A Novel Trench Electrode BRT with the Intrinsic Region for Power Electronics

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Abstract: In this paper, we have proposed a novel trench electrode Base Resistance Thyristor(BRT) and trench electrode BRT with a intrinsic region. A new power BRTs have shown superior electrical characteristics including snab-back effect and forward blocking voltage more than the conventional BRT. Especially, the trench electrode BRT with intrinsic region has obtained high blocking voltage of 1600V. The blocking voltage of conventional BRT is about 400V at the same size. Because the breakdown mechanism of BRT is avalanch breakdown by impact ionization, the trench electrode BRT with intrinsic region has suppressed impact ionization, effectively. If we use this principle, we can develope super high voltage power device and applicate to another power device including IGBT, EST and etc.

1. Introduction

The ratings of the EST and the BRT are expressed as the maximum controllable current density, the forward breakdown voltage and the snap-back voltage. The low snap-back voltage and the maximum controllable current density have been improved by the reformation of the structure but the forward breakdown voltage has not made big advances yet.

Therefore, in this paper, a trench electrode BRT with an intrinsic region, which has a superior breakdown voltage as well as a suppressed snap-back voltage, has been proposed. The two dimensional numerical simulations were carried out using MEDICI to verify the validity of the device.

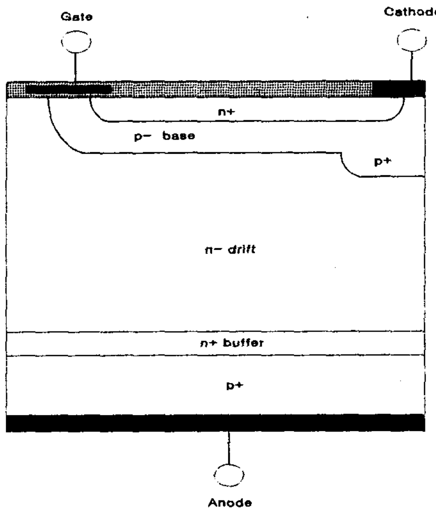
2. Device structures and operation

Cross sections of the conventional vertical BRT structure and the trench electrode BRT structure with the intrinsic region are shown in Fig. 1. Design parameters of the devices are shown in Table 1.

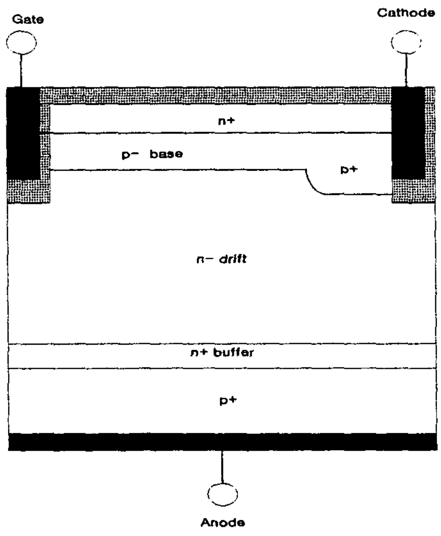
In this paper, the cathode and gate electrodes have been replaced by the trench type of the proposed device. Thus, forward operation of the proposed device is the same as that of the conventional device. Forward operation of the BRT is started by applying a voltage higher than the threshold voltage at the gate. Electrons depart from the n+ emitter and are injected into the n- drift region via the n+ cathode region and n- channel. The injected electrons as a base current in the pnp transistor drive the transistor.

In this manner, since the BRT device is turned-on in the transistor mode at the initial stage, it exhibits a high on-state resistance. As the anode voltage is increased gradually, the amount of holes injected from the p+ anode region is increased thus that of holes arrived at the p- base region is also increased. If the hole current is increased, the potential within the junction reaches 0.7V, the junction between the p- base region and the n+ cathode region is turned-on in the forward direction, and the npn transistor is turned-on in the end. In this case, the device operates in the thyristor mode and exhibits a low on-state resistance.

Because of the difference of the on-state resistance in operation of the two devices, a snap-back region including a negative-resistor region is formed. However, it is considered that so far the many studies of the snap-back characteristic have been accomplished and the remarkable improvement of the snap-back has been achieved to some extent.



