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Switching Characteristic of a High Voltage BMFET

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ABSTRACT: In past paper it has shown a power device can be obtained a FET working in a bipolar mode (BMFET). This paper explains how a BMFET has been improved to obtain a bocking voltage of up to 1500 V and a full Reverse Bias Safe Operating Area.

1-INTRODUCTION

Structure obtained from the basic vertical JFET configuration have recently been proposed (1-2). These devices have been named according to the way in which the current flow is controlled: SIT, BSIT, JFET etc; the output characteristic follow the ohmic (JFET) or exponential relationship (SIT) or show a current saturation after an almost ohmic characteristic (BSIT).

Some devices are normally off at V_{GS}=0 (BFET; JFET, SIT).

But a power device must show:

- normally off characteristic until BV (at V_{GS}=0)
- low Ron
- switching efficiency 99%.

None of the above mentioned devices have these 3 characteristics at the same time. We have recently presented a device with these characteristics, achieved by a switable layout and physical design; we have called this device the BMFET.

2-BMFET DESCRIPTION

A cell of the BMFET is shown in fig.1. The layout is the same as in LSI. The source strips are 6um the resulting channel is 1.5um and the metal strips are 8um. The cells are repeated to obtain a device with the requested Ron. The device is completely sorrounded by an edge structure to obtain voltages higher than those possible with the usual planar jiunction (see figs. 2 and 3). The length and width of channel are such that there is no static induction until the breakdown voltage is reached (fig.4).

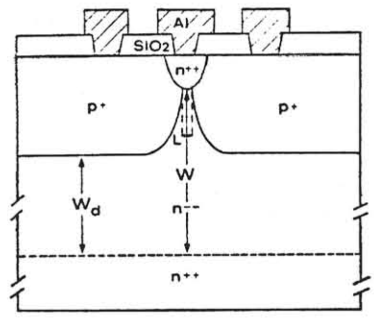

fig.1- Basic cell schematic structure

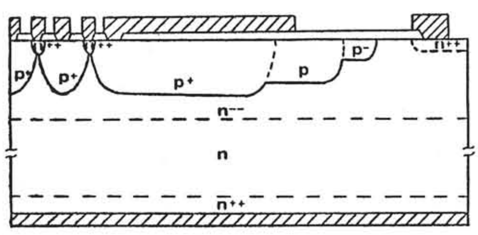

fig.2- Schematic structure of the basic cell (left) and of the H.V. termination (right).

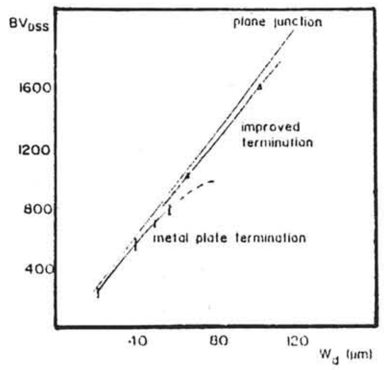

fig.3- BV Versus epilayer thickiness.

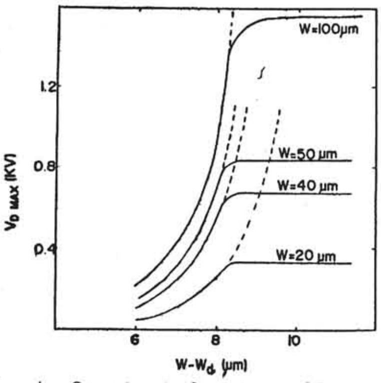

fig.4- Static induction effect versus channel lenght.

3-DISCUSSION

In the BMFET the channel is completely pinched off also at zero voltage. The potential barrier blocks the current flow from the source to the drain (figs. 5 and 6).

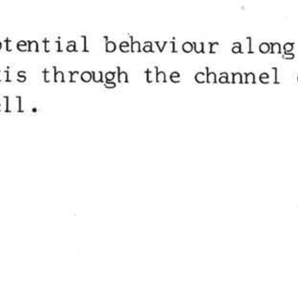

fig.5- Potential behaviour along the vertical axis through the channel of the basic cell.

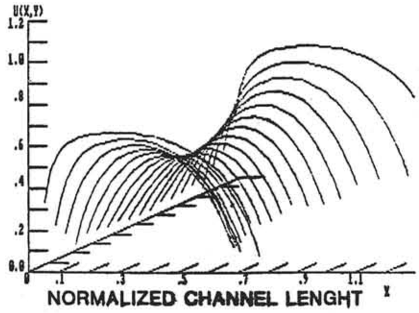

fig.6- Bidimentional plot of the potential within the channel.

The effect of static induction is negligeble due to the high resistivity of the drain epi-layer. The Ron of the device is reduced by the minority carriers injected in the drain from the gate by a positive bias. This positive bias also reduces the barriers height and opens the channel.

Three phenomens can be distinguished in the operation of the device:

- electron injection through the potential barrier;
- the diffusion of majority carriers across the drain;
- the presence of positive and negative carriers in the channel and under the gates.

