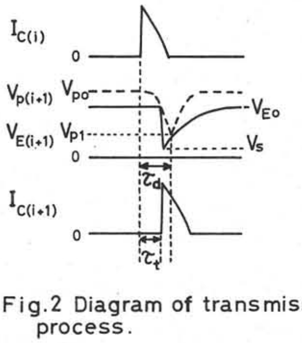

Fig.2 Diagram of transmission process.

When original peak voltage V_{PO} is 3.6V and V_{EO} is 3.5V, the mean triggering time is 38 ns/step and transmission velocity of the signal is 9.9×10^{4} cm/sec, which is an order higher than the reported value in semi-distributed PNPN diode [2].

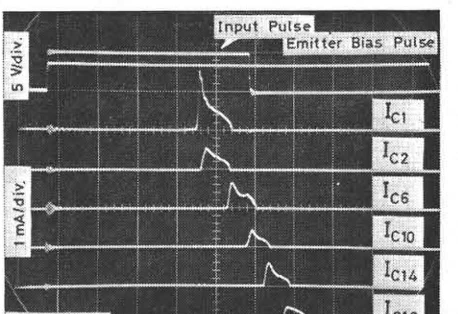

Fig.3 Oscilloscope traces showing an active-line operation.

2. Plasma-coupled flip flop

It is possible to construct a bistable multivibrator or flip flop based on the plasma-coupled scheme. One example of such circuits is shown in Fig.4 . In this case, a gate electrode formed by n^+diffusion is used as a triggering electrode. Both positive and negative voltage pulses can be applied for triggering. Fig.5 is the oscilloscope traces showing the binary operation by negative triggering pulses. The values of V_{E0}, R_0, R_1 and R_2 are chosen in such a way that, when the 1st element at left is "on", the voltage V_{E2} at the emitter of the 2nd element becomes lower than the peak voltage V_{P2}, which is reduced by plasma-coupled effect . When the negative pulse is applied to the gate, the plasma, carrying current in the 1st element, flows into the gate and the 1st element turns off. Simultaneously the peak voltage of the 2nd element decreases and the element begins to turn on. For the device with the distance of 100μ between elements maximum frequency attained is 200kHz. Higher frequency operations will be possible by using a device with smaller dimensions. Monostable multivibrator operation is also achieved by almost the same circuit configuration.

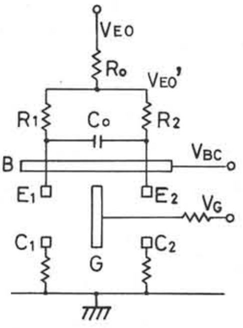

Fig. 4 Plasma-coupled flip-flop.

3. High sensitive imaging operation

A lateral PNPN diode formed between the emitter and collector electrodes of the device with hook structure has higher photosensitivity than the same device has when used as a three terminal unijunction transistor (Fig.6). A high sensitive imaging operation is realized utilizing this fact by appropriate manipulation of electrode potentials, as shown in Fig.7. At first stage the base circuit is opened and a constant voltage is applied to the emitter electrode through a load resistor. The element acts as a PNPN diode, so it turns on and stays at B point in Fig.6 when illuminated. Succeedingly, the base circuit is closed. A constant voltage is applied across the base and collector electrodes, and the element is converted to the three terminal negative resistance device. So the operating point moves from B to C in Fig.6. This C point is the normal "on" state and the device is ready to perform the usual shift register operation as PCD. Actually the whole imaging operation is achieved by applying the base voltage a little after the first pulse of shifting clock pulses.

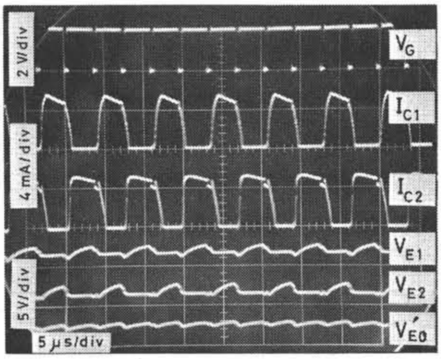

Fig.5 Waveforms of flip-flop operation.

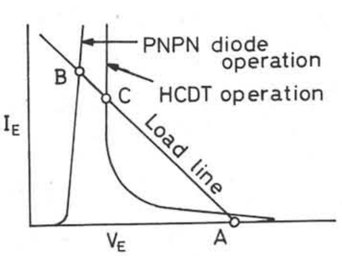

Fig.6 V-I characteristics of PNPN diode and HCDT operation.

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1)T. Suzuki & Y. Mizushima, Proc. 3rd Conf. on Solid State Devices. 40 ('71) ; Digest of Technical Papers ISSCC 28 ('72)
2)H. D. Crane, Proc. IRE 50 2048 ('62)

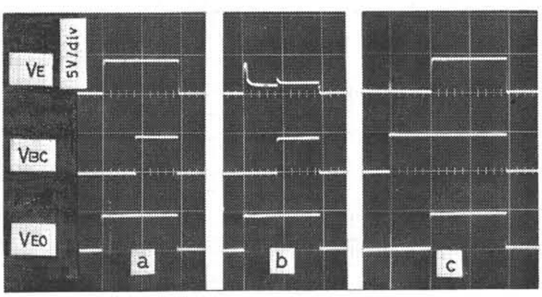

Fig.7 Oscilloscope traces showing high sensitive imaging operation.