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Superjunction MOSFET with a Trench Contact and Embedded SiO2 Insulator for Excellent Reverse Recovery

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ABSTRACT

A new superjunction MOSFET (SJ-MOSFET) with a trench contact and embedded SiO_2 insulator (ESO) is proposed and investigated by TCAD simulations. At the reverse conduction state, since electrons in the n-pillar can be easily collected by the trench contact, the hole injection efficiency of the body diode can be lowered to reduce the reverse recovery charge (Q_{rr}). In addition, the SiO_2 insulator is embedded in the p-pillar, which can increase the resistance of the hole extraction path during reverse recovery so as to reduce the current recovery rate (di_r/dt) from the peak reverse current (I_{rrm}) to zero. Simulation results show that, compared with the conventional SJ-MOSFET, Q_{rr} and di_r/dt of the proposed SJ-MOSFET can be reduced by 44% and 82%, respectively.

DEVICE STRUCTURES

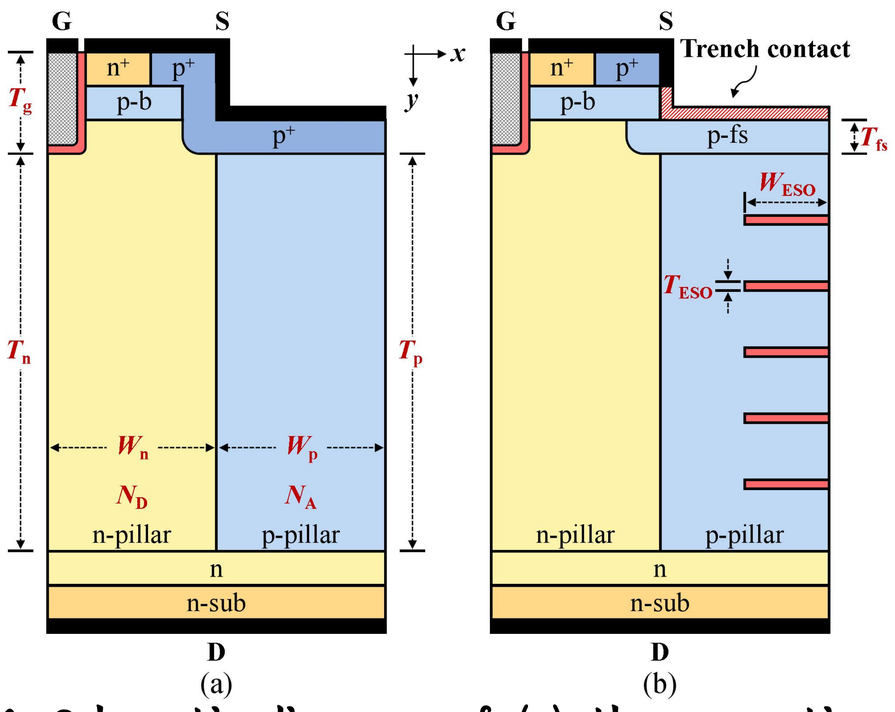

Figure 1. Schematic diagrams of (a) the conventional SJ-MOSFET; (b) the proposed SJ-MOSFET.

The trench contact on the p-b region and p-fs layer can be a Schottky contact or ohmic contact. Furthermore, a 5-layer SiO_2 insulator is embedded in the p-pillar.

KEY PARAMATERS

Parameters	Conv. SJ	Prop. SJ
N_D (cm^{-3})	4×10^{15}	4×10^{15}
N_A (cm^{-3})	4×10^{15}	4×10^{15}
W_n (μm)	2	2
W_p (μm)	2	2
T_n (μm)	38	38
T_p (μm)	36	36
T_g (μm)	2.5	2.5
T_{fs} (μm)	-	0.5
D_{fs} (cm^{-2})	-	1.7×10^{12}
W_{ESO} (μm)	-	1.0
T_{ESO} (μm)	-	0.1

Table 1. Key Parameters of the conventional SJ-MOSFET and the proposed SJ-MOSFET.

The number of Embedded SiO_2 Insulator (ESO) layers are 5. The doping dose of the p-fs layer (D_{fs}) is set to be 1.7 $\times10^{12}$ cm^{-2} to avoid the punch-through breakdown.

