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Reduction of the Floating-Body Effect in SOI MOSFETs by Using Schottky Source/Drain Contacts

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1. Introduction

In SOI(Silicon On Insulator) MOSFETs, the floating-body effect causes such detrimental phenomena as the early drain-to-source breakdown. Various methods have been investigated to suppress the floating-body effect, which include the use of heterostructure at the source[1,2] and introducing the recombination center at the source[3]. In this work, we propose a new SOI-MOSFET structure that employs the Schottky contacts at the source and the drain contacts as shown in Fig. 1. By using Schottky contact at the source instead of n^+/p junction, excess holes in the channel region are smoothly absorbed to the source. The Schottky contact at the drain reduces the electric field near the drain and, thus, reduces the impact ionization. We report results of simulation and self-aligned device fabrication using Er silicide as the contact material.

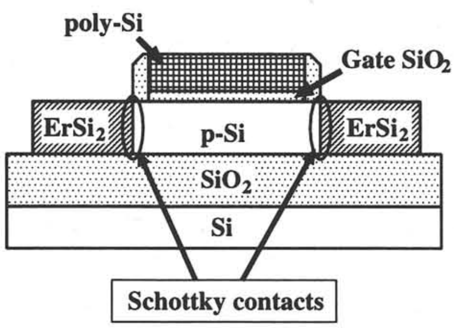

Figure 1: Schematic cross-section of the proposed and fabricated n-channel SOI-MOSFET.

2. Fundamental

For the proposed n-channel SOI MOSFET, Er silicide is a good candidate for the contact material because its work function is relatively small. We have investigated the Er silicide/p-Si Schottky contact and obtained a good rectifying characteristic. The experimentally obtained work function of Er silicide is 4.25eV. Figure 2 shows the band structure at the source-body region (or drain-body region) of the proposed n-channel SOI MOSFET having an Er silicide contact at thermal equilibrium. In the figure the acceptor concentration N_a in the active layer is assumed to be $3 \times 10^{15}\mathrm{cm}^{-3}$. In this case, the built-in potential Φ_D becomes 0.68eV. Since this built-in potential is about 0.2eV lower than that of a pn junction, the number of holes that move through the barrier is expected to increase and, therefore, the accumulation of excess holes in the body is suppressed. On the other hand, Er silicide may form an ohmic contact with n-channel because the barrier height Φ_B is as small as 0.20eV. Hence, it can be considered that there is little effect of the Schottky source contact on the transconductance of the MOSFET.

Concerning the effect at the drain region, the Schottky drain contact is expected to be useful in reducing the field near the drain. This is because the Schottky barrier Φ_B produces a built-in field which opposes the field produced by applying the drain voltage. This is similar to the effect of the LDD structure. Thus the Schottky drain contact is expected to suppress the generation of electron-hole pairs by the impact ionization without using complex processes.

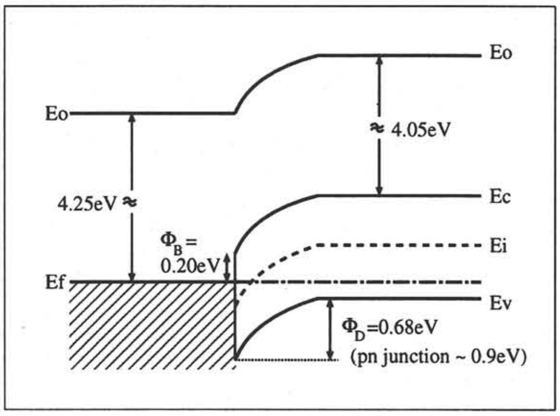

Figure 2: Band diagram for Er silicide/p-Si contact.

3. Simulation

We have analyzed the proposed SOI MOSFET by two-dimensional device simulation. The device parameters used in this analysis are as follows; W/L=10μm/1μm, T_{SOI} = 200nm, impurity concentration in the active region = $2 \times 10^{16}\mathrm{cm}^{-3}$, source and drain regions = Er silicide for the Schottky contacts or n^+-layer($2 \times 10^{20}\mathrm{cm}^{-3}$) for the conventional MOSFET.

Figure 3 shows the $I_D - V_{DS}$ curves for the proposed Schottky source/drain MOSFET and for the conventional n-channel MOSFET. We can see that, as was expected, the drain-breakdown voltage increases in the Schottky source/drain MOSFET. The improvement in the drain-breakdown voltage is approximately 2V. Although current drive is reduced by using the Schottky contacts due to the source contact resistance, the reduction in transconductance is within 10%.

