Comparison of Different Ways of Extra Phosphorus Implantation Which Decrease the Threshold Voltage and On-resistance of UMOS

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***Abstract* ─** A method to decrease the threshold voltage and on-resistance is discussed in this paper, which is adding extra phosphorus implantation into silicon. There are two ways to implant extra phosphorus without adding a mask. The first way is to implant extra phosphorus after the field oxide etching, and the second way is to implant extra phosphorus with the source region mask before the N+ implantation. Compare the results of the two ways to find their characteristics and choose the appropriate one.

***Index Terms* ─** Extra phosphorus implantation, on-resistance, threshold voltage, UMOS.

I. INTRODUCTION

Threshold voltage and on-resistance (R_{on}) are important indexes to measure the performance of the device [1]. Under the premise of guaranteeing the anti-noise ability of the device, the low threshold voltage is conducive to the drive of the device [2], and the low on-resistance is conducive to decreasing the power consumption [3]. Extra phosphorus implantation is an easy method to decrease threshold voltage and on-resistance. In order not to add a new mask and save costs, extra phosphorus implantation can be carried out after field oxide etching or before N+ implantation [4]. Comparing these two ways can help to choose the one which is better to improve the performance of device from process.

II. EXPERIMENT

For UMOS with a breakdown voltage of 100V, in order to ensure the reliability of the device, the breakdown voltage is usually designed to exceed 100V. Extra phosphorus implantation is carried out after field oxide etching and before N+ implantation respectively. The implant energy is 90KeV and 200KeV. The implant dose of extra phosphorus is the same, and choose the different dose to find the changing trend of the electrical parameter.

III. SIMULATION RESULTS

The simulation software is Sentaurus TCAD. Furthermore, the DopingDependence model, Lackner model and some other models are used in the simulation. The resistivity of epitaxy is 1.425 Ω·cm and the thickness of epitaxy is 9 microns.

The structure of the device is shown in Fig. 1. The concentration distribution of structures corresponding to different implant dose and energy by the first way is shown in Fig. 2, and the simulation results are shown in the Table 1. When the implant energy is 90KeV, the threshold voltage and on-resistance can be decreased more by the first way which is implant extra phosphorus after field oxide etching. However, the breakdown voltage will be sacrificed.

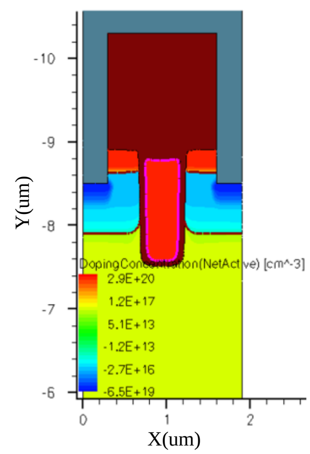

Fig. 1. The structure of the 100V UMOS.

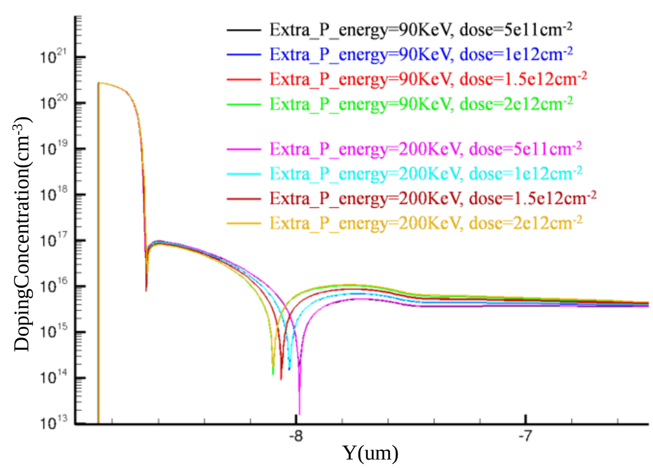

Fig. 2. Doping concentration curve of the 100V UMOS.

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Table 1: Simulation results of different extra phosphorus implantation dose and energy

Parameter \ Extra_P_imp_dose		Extra_P_imp_energy=90KeV				Extra_P_imp_energy=200KeV			
		5e11cm^{-2}	1e12cm^{-2}	1.5e12cm^{-2}	2e12cm^{-2}	5e11cm^{-2}	1e12cm^{-2}	1.5e12cm^{-2}	2e12cm^{-2}
After field oxide etching	Vth /V	2.04	1.95	1.86	1.78	2.03	1.95	1.88	1.76
	BV /V	110	108	105	102	110	107	104	101
	Vg=4.5V, I_D=2A R_{on} /mΩ	23.57	22.75	22.08	21.54	23.43	22.56	21.90	21.25
	Vg=10V, I_D=2A R_{on} /mΩ	21.09	20.41	19.90	19.48	20.99	20.24	19.69	19.18
Before N$^+$ implantation	Vth /V	2.09	2.06	2.03	2.01	2.00	1.90	1.80	1.70
	BV /V	112	112	112	112	112	112	112	112
	Vg=4.5V, I_D=2A R_{on} /mΩ	24.64	24.59	24.51	24.49	24.46	24.27	24.11	23.97
	Vg=10V, I_D=2A R_{on} /mΩ	22.05	22.05	22.05	22.05	22.00	21.98	21.96	21.92

When the implant energy is 200KeV, the second way which is implanting extra phosphorus before N+ implantation can decrease more threshold voltage but on-resistance doesn’t. At this time, the breakdown voltage is constant.

IV. ANALYSIS

In medium and low voltage devices, channel resistance occupies a large proportion, and the expression of channel resistance is shown in equation (1) [5]:

$$R_{\mathrm{CH,SP}} = \frac{L_{\mathrm{CH}} W_{\mathrm{Cell}}}{2\mu_{\mathrm{ni}} C_{\mathrm{OX}} \left(V_{\mathrm{G}} - V_{\mathrm{TH}}\right)}. \qquad (1)$$

It can be found that when the threshold voltage decreases, the channel resistance decreases and the on-resistance decreases. For extra phosphorus implantation carried out after field oxide etching, since both the epitaxy and phosphorus are n-type, the larger the implant dose of phosphorus is, the higher the doping concentration at the top of the epitaxy will be, which will decrease the resistivity and breakdown voltage [6]. Meanwhile, the concentration distribution at the channel will be changed, which decrease the threshold voltage and on-resistance. In addition, it can be seen from Fig. 2 that the implant energy is different though, the concentration distribution curve of the same implant dose almost coincides. Which is the reason that the electrical parameters of the first way hardly change even the implant energy is larger.

For extra phosphorus implantation carried out before N+ implantation, the phosphorus is compounded in the p-base region, which changes the distribution of impurities at the channel. However, if the implant energy is not large enough, the concentration distribution at the channel will not change significantly. Due to the second way doesn’t change the resistivity, the breakdown voltage doesn’t change, too.

V. CONCLUSION

Extra phosphorus implantation can decrease threshold voltage and on-resistance. It is found that under the condition of the same implant dose of extra phosphorus, if the designed breakdown voltage margin is large, the first way which is implanting extra phosphorus after field oxide etching is better. while if not, the second way which is implanting extra phosphorus before N+ implantation is better.

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