BLOCKING CHARACTERISTICS

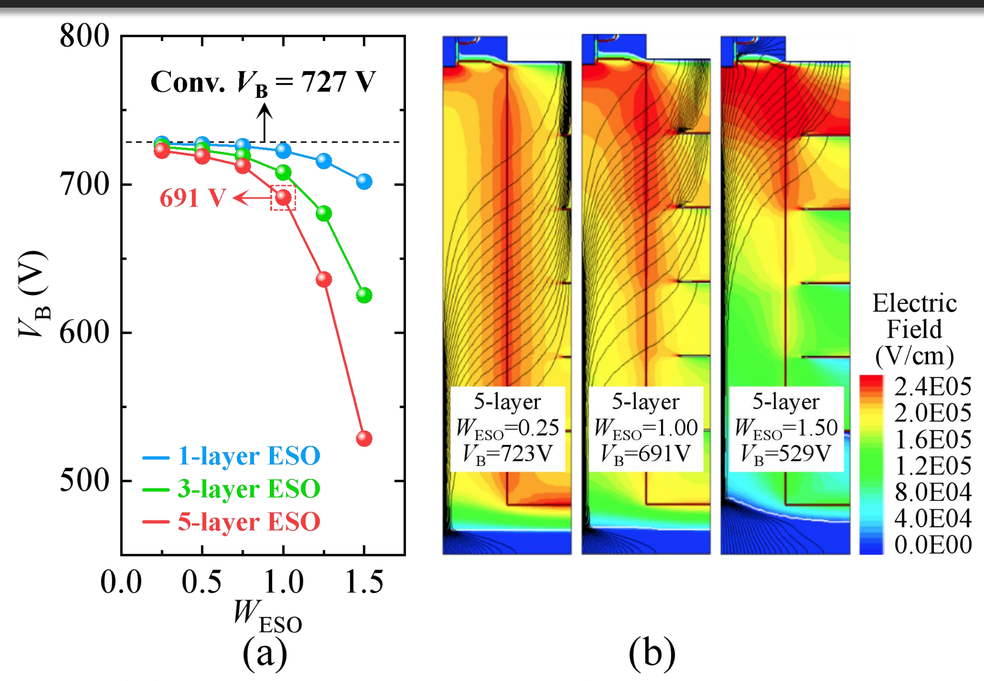

Figure 2. (a).Effects of W_{ESO} on breakdown voltage; (b) Distributions of electric field and current flowlines under V_B.

With the increase of W_{ESO} and the number of ESO layers, V_B shows a decreasing trend. V_B of the Conv. and the Prop. are 727 V and 671 V, respectively.