In order to analyze the effects of Schottky contacts, potential and behavior of carriers have been investigated. It has been found that, comparing with the conventional MOSFET, excess holes are smoothly absorbed to the source contact and the impact ionization near the drain is reduced in the Schottky source/drain MOSFET. Further analyses with Shottky source, n^+/p-drain structure and vice versa have revealed that the effect of at the source contact, that is absorbing excess holes, contributes to the improvement of the drain-breakdown voltage rather than the effect at the drain region.

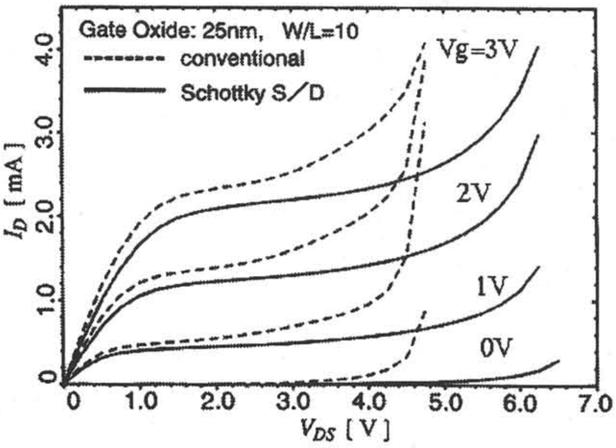

Figure 3: I_D-V_{DS} curves for SOI MOSFETs having Schottky contacts(solid lines)and conventional structure(dashed lines).

4. Experimental

We have fabricated a test-device using the self-aligned silicide technique. Er was deposited by vacuum evaporation in ultra high vacuum. Annealing for 2 hours at 400°C was found to be optimum for silicidation. Figure 4 shows the cross-sectional SEM image of MOSFET structure with Er silicide source/drain using Schottky contacts. We can see that the self-aligned structure is successfully formed.

Figure 5 shows $I_D - V_{DS}$ curves for SOI nMOSFET fabricated by using the Er salicide process. We can see that SOI MOSFET having Er silicide contacts behaves as an FET although the performance is not satisfactory at the present.

Rise in drain current is not sharp in this figure, suggesting high source resistance. Two causes can be taken into account for the high source resistance. One is the relatively high resistance of the Er silicide layer($\approx 100\Omega/\square$) The other is the incomplete self-alignment which caused an unintimate contact between the source and the channel. Refining the process condition will improve the performance.

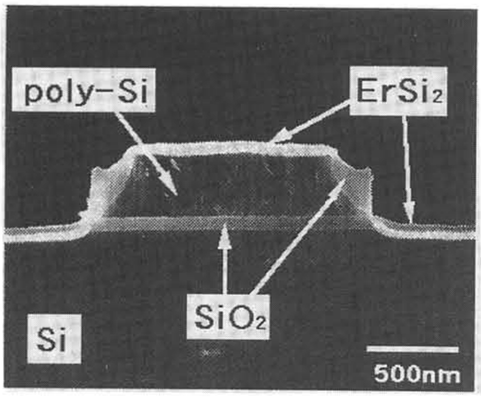

Figure 4: Cross-sectional SEM image of a MOSFET with source/drain using Schottky contact fabricated by using the Er salicide process.

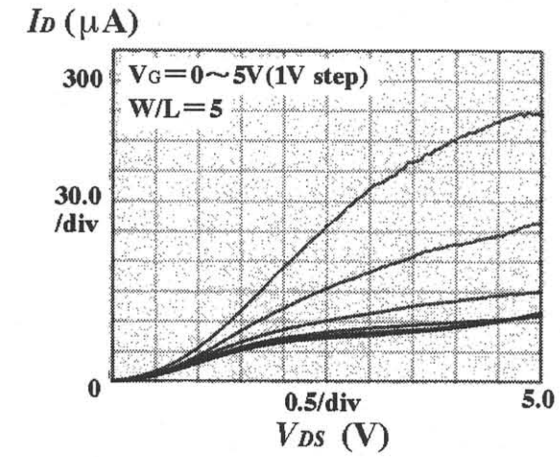

Figure 5: I_D-V_{DS} curves for SOI nMOSFET having $ErSi_2$ Schottky contacts.

5. Conclusions

A new SOI MOSFET structure has been proposed, which employs the Schottky contacts at the source and drain. The Schottky contact structure is very useful to suppress the floating-body effect of n-channel SOI MOSFETs. This is because that excess holes in the channel region smoothly flow into the source and that the impact ionization near the drain is reduced. Operation of the new MOSFET has been verified by fabricating a test device using the Er salicide process. Further investigation of process technology is in progress.

References

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3) T. Tsuchiya et at. : Ext. Abstr. (43rd Spring Meet., 1996) Japan Society of Applied Physics, 26p-E-10 [in Japanese]