LETTER

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A lateral DMOS with partial buried-oxide layer to achieve better RESURF effect

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Abstract: A novel lateral double diffused MOSFET (LDMOS) structure with partial buried-oxide layer under the n-drift region, which is suitable for the bulk silicon epitaxial process, is proposed. The introduction of the buried-oxide layer produces an inversion layer at buried-oxide/p-sub interface and achieves better reduced surface field (RESURF) effect comparing with the conventional device with buried-pwell. Moreover, the buried-oxide can prevent the impurity diffusion and improve the doping concentration of the n-drift region. As a result, the proposed structure improves the breakdown voltage about 12% and increases the current capability over 30% at the same time.

Keywords: partial buried-oxide, RESURF, inversion layer, LDMOS, breakdown voltage

Classification: Electron devices, circuits, and systems

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1 Introduction

High-voltage lateral diffused metal-oxide-semiconductor (LDMOS) transistors have been widely used in many smart power applications because of their compatibility with the standard low voltage CMOS process. And the trade-off between the breakdown voltage (BV) and the current capability for the LDMOS is always a hot topic in the research area of power devices [1, 2, 3]. The buried-pwell under the n-drift region is a frequently-used method in bulk silicon process to reduce surface field (RESURF) and achieve the trade-off between BV and current capability. However, the doping concentration of the buried-pwell should not be too high to avoid the premature breakdown of the vertical junction [4]. As a result, the RESURF effect is limited.

In this letter, a novel n-type LDMOS structure with partial buried-oxide layer under the n-drift region is proposed. The buried-oxide will produce an inversion layer at the buried-oxide/p-sub interface under high drain voltage (V_{ds}) condition. The produced inversion layer, which has high concentration negative space charge, could effectively reduce the surface electric field and enhance the lateral breakdown voltage. Moreover, the buried-oxide layer could prevent the impurity diffusion and increase the doping concentration of the n-drift region. Therefore, the current capability is also improved for the proposed structure.

2 Device structures

The schematic cross-sections of the conventional device with buried-pwell and the proposed device with partial buried-oxide under the n-drift region are shown in Fig 1 a and b, respectively. The buried-oxide layer can be carried out by SIMOX technology before the epitaxial layer deposition. The thickness of the epitaxial layer is about 1.5 μm. The buried-oxide layer thickness is about 1 μm. The effective channel length (L_{ch}) is 2.5 μm, the n-drift region length is 11.5 μm. It is noted that the buried-oxide and the n-drift region could be generated with the same one mask. Thereby, the

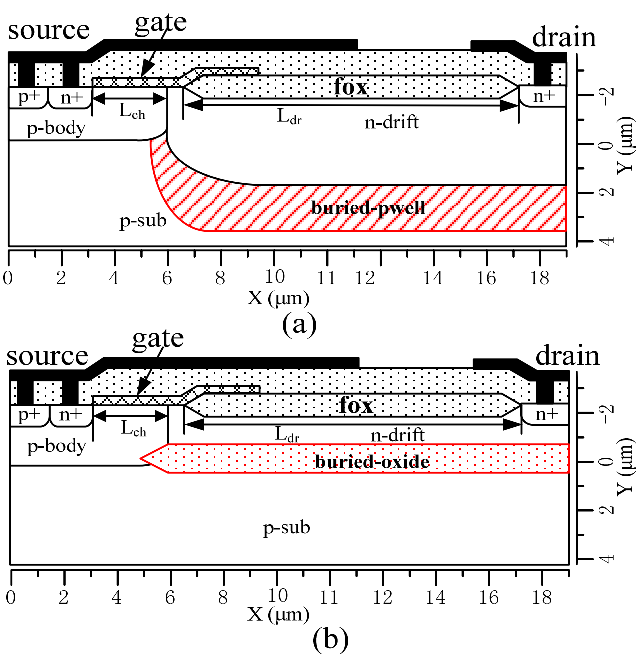

Fig. 1. The schematic cross-sections of the devices used in the letter.
a Conventional device with buried-pwell
b Proposed device with partial buried-oxide

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process cost can be reduced for the new structure.