REVERSE CONDUCTING CHARACTERISTICS

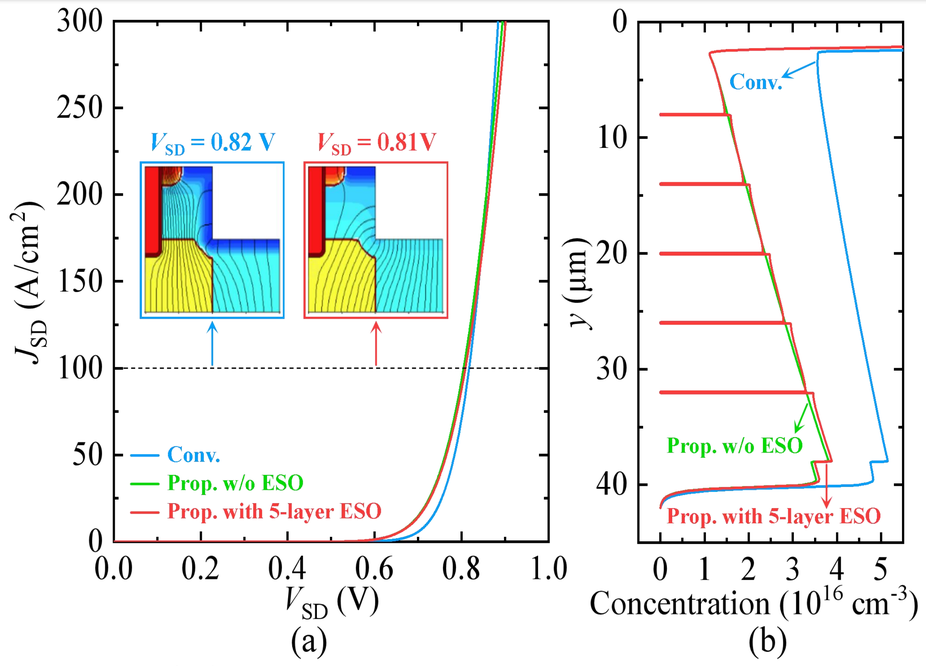

Figure 3. (a).Reverse conducting IVs and current flowlines distributions at J_{SD} = 100 A/cm²; (b).Hole distributions along x = 4 μm at J_{SD} = 100 A/cm².

The carrier-storage in the p-pillar of the proposed SJ-MOSFET and the case without the ESO is much lower than that of the conventional SJ-MOSFET.

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REVERSE RECOVERY WAVEFORMS

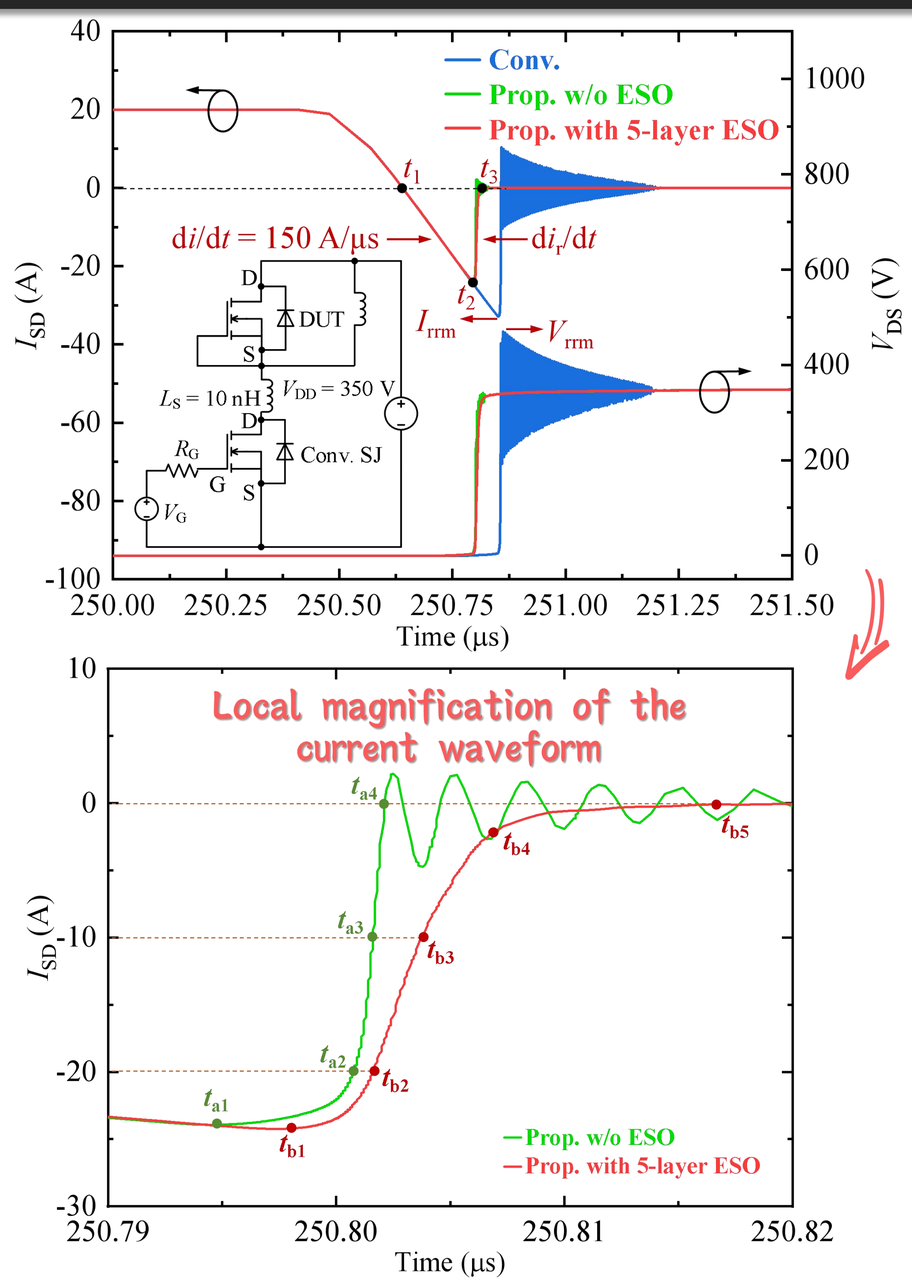

Figure 4 & Figure 5. Reverse recovery waveforms of body diodes and the simulation circuit.

