Simulation of a Novel Schottky Body-Contacted Structure Suppressing Floating Body Effect in Partially-Depleted SOI nMOSFET's

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Abstract: A novel Schottky body-contacted structure for partially depleted SOI nMOSFET's is presented. This structure can be realized by forming a shallow n^+-p junction and two sidewall spacers in the source region, and then growing a thick silicide film, which can punch through the shallow junction and make a Schottky contact to the p-type silicon. Simulation results show that the anomalous subthreshold slope and kink effects are suppressed successfully and the drain breakdown voltage is improved considerably. This method has the same device area and is completely compatible with the bulk MOSFET process.

Key words: SOI; nMOSFET; floating body effect; body contact

EEACC: 2570D; 2570F

CLC number: TN386 **Document code:** A **Article ID:** 0253-4177(2002)10-1019-05

1 Introduction

In view of their low-power consumption and high-speed performance, silicon-on-insulator (SOI) CMOS devices are most useful candidates for future LSI and ULSI devices. Due to the floating body (FB) structure, the impact ionization effect of SOI nMOS devices is much more important than that of bulk nMOS devices[1]. In case of fully depleted (FD) SOI nMOSFET, the source-bulk potential barrier is always small, the accumulation of holes can not take place in the bulk. The influence of the body potential on the device behavior is small. In partially depleted (PD) SOI nMOS devices, owning to the existence of the neutral region in the bulk, the source-body potential barrier is large. The holes generated near the drain are easily trapped in the neutral body region. The increase of body potential gives rise to a decrease of the threshold voltage. This decrease of threshold voltage induces an increase of drain current as a function of the drain voltage. This is the so-called kink effect. Another floating body effect is the early device breakdown induced by the parasitic lateral npn bipolar transistor with floating base.

Different methods have been proposed to reduce the floating body effect[2~7]. A straightforward approach would be the body tied PD device[1], where a p^+ diffusion region is formed to one end of the gate which is in contact with the p-type silicon underneath the gate. The body con-

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Received 25 February 2002, revised manuscript received 15 April 2002

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tact (BC) helps to reduce the floating body effects, but do not completely eliminates them because of distributed resistance from the contact to portions of the body node. In this study we designed a novel body contacted structure which is independent of the channel width. The simulation results are presented.

2 Description of device structure

Figure 1 shows the schematic cross section of the novel Schottky body contacted structure. The device has a buried oxide with a thickness of 400nm. Before gate oxide formation B^+ and BF_2^+ are implanted with energy of 70keV, dosage of $2\times10^{13}cm^{-2}$ and energy of 100keV, dosage of $5\times10^{11}cm^{-2}$, respectively. After growing a 20nm gate oxide, a 160nm silicon film is left, then a

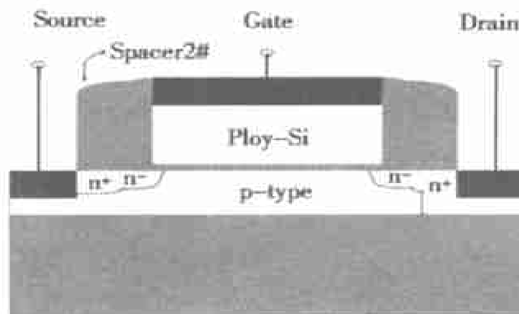

Fig. 1 Schematic cross-section of the novel Schottky body contact structure

350nm n^+ poly-silicon layer is deposited. The poly-silicon is patterned and etched to form the gate with a length of 0.8μm. Then phosphorus implantation with energy of 30keV, dosage of $2.5\times10^{13}cm^{-2}$, is performed to form LDD/LDS structure. After a 150nm oxide spacer formation n^+ doping is performed by the implantation of As (30keV, $2.5\times10^{15}cm^{-2}$), which forms a shallow n^+-p junction (~90nm in depth) in both source and drain regions. When the source region is protected with photoresist, a second As implantation (100keV, $4.5\times10^{15}cm^{-2}$) is carried out only in the drain region, which makes the drain n^+ region reach the buried oxide. Then the photoresist is etched up and a second oxide spacer for 150nm thick is formed. In order to activate the impurities implanted in the silicon film, a rapid thermal processing (RTP) at 1000 ℃ is performed for 8s. A Cobalt film for 30nm thick is deposited. It is expected that a Cobalt silicide film with a thickness of 110nm will be formed after rapid thermal annealing (RTA) at 800 ℃. It is considered the silicide in the source region will punch through the deep junction of 90nm and form a Schottky contact to the p-type silicon. The thick silicide in the drain region will not destroy the drain junction because the second oxide spacer keeps it away from the body-drain junction.

