Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

6th International Conference
on Electrical Engineering
ICEENG 2008

A novel thin-film power MOSFET with an asymmetrical buried oxide double step structure

By

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Abstract:

In this paper, we have proposed a novel Silicon-On-Insulator (SOI) power MOSFET structure .This structure is a combination of two sub structures: a buried oxide step (BOS) and a buried oxide double step (BODS) that named asymmetrical buried oxide double step (ABODS). Using two-dimensional simulation, we have investigated the improvement in device performance focusing on the breakdown voltage. The ABODS structure exhibits a high breakdown voltage respected to other SOI structures at a much higher impurity concentration that can causes lower on-resistance (R_{ON}).

Keywords:

Silicon-on-insulator (SOI), Power MOSFET, Breakdown Voltage, Buried Oxide Double Step Structure.

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1. Introduction:

Power devices on SOI substrates have become of great interest because they provide ideal isolation between devices. To get a good dielectric isolation use thin silicon layers due to the problems relating to trench technology [1-2]. Obtaining a high breakdown voltage on a relatively thin SOI active layer has been a major issue in the past few years [3]. For the SOI power devices, it has been shown that lateral electric field peaks in two points the thin-film region. A high breakdown voltage is achievable by reducing either of these electric field peaks [4]. A Buried Oxide Step (BOS) structure can provide a higher breakdown voltage than that in conventional SOI (C-SOI) MOSFETs by introducing an extra electric-field peak in the surface of the thin film region and more reducing electric field peak in junction of drain-drift regions [5].

In this paper, we have proposed for the first time an Asymmetrical Buried oxide Double Step (ABODS) structure to further reduce the amplitudes of peaks in the surface electric field. The electric field peak is positioned near the middle of the channel in the ABODS structure and reduces the peak strength at the drain edge. Based on our simulation results, we demonstrate that the proposed ABODS structure is superior to the BOS and C-SOI structures in improving the breakdown voltage [6]. We further explain device structure that is designed and express simulation results.

2. Device Structure:

The schematic of the cross-sectional view of a MOSFET with an ABODS structure is shown in Fig. 1. As can be seen from this figure, shape of the buried oxide is asymmetrical double step and provides a more uniform surface electric field in the ABODS structure respect to the BOS structure. A prominent feature of this structure is that the silicon thin layer in source side ($t_{s'}$) is advantageous to isolation technology while the silicon thick layer in drain side (t_s) is helpful to high breakdown voltage. Also, the thickness of buried oxide increased in drain side ($t_{box} = t_{ox} + t_{diff}$) respect to source side (t_{ox}). The doping of silicon in the drift region, channel, and the substrate regions are N_d, N_{p+}, N_{p-}, respectively. The length of the drift region (L_d) is the sum of L_{d1} and L_{d2}. The device parameters used in our simulation are shown Table I. All the device parameters of the ABODS MOSFET are equal to those of the Conventional SOI (C-SOI) MOSFET unless otherwise stated.

An ideal uniform lateral electric field distribution can be obtained if the thickness of SOI layer is increased linearly from source to drain. This result to the fact that a higher electric field peak is produced at the double step in the ABODS structure. While BOS structure increases breakdown voltage, the new step in the silicon layer reduces the effective thin film thickness as compared with the C-SOI or BOS MOSFET structure.

This reduced effective thin film thickness results in a lower R_{ON} in buried oxide double step structure. Therefore, the ABODS structure can provide higher breakdown voltage and lower R_{ON}. It is worth noting that the ABODS structure can be fabricated by the silicon oxidization after it is etched into step shape.

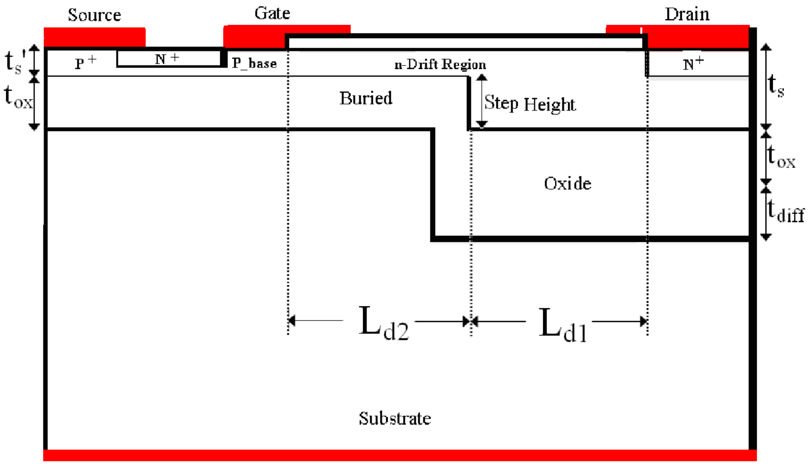


Figure (1): *Cross section of the ABODS structure.*

Table (1): Simulation parameters

Parameter	**Value**
Thin Si layer thickness ($t_{s'}$)	0.5 μm
Thick Si layer thickness (t_s)	1.5 μm
Buried oxide thickness in drain side	2 μm
Buried oxide thickness in source side	1 μm
Gate oxide thickness	80 nm
Drift doping	2.6×10^{16} cm^{-3}