The t_r and the di_r/dt of the conventional SJ-MOSFET are 3.93 ns and 8004 A/μs, respectively. The t_r and the di_r/dt of the proposed SJ-MOSFET are 16.17 ns and 1432 A/μs, respectively.

PROCESS OF REVERSE RECOVERY

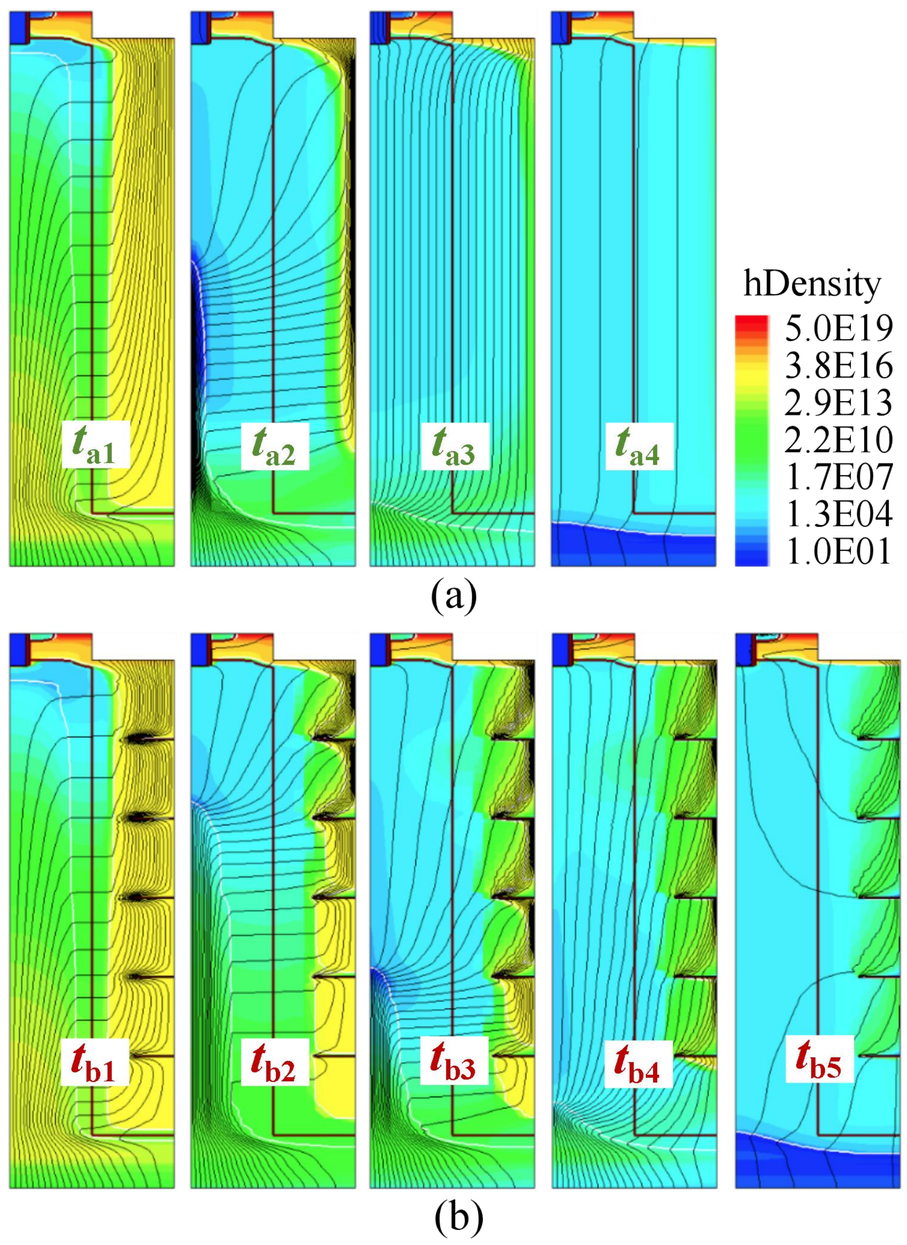

Figure 5. Distributions of hole density and current flowlines during t_2 - t_3.

