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B — 3 — 2 Lateral Unidirectional Bipolar-type Insulated-gate Transistors

-Operations, Characteristics and Applications-

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Structure and physical concepts of a new transistor, Lubistor(Lateral unidirectional bipolar-type insulated-gate transistor) have been proposed(1). In this paper, operation mechanisms, characteristics and applications of a new family of Lubistor as well as the previous one are discussed. Cross-sectional views of the Lubistors are shown in Fig. 1. A self-aligned gate(SAG) Lubistor(1) is shown in Fig. 1(a) and a new anode-offset gate(AOG) Lubistor in Fig. 1(b). Essential mechanism in the Lubistors is to control the minority-carrier injection from a p-n junction by a MOS gate. To achieve this operation, it is necessary that the thickness, t_c, of a semiconductor layer on the top of an insulator is less than the effective Debye length, L_{DE}(2). The Lubistors were fabricated on a buried oxide, formed by ion implantation of oxygen atoms into the silicon wafer. Device parameters are listed in Table I.

For the SAG-Lubistor, triode-like current-voltage characteristics shown in Fig. 2(a) were obtained from the positive anode-to-cathode voltage, V_{AK}, with the zero substrate-to-cathode bias. Anode-to-cathode current, I_{AK}, increases monotonically with increasing V_{AK}. The I_{AK}-V_{AK} curve shifts continuously toward the positive direction of V_{AK} as the gate-to-cathode voltage, V_{GK}, increases. Pentode-like current-voltage characteristics were also obtained from the negative cathode-to-anode voltage, V_{KA}.

For the AOG-Lubistor, conventional pentode-like current-voltage characteristics shown in Fig. 2(b) were obtained from the positive V_{AK} in contrast to the SAG-Lubistor. Triode-like current-voltage characteristics, of cource, were obtained from the negative V_{KA}. I-V characteristics features of the Lubistors are summarized in Table II.

The mechanism behind the Lubistor's operation is speculated to be as follows. As accumulation layer thickness is approximately equal to $(\pi/2)L_{DE}$(2), the electron concentration over the channel region is able to be enhanced at $V_{GK}>V_{FB}$ in case of $t_c<L_{DE}$. V_{FB} stands for the flat-band voltage. The "OFF" state is achieved at $B(V_{GK}-V_{FB})>V_{AK}$, where $B<1$. As long as the relationship holds, the number of electrons in the channel region is enhanced: namely, the potential of confined conductive layer is able to be kept high, because the gate oxide is much thinner than the buried oxide. As a result, hole injection from the anode is limited. The "ON" state is achieved at $V_{AK}>B(V_{GK}-V_{FB})$. The anode junction is effectively forwardly biased, by the amount of $V_{AK}-B(V_{GK}-V_{FB})$. A large number of holes are injected from the anode. It is believed that all the holes recombine in the channel region, which is suggested by the experimental result that I_{AK} is expressed by $[V_{AK}-B(V_{GK}-V_{FB})]^n$.

On the other hand, the mechanism behind the AOG-Lubistor's operation is speculated to be as follows. In Lubistors, it is believed that the channel length must be longer than the diffusion length of minority carriers. The "OFF" state is achieved at $V_{GK}<V_{TH}$, where V_{TH} is the threshold voltage: namely, electrons are not injected from the cathode since the channel region under the gate is depleted completely at the threshold and holes injected from the anode recombine completely just this side of the cathode. The "ON" state is achieved at $V_{GK}>V_{TH}$. On this condition, a neutral region exists under the gate, and electrons injected from the cathode are transported to the anode. The amount of injected electrons are successfully controlled by the gate because of $t_c<L_{DE}$: that is, a higher V_{GK} leads to a larger I_{AK}.

Anode current increases monotonically with increasing V_{AK} at $V_{AK}<V_{GK}$. At $V_{AK}>V_{GK}$, on the other hand, the potential of the channel region beneath the anode-side gate edge becomes larger than the gate potential: the corresponding channel region is depleted. As a result, I_{AK} saturates because the supply of electrons is limited.

Generally, in Lubistors, a high current density, of the order of $\sim 10^5$A/cm^2, and a few times as large transconductance as conventional MOSFETs are easily achieved. Therefore, Lubistors are applicable not only to high-frequency and high-power analog devices, but also to the active matrix in display devices which require the ability to drive a heavy load.

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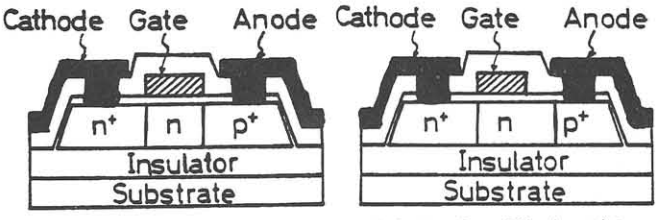
(1) Y. Ōmura, Appl. Phys. Lett. March(1982).

(2) Y. Ōmura and K. Ohwada, Solid-St. Electron. vol. 24, pp. 301(1981); a relevant discussion has been presented there.



(a) Self-aligned gate Lubistor

(b) Anode-offset gate Lubistor

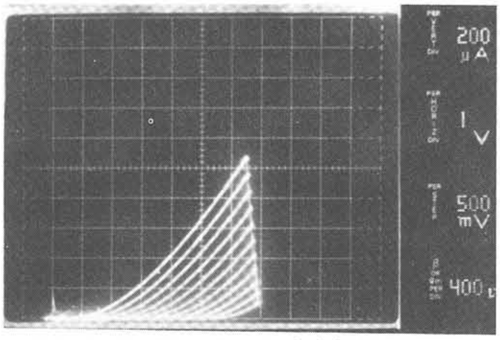
Fig. 1. Cross-sectional views of Lubistors

Table I. Device parameters

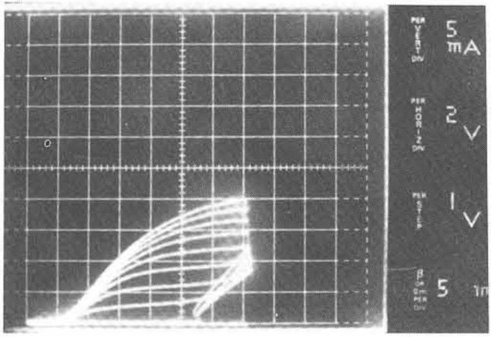
Channel region thickness	0.11, 0.26 µm
Doping concentration in the channel region	4×10^{14}, 1×10^{16}atoms/cm^3
Gate oxide thickness	50 nm
Buried oxide thickness	0.47 µm
Gate length	5 µm
Gate width	30, 35 µm

Table II. I-V characteristics features of Lubistors

Devices / Bias	SAG-Lubistor	AOG-Lubistor
$V_{AK}>0$ $(V_{GK}>0)$	Triode-like	Pentode-like
$V_{KA}<0$ $(V_{GA}<0)$	Pentode-like	Triode-like



(a) Self-aligned gate Lubistor



(b) Anode-offset gate Lubistor

Fig. 2. I_{AK}-V_{AK} characteristics of Lubistors