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A New Lateral Dual-Gate Thyristor with Current Saturation

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1. Introduction

MOS-gated thyristor, which has the advantage of high input impedance of MOSFET and low forward voltage drop of thyristor, has attracted attentions as a power device. Recently, lateral MOS-gated thyristor has received considerable attentions in applications of PICs (Power Integrated Circuit) because of reduction in chip size[1]. However, as gate voltage is increased, conventional MOS-gated thyristor such as MCT, BRT and EST has the problems in device-control, which result from the latch-up of parasitic thyristor [2,3].

In this paper a new lateral dual-gate thyristor was proposed and fabricated, which has shown excellent current saturation characteristics of 1200A/cm^2 even at a 29V anode-gate voltage, by eliminating the parasitic thyristor. The excellent current saturation characteristics of the new device were verified through the comparison with the LIGBT at both 25℃ and 125℃.

2. Structure and operation principle

The structure of a new lateral dual-gate thyristor is shown in Fig.1.

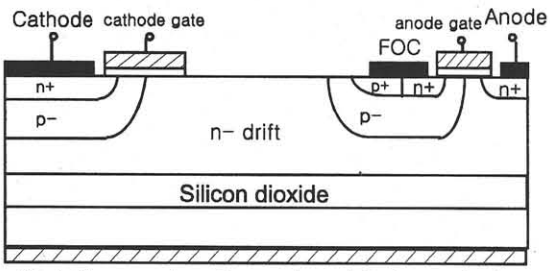

Fig.1 Cross section of a new lateral dual-gate thyristor

The n+ anode was substituted for p+ anode of conventional MOS-gated thyristors in order to eliminate parasitic thyristor structurally. The p+ under FOC(Floating Ohmic Contact) was inserted intentionally for injection of holes in thyristor action. NMOSFET, which consists of the n+ under FOC, the n+ anode and the anode-gate, controls total currents in the proposed device by applied anode-gate voltages.

Device operation principles are as follows. Positive voltage is applied at cathode-gate and anode-gate. At first, the device operates like LDMOS because electrons injected from cathode enter n+ anode via n-drift region. As anode voltages is increased, increased amounts of electrons, which were injected from cathode, induce voltage drop under the p-well. Holes are injected from the p+ to the n-drift region at about 0.7V voltage drop between pn junction. By the charge conservation in FOC[4], same amounts of electrons move to n+ anode through n-channel. The injected holes are accumulated in the p-base until the junction between the p-base and the n+ cathode turns on. At the turn-on, a thyristor which consists of the p+, the n-drift, the p-base and the n+ cathode, begins to turn on. Because the amount of hole currents injected from the p+ under FOC are identical to that of electron currents passing via NMOSFET, the thyristor currents are determined by anode-gate voltages which control electron currents passing via NMOSFET. By eliminating parasitic thyristor in device structure, the proposed device has no problem in device control caused by parasitic thyristor latch-up, so it exhibits excellent current saturation characteristics even at high anode voltages.

3. Device parameters and fabrication process

Parameters used in fabrication are summarized in Table 1. The process went on as following sequences. After the gates were formed first, the p-well and the p-base and then the p+ under FOC were formed by implantation and drive-in. Then the n+ cathode, the anode and the n+ under FOC were formed. Finally, metal electrodes was formed.

Table 1. Device parameters

Experimental Parameters	Data
Concentration of N-epi layer	$6\times 10^{14} cm^{-3}$
Concentration of p- base	$5\times 10^{17} cm^{-3}$
Thickness of p- base	2 um
Thickness of epitaxial layer	5 um
Thickness of buried SiO_2	1 um
Thickness of gate oxide	500Å
Drift length	15 um

4. Experimental forward I-V characteristics

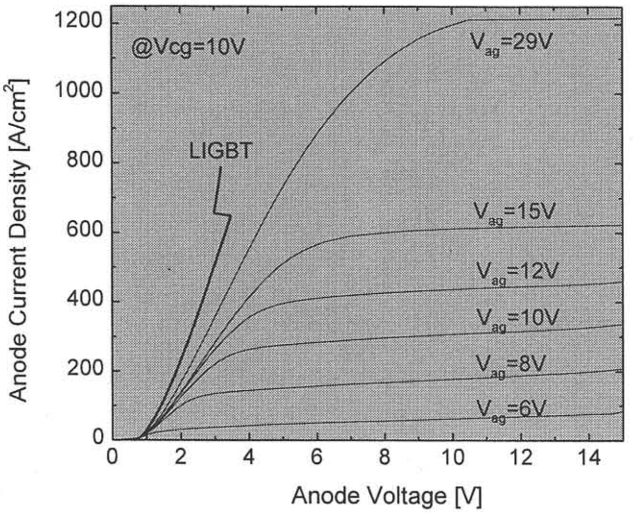

Fig.2 Forward characteristics of the proposed device and LIGBT

Fig.2 shows measured forward I-V characteristics of the proposed device and LIGBT. 10V cathode gate was applied. As the anode-gate voltage is increased, electron current passing the n-channel of NMOSFET increases. Hole current injected from the p+ under FOC also increases by charge conservation in FOC. Therefore, thyristor current is increased at increased anode-gate voltages. In case of LIGBT, at an increased anode-gate voltage, gate control was lost because of the latch-up of parasitic thyristor at 670A/cm^2. However, the proposed device, exhibited excellent current saturation characteristics even at high anode-gate voltages because it eliminated the parasitic thyristor in device structure. At anode-gate voltage of 29V, current saturation characteristics of current density of 1200 A/cm^2 was obtained.

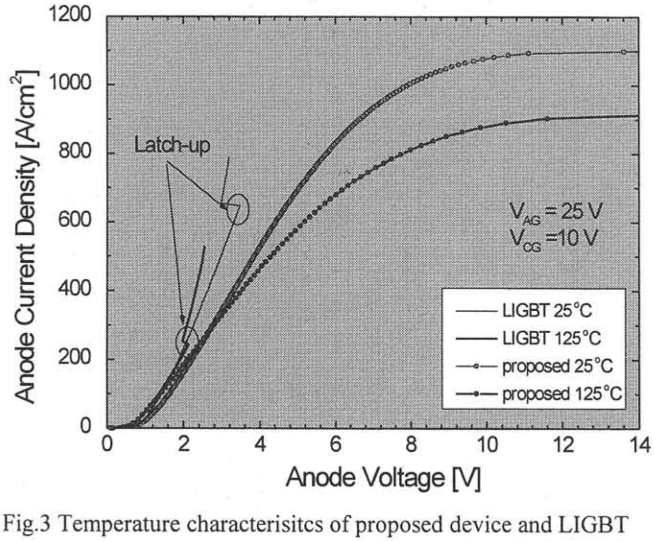

Fig.3 Temperature characterisitcs of proposed device and LIGBT

Fig.3 shows the temperature characteristics of the proposed device, compared with LIGBT. At 125℃, the latch-up current density of LIGBT was significantly reduced to 220A/cm^2. On the other hand, at 125℃, the proposed device exhibited excellent current saturation characteristics and better forward voltage drop characteristics than that of 25℃. Therefore, the proposed device also has advantages in high temperature operations.

5. Conclusions

A new lateral dual-gate thyristor was proposed and fabricated. The device exhibited excellent current saturation characteristics of 1200 A/cm^2 at high anode voltage of 29V because it has no parasitic thyristor in structure. The proposed device could be attractive in applications such as PICs and lamp ballast which need the stable operations of device at high temperature.

References

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