During the second stage (t_{b2} - t_{b5}), the stored holes will be extracted through the high-resistance depletion region. So, the second stage has a positive impact on decreasing di_r/dt.

OTHER CHARACTERISTICS

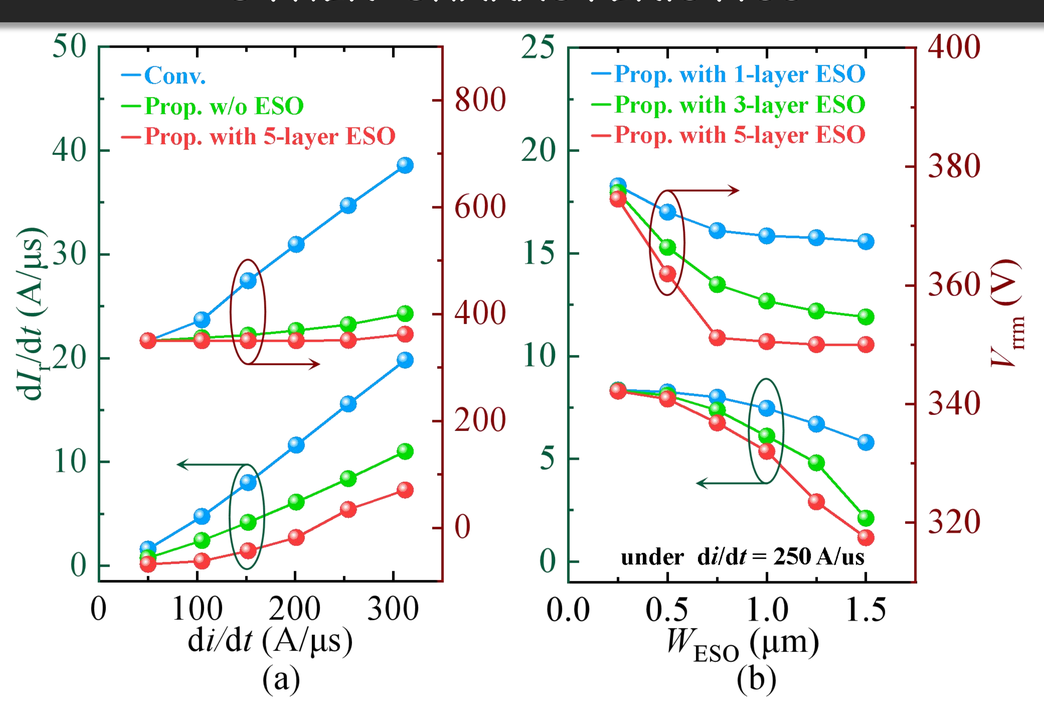

Figure 2. Effects of di/dt and W_{ESO} on di_r/dt and V_{rrm}.

With the increase of W_{ESO} and the number of ESO layers, V_B shows a decreasing trend. V_B of the Conv. and the Prop. are 727 V and 671 V, respectively.

CONCLUSION

An SJ-MOSFET with a trench Schottky contact and an embedded SiO_2 insulator is proposed and investigated by simulations. At the reverse conduction state, the hole injection efficiency of the body diode can be lowered by adopting the trench contact, which helps to greatly reduce Q_{rr}. Besides, the SiO_2 insulator is embedded in the p-pillar, so the resistance of the whole p-pillar can be much higher than a uniformly doped p-pillar during reverse recovery, which contributes to suppressing reverse recovery oscillations of the body diode. Simulation results indicate that, in comparison to the conventional SJ-MOSFET, the proposed SJ-MOSFET exhibits a 44% reduction in Q_{rr} and an 82% decrease in di_r/dt. Additionally, reverse recovery oscillations can be significantly suppresseed.