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A New Basic Element for Neural Logic Circuits

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1. Introduction

Neural logic devices and circuits have been extensively studied, and recently, a νMOS transistor and its logic circuits are proposed [1]. While quantum effect devices may contribute to new functional applications [2], they are still somewhat immature in terms of practical application.

In this paper, a new neural logic device is proposed and simulation results of some circuit operations are shown. The device, lateral, unidirectional, bipolar-type, insulated-gate transistor on SOI substrates (lubistor) [3] can be used to realize key neural logic operations.

2. Device operation and new logic element

A cross-sectional view of lubistor and typical I-V characteristics are shown in Figs. 1 and 2, respectively. When the bias configuration is as shown in Fig. 1(b), the lubistor shows a MOSFET-like tetrode characteristic at low anode voltages (V_A) and a forward-biased pn-junction-like triode characteristic at high V_A. It is an important point that the anode current is suppressed as the gate voltage (V_G) increases at high anode voltages.

Figure 3(a) shows, as an example, the simplest logic element, an inverter, which is composed of an nMOSFET/SOI and a p-p-n type lubistor. The logic element has a control gate terminal (denoted by "C"), an input signal terminal (denoted by "I") and an output signal terminal (denoted by "O"). Simulated results of input-output characteristics are shown as a parameter of the control gate voltage in Fig. 3(b). It can be seen that the output voltage (V_{out}) initially increases as the input voltage (V_{in}) increases and reaches the certain peak value of V_{op}. Subsequent increase in V_{in} leads to a steady fall in V_{out}. V_{op} and V_{ic} decreases as the control gate voltage (V_{cg}) increases. This characteristic is very interesting and useful.

3. Circuit applications and discussion

The characteristic of the element shown in Fig. 3 readily suggests a couple of new applications. A simple example is shown in Fig. 4. Fig. 4(a) shows a pair of basic elements in which each lubistor has a different gate width. Their input-output characteristics, which differ significantly, are shown in Fig. 4(b). Two basic elements are followed by a differential amplifier (denoted by "DA") and two pairs of CMOS inverters with different logic threshold voltages (V_{LT}). V_{cg} and the supply voltage are 3 V. Here, it is assumed that the $V_{in,1}$ and $V_{in,2}$ change with the same phase.

The difference of lubistor gate width yields different values of V_{op}, V_{ic} and two final output voltages. This means that output signal forms and levels are different even when the same input signals are used. When the gain of DA is unity, its input-output characteristics are shown in Fig. 4(c). Since the two pairs of CMOS inverters have different V_{LT}, their output signals differ greatly as shown in Fig. 4(d).

The important feature is that we can utilize the DA output signal as a source signal for neural logic signal operations. A very low-level signal below V_{ic}' is passed only to a CMOS inverter with low V_{LT} (CMOS(B) in Fig.4(c)), while a high-level signal that is below V_{ic}' is passed to both CMOS inverters (CMOS(A) and CMOS(B) in Fig.4(c)). On the other hand, a signal over V_{ic}' is passed to both CMOS inverters with low or high V_{LT} value. However, since the output signal level of the DA falls below the high V_{LT} consequently as shown in Fig. 4(c), such a high-level input signal is rejected as shown in Fig. 4(d) ($V_{out,A}$ of CMOS(A)). This is a very important feature of this logic circuit. The sensitivity of the basic element to the input signal can be controlled easily by the control gate "C" as shown in Fig. 3(b). When one of low-level output signals of the CMOS inverters connected to a certain basic element is fed back to the control gate [4], the output signal level of the basic element becomes very low. In other words, the basic element becomes quite insensitive to input signal level. Furthermore, an exclusive OR circuit with two inputs is easily realized using two identical basic elements in Fig. 4(a) [4].

Thus, the basic element can be applied to both digital and analog circuits for neural logic applications.

Acknowledgement

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References

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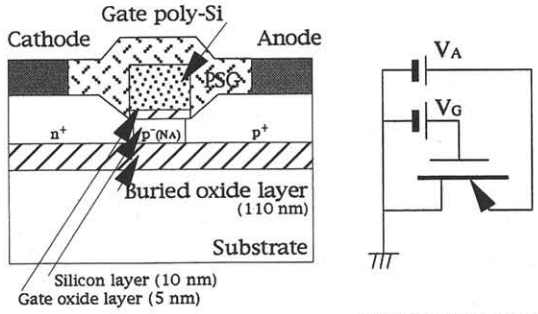
[3] Y. Omura: Appl. Phys. Lett. **40** (6) (1982) 528.
[4] Y. Omura, in submission.