3. Results and Discussion:

An ideal buried oxide shape should be asymmetric and encounter a double step in order to provide a more uniform horizontal electric field distribution. For this approach, both buried oxide thickness and silicon layer thicknesses on its top are taken as variables. Simulation results show that increasing both buried oxide thickness and the thin silicon film thickness near the drain provide a more uniform electric field distribution in the MOSFET by reducing electric field peak in drain side. The lateral electric field distributions are shown in Fig. 2 at the top surface channel for three structures with their optimized conditions. As can be seen from the figure, a higher peak is generated near the drift mid point region middle in the ABODS, and causes the height of electric-field peak at the channel-drain junction to decrease dramatically. Fig. 3(a) shows the electric-field distributions in surface of ABODS when the L_{d2} is variable. It is apparent that the electric-field peak moves gradually by virtue of the length of L_{d2}, and there is an optimum location for peak electric field if the L_{d2} is $(1/2)L_d$. This can be verified by Fig. 3(b), which shows dependency of breakdown voltages on the L_{d2} in ABODS. The breakdown voltage is maximum when L_{d2} is $(1/2)L_d$. Fig. 4 shows the breakdown voltage dependency on difference between the buried oxide thicknesses in source and drain sides (t_{diff}). It indicates that the breakdown voltage increases since the buried oxide thickness in drain side increased (t_{diff}). Fig. 5 shows the dependence of breakdown voltage on the step height that is generated in the middle of buried oxide. When the step height increases, peak of electric-field in the step location increase, as a result, breakdown voltage increases. The breakdown voltage dependency on the dopant concentration in the drift region is shown in Fig. 6. There exists an optimum the dopant concentration for the drift region for each structure. The optimum concentration of ABODS is higher than that in C.SOI and BOS .This is due to use of a thinner silicon layer in this structure. The maximum oxide field dependency on the drift region doping is illustrated in Fig. 7. A high dose in the drift region leads to an increase in the oxide electric field, since in this case the voltage drop inside the drift region is reduced and the potential at the gate edge of the drift region is increased. Simulations carried using the 2-D device simulator ISE-TCAD that employed the ionization coefficients of Van Overstraeten and DeMan [7-8].

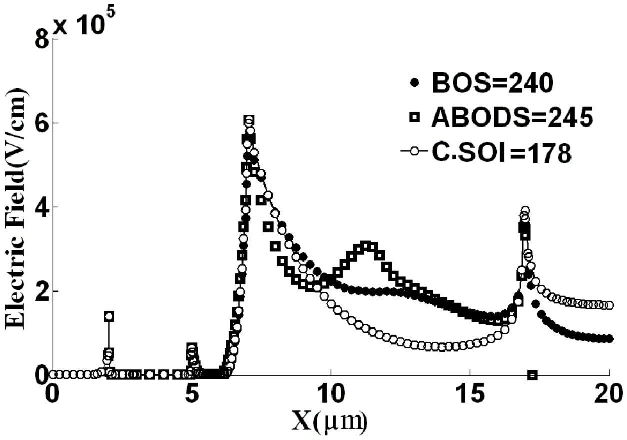
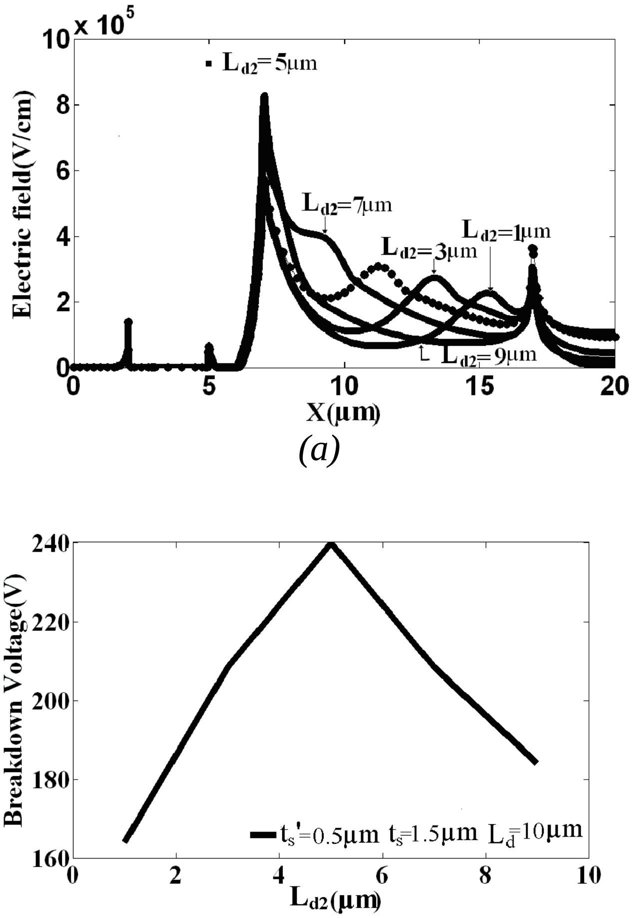


