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A-7-1 A NEW BIPOLAR TRANSISTOR WITH GATES PROJECTED INTO COLLECTOR REGION

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Recently, power amplifications in class D and E have attracted much attention to their high efficiency operations. Transistors used for these purposes are required to have high cut-off frequencies and high breakdown voltages simultaneously. But it is difficult for coventional bipolar transistors to satisfy these requirements, because a thin base width necessary to realize a high cut-off frequency causes the reduction of breakdown voltage.

A new bipolar transistor is proposed here to break through the above difficulty. Fig.1 shows a schematic cross section of the new transistor. It has a unique base region. A part of the base region operates as an ordinary base at ON condition. Another part of the base region, projected into collector region and doped with higher impurity concentration than the others, acts as gates of J-FET at OFF condition.

Features of the new transistor are as follows:

1) The new transistor has higher breakdown voltage than the conventional transistor when both transistors have a same base width. For example, the new transistor with a base width of 0.2μm had the breakdown voltage of 200V, while the conventional one with a same base width had that of 20V.
2) The new transistor has a thinner base width than the conventional transistor to attain a same breakdown voltage. From this result, the cut-off frequency of the new transistor is higher than that of the coventional one.
3) The new transistor has a shorter fall time t_f than the conventional transistor when the base width is thin, because highly doped gates decrease the transverse base resistance.

Fig.2 shows an equivalent circuit of the new transistor. As the gates are designed to pinch off the channel between them, FET action at OFF condition raises the breakdown voltage of the new transistor $1+\mu$ times as large as that of the conventional transistor. μ is the voltage amplification factor of the J-FET.

Fabrication of the new transistor was realized by adding only one diffusion process to a conventional bipolar transistor fabrication processes.

Table 1 shows typical electrical characteristics of the new transistor and conventional transistor. The base width of the former was one tenth of that of the latter. Therefore, the cut-off frequency of the former increased by 4 times that of the latter. Rise time t_r , storage time t_s and fall time t_f were decreased in the former.

The new transistor had a cut-off frequency of 80MHz and a breakdown voltage of 500V.

Fig.3 shows a relation of the emitter-collector voltage V_{EC} at second breakdown and ON state collector current I_C when the transistor with an inductive load is turned off. The safe operation region of the new transistor with a base width of 1μm was larger than that of the conventional transistor with a same base width and comparable to that of the latter with a base width of 10μm.

In conclusion, the new transistor could have a high breakdown voltage even though its base width was made thin enough to cause punch-through in the case of the conventional transistor. It had a high cut-off frequency without reduction of the breakdown voltage. Transistors with a cut-off frequency of 80MHz and a breakdown voltage of 500V were developed for the first time in the power devices.

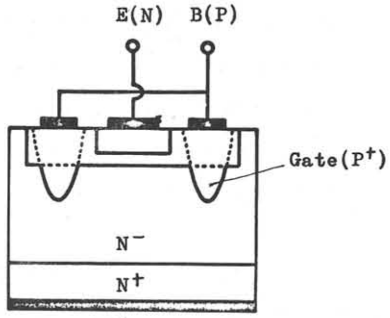

Fig.1 A schematic cross section of the new transistor

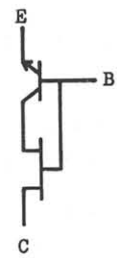

Fig.2 An equivalent circuit of the new transistor

Table 1 Electrical characteristics of the new transistor & the conventional transistor

	New TR.	Conv. TR.
V_{CBO} (V)	500	500
I_C (A)	10	10
f_T (MHz)	80	20
t_r (μS)	0.11	0.16
t_s (μS)	0.24	2.6
t_f (μS)	0.07	0.34
h_{FE}	36	30

Ackowledgements:

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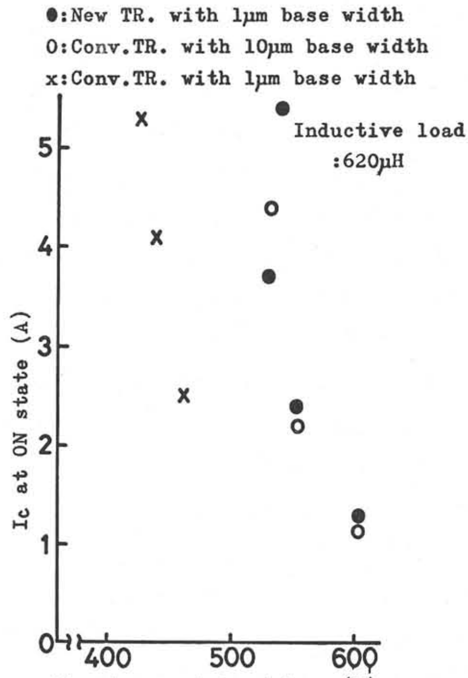

V_{EC} at second breakdown (V)

Fig.3 A relation of V_{CE} at second breakdown and Ic at ON state