3 Simulation results and discussion

Impurity concentration in the source and drain region is simulated just after RTP at 1000 ℃ and before silicide growth. The simulation was performed using Tsuprem4[8]. Figures 2 and 3 show the impurity concentration distribution at the place of 0.5μm away from the edge of n^+ poly-silicon gate in the source and drain region, respectively. It can be seen that boron shows a retrograde distribution in the silicon film. It is shown in Fig. 2 that a shallow n^+-p junction with a depth of ~90nm was formed in the source region. In Fig. 3 the n^+-p junction in the drain region reaches the buried oxide because of the second heavy As implantation (100keV, $4.5\times10^{15}cm^{-2}$).

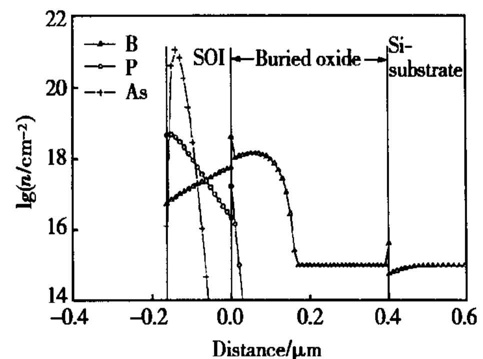

Fig. 2 Impurity concentration distribution in the source region of the SOI nMOSFET

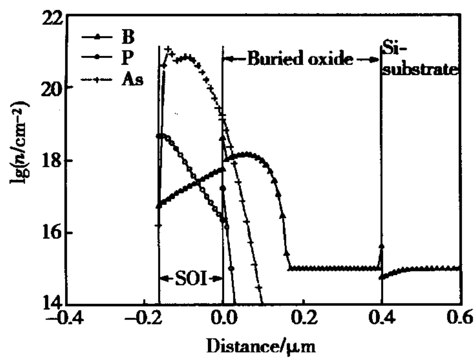

Fig. 3 Impurity concentration distribution in the drain region of the SOI nMOSFET

Figure 4(a) presents the simulated I_{DS}-V_{GS} characteristics of a conventional SOI nMOSFET with floating body. In contrast, Fig. 4(b) shows that of the novel silicide body-contacted device. The simulation is performed by using Medici[9]. Both FB and BC devices have the same gate length of 0.8μm and silicon film thickness of 160nm. The conventional device has the same structure and impurity profile as those of BC device except in the source region.

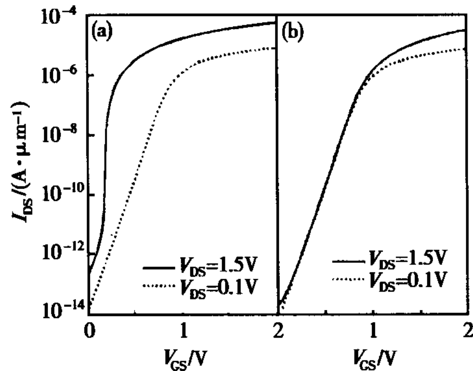

Fig. 4 Simulated I_{DS}-V_{GS} characteristics (a) Conventional (FB); (b) Novel (BC)

The anomalous subthreshold slope (12mV/dec) is observed in Fig. 4(a) at a drain bias of 1.5V. For the conventional floating body PD SOI nMOSFET, the threshold voltage is 0.8V at a drain bias of 0.1V while the threshold voltage is 0.25V at a drain bias of 1.5V. Because the holes generated near the drain are accumulated in the floating body and elevate the body voltage, the threshold voltage is decreased.