Figure (2): *Lateral electric-field distributions in the conventional BOSS and ABODS at the top surfaces of the silicon layers:* t_{ox}*=1µm,* t_{box}*=2 µm,*L_d*=10 µm and* $L_{d2}=(1/2)L_d$ *in the ABODS structure.*



(a)

(b)

Figure (3): *(a) Lateral electric-field distributions and (b) breakdown voltage at different value of L_{d2} in ABODS: t_{ox}=1 µm, t_{box}=2 µm, L_d=10 µm.*

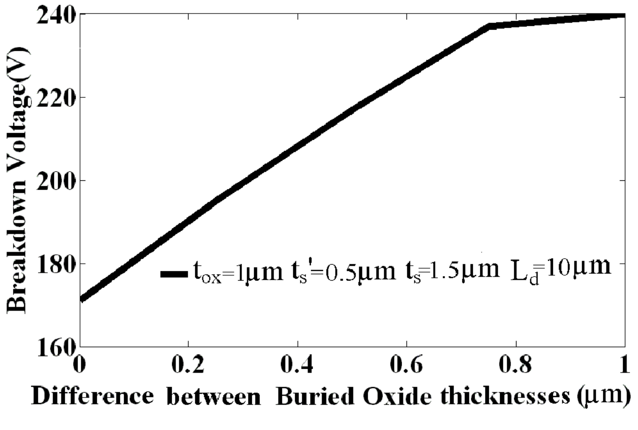


Figure (4): *Breakdown voltage as a function of the difference between buried oxide thicknesses in drain and source sides.*

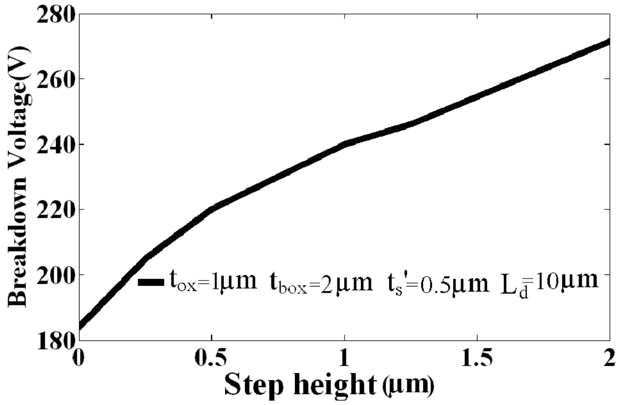


***Figure (5):** Breakdown voltage as a function of step height in ABODS structure.*

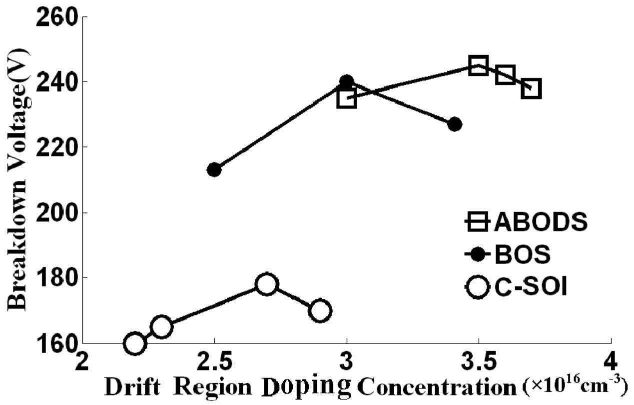


***Figure (6):** Breakdown voltage dependency on impurity concentrations in ABODS structure*

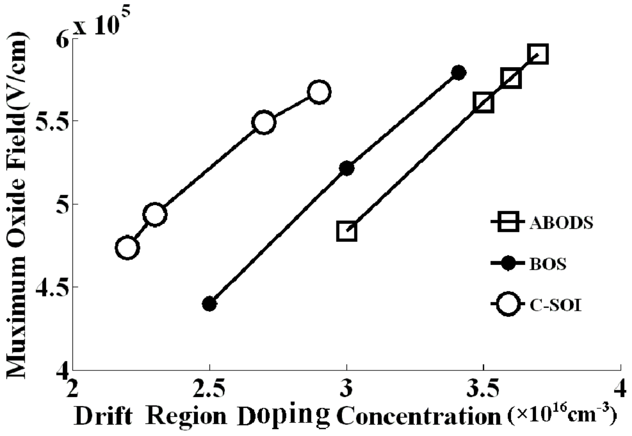


***Figure (7):** Doping concentration dependency of maximum oxide field at the gate edge.*

4. Conclusions:

A novel device structure named ABODS was proposed for SOI power MOSFETs. It is a combination of the two structures that are beneficial to achieving high breakdown voltage. The effects of fabrication parameters on breakdown voltage are investigated. Simulation results indicate that higher breakdown voltage and lower R_{ON} are achieved for the ABODS than those in the conventional SOI and BOSS structure. This is due to a higher electric field peak introduced in step and effective thin silicon layer, respectively.

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