(a) Schematic of the structure of insulated-gate pn-junction device (lubistor)

(b) Bias configuration for device operation and symbol of device

Fig. 1. Schematic of device structure and its symbol

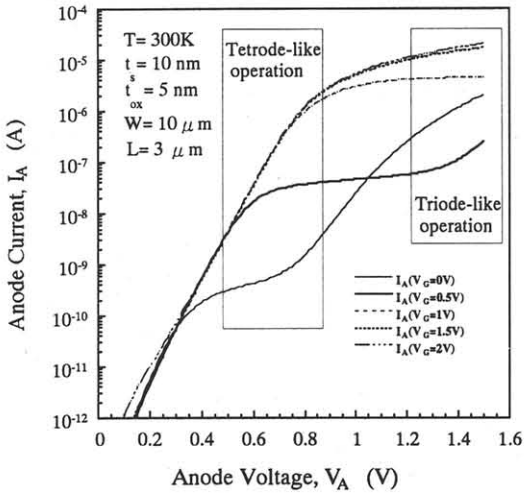
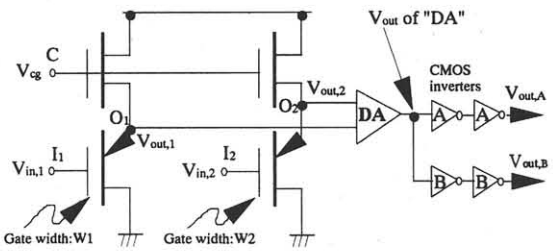
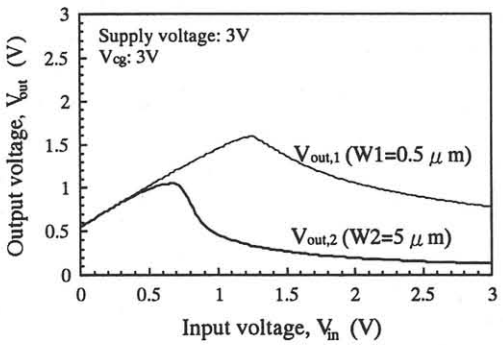


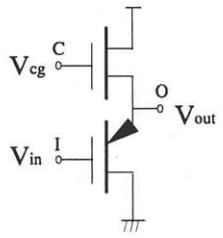
Fig. 2. Current-voltage characteristics of lubistor. Tetrode-like or triode-like characteristics is found in different regions.



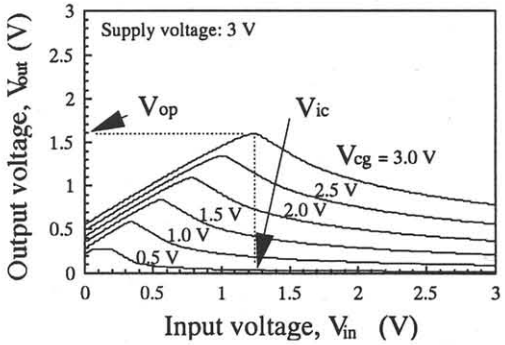
(a) An example of circuit application



(b) Input-output characteristics of basic logic elements

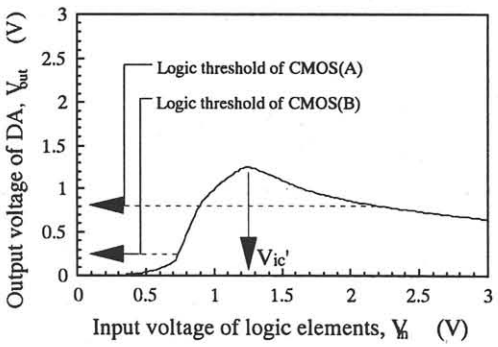


(a) Basic logic element

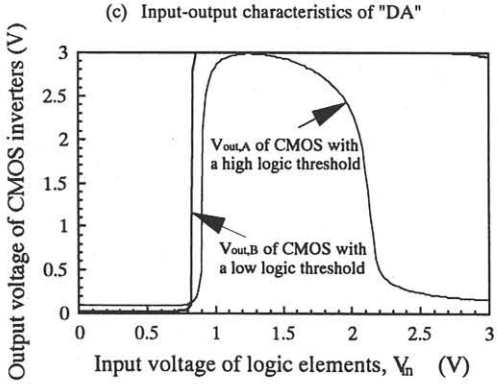


(b) Input-output characteristics of the basic logic element

Fig. 3. A basic element and input-output voltage characteristics



(c) Input-output characteristics of "DA"



(d) Input-output characteristics of CMOS inverters

Fig. 4. An example of circuit application and input-output characteristics