It can be seen in Fig. 4(b) that the subthreshold slope values of BC device (at V_{DS} = 0.1V and 1.5V) are almost identical to that of the FB device at a drain bias of 0.1V (~108mV/dec). Because the built-in barrier of Schottky contact is much lower than that of a conventional n^+-p source-body junction, the amount of accumulated holes is confined to a small value, the body voltage can not be elevated too much. Thus the anomalous subthreshold slope effect induced by the floating body is suppressed.

In Fig. 5 the simulated drain characteristics of the Schottky body-contacted SOI nMOSFET are compared with those of the conventional SOI nMOSFET. The gate is biased at 0.5, 1, 1.5, 2, 2.5, and 3V, respectively. Clearly, the kink effect in the output characteristics disappears and the drain breakdown voltage is much higher for the body-contacted device (improved about 2V in saturation region). Thus the floating body effect in the conventional SOI nMOS device is suppressed successfully.

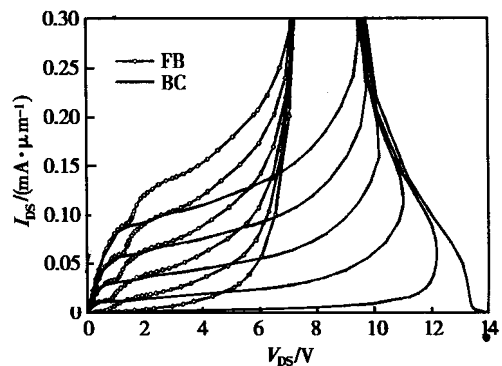

Fig. 5 Simulated drain characteristics of the novel BC versus the FB SOI nMOSFET

In case of a conventional SOI nMOSFET, the holes generated by impact ionization near the drain junction migrate towards the place of lowest potential, i. e., floating body. The injection of holes into the floating body forward biases the source-body diode[1]. The increase of body potential (an increase of 700~800mV) gives rise to a decrease of the threshold voltage, thus the "kink" was observed in the output characteristics of the device. As to the

novel body-contacted structure, the built-in barrier potential of the Schottky contact is much lower than that of a conventional n^+-p source-body junction. Simulation results show that the built-in barrier of the Schottky contact between silicide (with a work function of 4.8eV) and p-type silicon is 0.34eV. The increase of body potential is confined to a small value. At the same time the gain of the parasitic lateral npn transistor is decreased greatly. Therefore, both kink effect and lateral bipolar action are eliminated.

4 Conclusion

A novel body-contacted structure independent of device width is presented, which can be built up by forming a shallow n^+-p junction and two sidewall spacers in the source region, and then growing a thick silicide film which can punch through the shallow junction. Simulation result shows that the built-in barrier of the Schottky contact is about 0.34eV. The simulated I_{DS}-V_{GS} characteristics and output characteristics curves show that this structure can suppress the floating body effect effectively. This method has the same device area and is completely compatible with the bulk MOSFET process.

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一种能够抑制部分耗尽 SOI nMOSFET 浮体效应的新型 Schottkty 体接触结构的模拟

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摘要: 提出了一种新型的 Schottky 体接触结构, 能够有效抑制部分耗尽 SOI nMOSFET 的浮体效应. 这种结构可以通过在源区形成一个浅的 n^+-p 结和二次侧墙, 然后生长厚的硅化物以穿透这个浅结的方法来实现. 模拟结果表明这种结构能够成功抑制 SOI nMOSFET 中存在的反常亚阈值斜率和 kink 效应, 漏端击穿电压也有显著提高. 这种抑制浮体效应的方法不增加器件面积, 而且与体硅 MOSFET 工艺完全兼容.

关键词: 绝缘体上的硅; nMOS 场效应晶体管; 浮体效应; 体接触

EEACC: 2570D; 2570F

中图分类号: TN386　　**文献标识码**: A　　**文章编号**: 0253-4177(2002)10-1019-05

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2002-02-25 收到, 2002-04-15 定稿

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