3 Device performances simulations

The off-state leakage current curves and the output characteristic curves of the two devices are simulated using tsuprem4 and medici simulators. By comparing the results in Fig. 2 a and b, it can be seen that the proposed device improves the breakdown voltage about 12% and enhances the current capability over 30% at the same time.

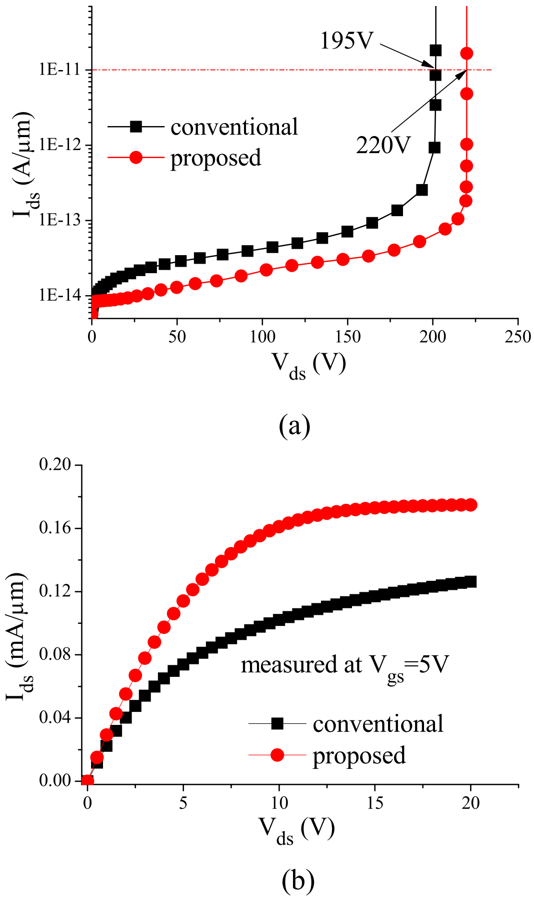

Fig. 2. The electric parameters comparison of the two different Devices.
a Off-state Leakage current curve
b Output characteristic curve

In order to study the inner mechanism that the BV is improved for the proposed device, the simulation of the two devices under BV conditions is performed. For LDMOS, the breakdown is prone to occur at the surface due to the higher doping concentration. Therefore, the reduction of the peak lateral electric field at the surface is the fundamental method to enhance the BV of a LDMOS. Fig. 3 shows the simulated lateral electric field along n-drift/fox interface for the conventional and the proposed devices under BV condition. It can be seen that the proposed device has more uniformly electric field distribution than the conventional one, especially at the drain side. This means that the proposed device has better RESURF effect than the conventional one. To interpret the phenomenon, the space charge amount for the two devices under BV condition at the end

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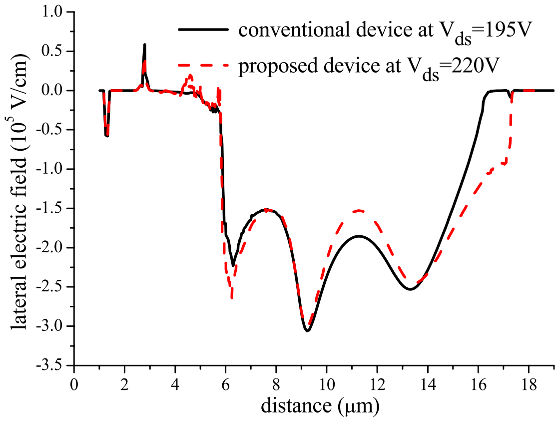

Fig. 3. The simulated lateral electric field distribution along n-drift/fox interface under BV condition.