(a)



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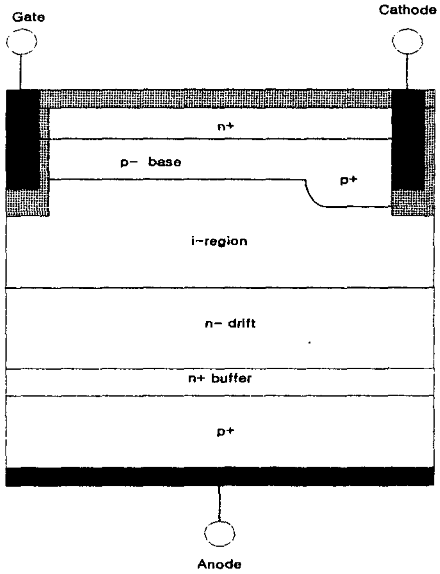

(c)

Fig. 1 The structures of the conventional and the proposed trench electrode BRTs (a) the conventional BRT (b) the proposed trench electrode BRT (c) the proposed trench electrode BRT with the i-region

Table 1. Device parameters used in the simulations

	Width (㎛)	Depth (㎛)	Concentration (cm^{-3})
N drift region	40	55	1×10^{14}
N+ Cathode region	10	0.5	1×10^{21}
P base region	22	2.5	1×10^{16}
P+ Cathode region	8	3.5	1×10^{18}
P+ Anode region	40	1.5	1×10^{21}
N+ Buffer region	40	3.0	1×10^{18}
Trench oxide region	5	6	
Electrode oxide region	40	0.0001	
Gate oxide region		0.00005	
Channel length	5		

For the case of the proposed structures, since all the electrodes are formed by the trench structures, the electric field applied within the devices is concentrated on the formed trench oxide layers. Thus, the higher breakdown voltage can be maintained when compared to that of the conventional structure.

The BRT structure with the i-region as shown in Fig. 1(c) have been proposed and they exhibit the considerably excellent breakdown characteristic maintaining the superior snap-back characteristic when compared to the conventional device.

3. Simulation and results

For The forward conduction characteristics of the conventional general-purpose device and the proposed devices with a depth of devices of 70 ㎛ are shown in Fig. 2. All of the proposed devices exhibit the superior snap-back characteristic shown at 0.9～1.1V when compared to the conventional general-purpose device that exhibits a snap-back voltage of 1.7V or so. Besides, the proposed device without the intrinsic region that has more carriers is found to exhibit the snap-back earlier by about 0.2V when compared to the corresponding proposed device with the intrinsic region.

The forward breakdown characteristic of the conventional general-purpose device and the proposed devices are shown in Fig. 3. For the case of the conventional device, the breakdown occurs at a voltage of 400V while the trench electrode device has a breakdown voltage of about 700V. The measured proposed device with the i-region provided a breakdown voltage of about 1000V in spite of a depth of the device of 70 ㎛.

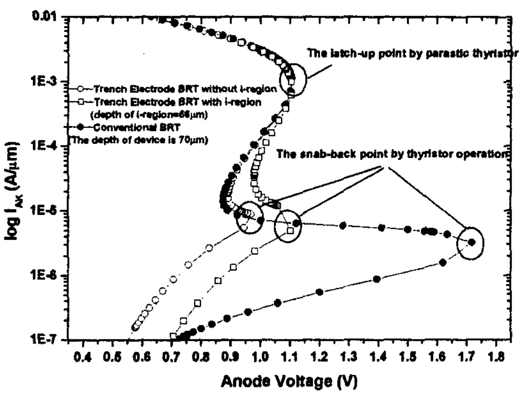

Fig. 2 The I-V characteristics of the conventional BRT and the proposed BRTs (The depth of devices=70 ㎛)

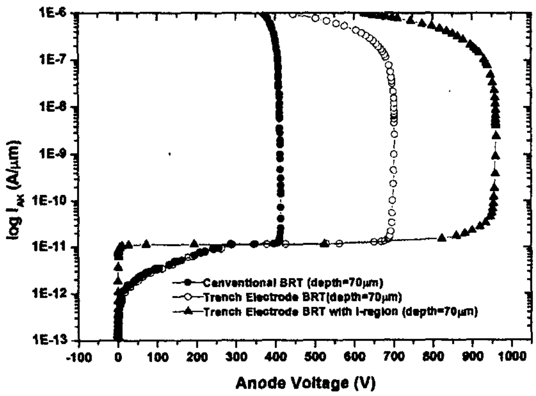

Fig. 3 The forward blocking characteristics of the conventional BRT and the proposed BRTs (The depth of devices=70 ㎛)

The depth of the i-region and the corresponding breakdown characteristics of the proposed BRTs are shown in Fig. 4. It can be observed that the highest forward breakdown voltage is obtained at the depth of the i-region of 70 μm which, in other words, has replaced the whole n-type epi layer. In this paper, the high blocking voltage of about 1000V can be obtained just by introducing an i-region without adjusting a size of device.

The measured forward conduction characteristics are shown in Fig. 5 with a depth of designed devices of 200 μm to raise the breakdown voltage up to more than 1000V. Since the conventional device exhibits the snap-back at a voltage of 6.0V, the device increased in size is expected to have a increased breakdown voltage, but it is supposed that a considerably serious result would be produced at a point of view of power dissipation. The trench electrode BRT without the i-region has a pretty excellent snap-back voltage of 1.6V which shows just little difference when compared to the device with a depth of 70 μm. The trench electrode BRT with the i-region exhibits the snap-back at a anode voltage of 4.5V due to lack of carriers though it has a trench electrode structure.