These three phenomens ensure that inside the channel the majority carriers are moved by an electric field, overcoming the voltage barriers. In the drain however they move by diffusion and in high injection the current can be represented approximation:

$$j = 2qD\frac{dn}{dx} = \frac{2q\,n(0)}{W}$$

It follows that h_{FS} depends the reserve ratio of the square of the drain thickness and by the reverse ratio means that the BMFET in high current behaves as a bipolar transistor (figs. 7 and 8).

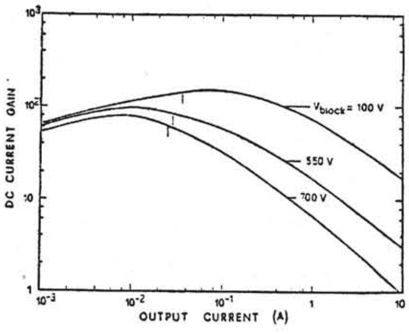

fig.7- h_{FS} Versus I_D

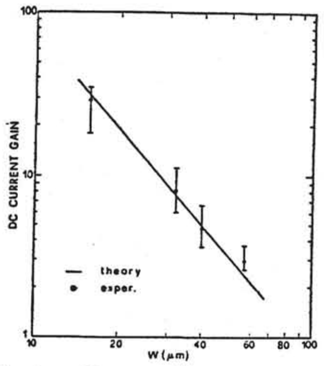

fig.8- h_{FS} Versus W_D

It has been experimental proved that it behaves as a bipolar transistor also in switching.
So to reduce the switching losses and to mantain the normally off characteristic a double epitaxial layer has been designed. The upper layer has a high resistivity while the lower layer has one which allows the requested breackdown and minimize the switching losses (fig. 9).

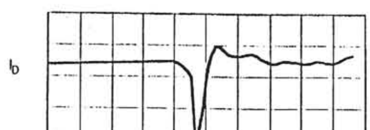

fig.9- Swithing losses reduction (B instead if A)

The final structure is shown in fig. 10.

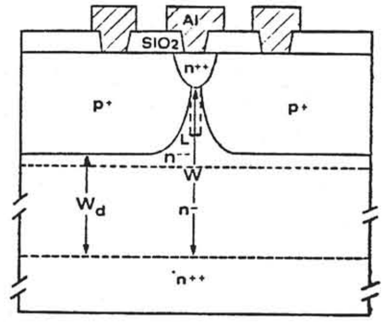

fig.10- Improved structure.

An important feature for devices to be used in switching is the ability to switch the maximun current possible at a given voltage. The Reverse Bias Safe Operating Area is the most important curve for a power device.
The secondary breakdown witch limits the maximin current is due to local concentration of high current density. Generally there is a current crowding in the center of the cell structure. The small source width greatly reduced this crowding.
Besides this, when not in the condition of high injection, there is no transversal current flow in the channel and so there is no crowding.
This means that the BMFET is able to switch off the maximun current at the maximun voltage BV (figs.11 and 12). In fig.13 typical switching times are shown.

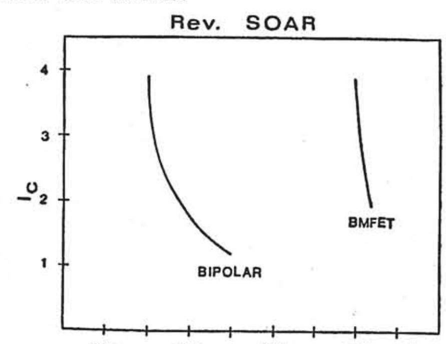

fig.11- 700 V BMFET and BJT comparison.

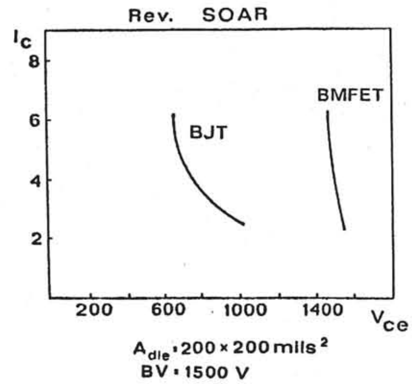

fig.12- 1500 V BMFET and BJT comparison.

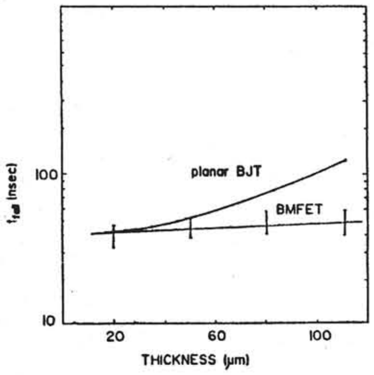

fig.13- tfall Versus drain thickness.

4-CONCLUSION

The device presented has a D.C. characteristic similar to a bipolar transistor.

- it is off at V_{GS}=0 up to BV_{DSS}
- it has a similar h_{FS} Versus current.

In switching it has notable advantages the RBSOA is much larger: a comparison with the best commercially available transistors shows an improvement in the switched power for unit by a factor of 2.

References

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