of the metal plate as a function of the vertical depth is simulated, as shown in Fig. 4. For the conventional device, the buried-pwell will be depleted and help the depletion of the n-drift region under high V_{ds} condition. However, the space charge distribution in Fig. 4 illustrates that the proposed device can produce an inversion layer at the buried-oxide/p-sub interface under high V_{ds} condition. The high concentration negative space charges in the inversion layer, just like a depleted high doping concentration buried-pwell, bring about better RESURF effect [5]. Meanwhile, the buried-oxide may enhance the vertical breakdown voltage for its small dielectric constant and high critical electric field [6]. Therefore, the BV of the proposed device can be improved.

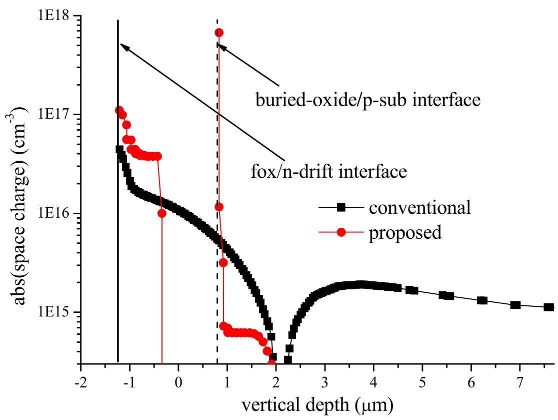

Fig. 4. The space charge distribution for the proposed and the conventional devices under the breakdown condition.

On the other hand, the current capability of the proposed device is significantly larger than that of the conventional device, as shown in Fig. 2 b. The doping concentration difference of the two devices in the n-drift region can be understood in Fig. 5. As show in Fig. 5, we can see that the n-drift region can diffuse to a 3 μm depth for the conventional device. Moreover, the buried-pwell will neutralize some impurity and decrease the doping concentration of the n-drift region. However, the buried-oxide layer of the proposed device can prevent the impurity diffusion and form a high doping concentration n-drift region. Furthermore, the current is prone to

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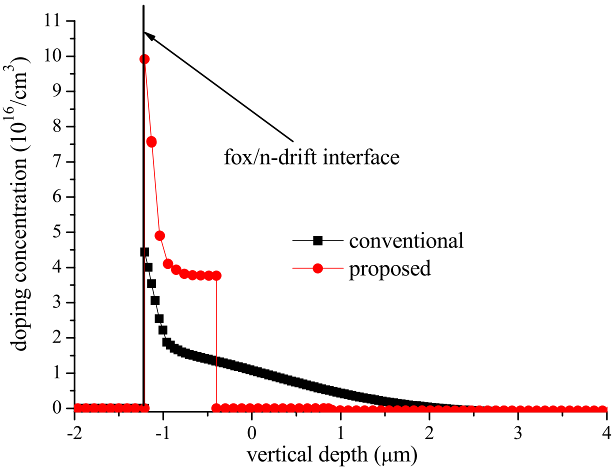

Fig. 5. The doping concentration as a function of vertical depth for the proposed and the conventional devices.

flow along surface in the n-drift region due to the attractive of the gate plate to the electrons under on-state condition. Therefore, the proposed device has lower on-resistance and higher current capability comparing with the conventional one.

4 Conclusions

In this letter, a novel LDMOS structure with partial buried-oxide layer under the n-drift region is presented. The structure is suitable to be fabricated with the bulk silicon epitaxial process. Based on our study, the buried-oxide would leads to an inversion layer at buried-oxide/p-sub interface and achieves better RESURF effect than the conventional device with buried-pwell. In addition, the high critical electric field of the buried-oxide layer improves the vertical blocking voltage. As a result, the proposed device has higher BV than the conventional device. Moreover, the introduction of the buried-oxide layer could prevent the impurity diffusion and improve the doping concentration of the n-drift region. Therefore, the proposed structure could enhance the current capability at the same time.

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