For the case of a depth of devices of 200 μm, the breakdown characteristics of each device are shown in Fig. 6. The breakdown of the conventional device occurs at a voltage of 400V which is the same as that of the device with a depth of 70 μm. The trench electrode BRT without the i-region also has a breakdown voltage of about 760V which is the same as that of the device with a depth of 70 μm. However, the trench electrode BRT with the i-region exhibits a breakdown voltage of 1600V which is 4 times higher than the conventional device since the drift layer makes impact ionization delayed.

To look into the breakdown characteristic in relation to the introduction of an i-region definitely, the breakdown voltages of the proposed BRTs according to the depth of the i-region are shown in Fig. 8. The breakdown voltage is found to increase in proportion to the depth of the i-region to a certain extent but decrease when the depth exceeds a critical value.

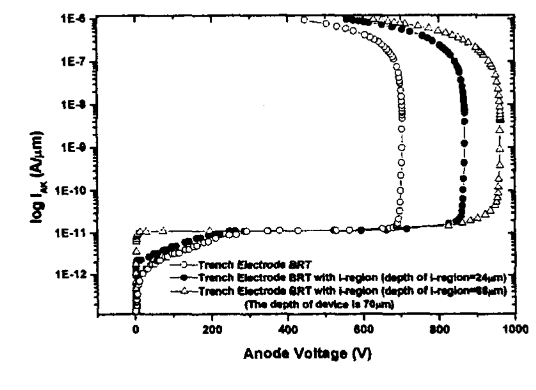

Fig. 4 The forward blocking characteristics of the proposed BRTs according to the depth of the intrinsic region (The depth of devices=70 μm)

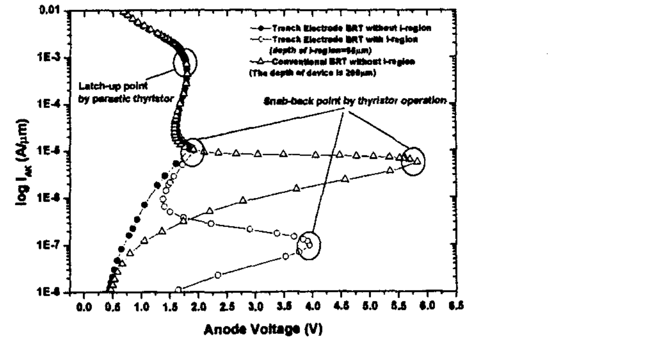

Fig. 5 The I-V characteristics of the conventional BRT and the proposed BRTs (The depth of the devices=200 μm)

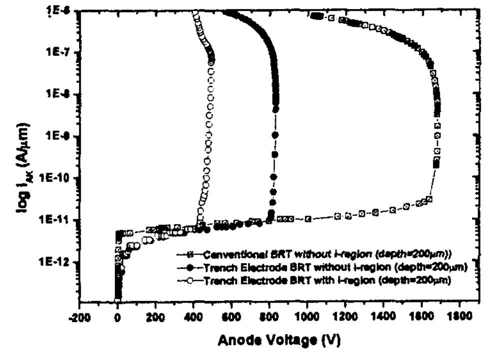

Fig. 6 The forward blocking characteristics of the conventional BRT and the proposed BRTs (The depth of the devices=200 μm)

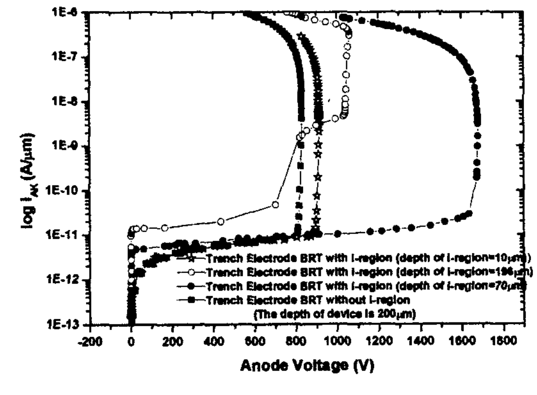

Fig. 7 The forward blocking characteristics of the proposed BRTs according to the depth of the intrinsic region (The depth of devices=200 μm)

4. Conclusion

In this paper, two types of power BRT structures have been proposed to improve their electrical characteristics including the blocking voltage. First, a trench electrode BRT device has been proposed to improve its blocking voltage and snap-back characteristic. Second, a trench electrode BRT device with an i-region has been proposed to obtain high blocking voltage. The two proposed devices have superior electrical characteristics when compared to conventional devices, and especially the i-region established structure, which has been introduced for the first time, was found to improve remarkably the breakdown characteristic which is dominated by avalanche breakdown.. It is supposed that a BRT device with extremely high blocking voltage which is more than 2000 to 3000V can be developed by using this principle and it is possible enough to apply to other power devices such as IGBT, EST, and Thyristor, etc.

5. Acknowlegement

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