EFFECT OF THE VARIOUS DOPING CONCENTRATION OF BF_2 ON POLYSILICON-GATE PMOS

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Introduction

The development of polysilicon technology was driven by the use of polysilicon as a gate electrode or as an intermediate conductor in two-level structure for integrated circuits [1]. Once it was developed, polysilicon technology has found use in the p-channel Metal Oxide Semiconductor Field Effect Transistor (PMOS) applications. In PMOS devices, the polysilicon gate or simply poly gate must be doped to render it conductive and this is done with either diffusion or ion implantation [2]. The PMOS transistor is built with an n-type substrate and has regions of p-type semiconductor adjacent to the gate called the source and drain, as shown in Fig.1 below.

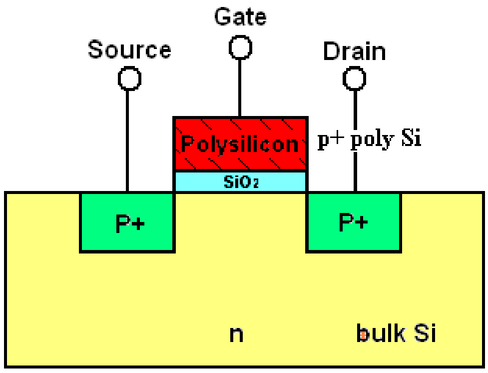

Fig.1 PMOS transistor.

This paper presents the effect of the various doping concentration of BF_2 at range 10^{11} to 10^{20} (atoms/cm^3) on polysilicon-gate PMOS using SILVACO TCAD software. It is seen that the effect of p-type doping at certain level of dose significantly effects the performance of the PMOS device. The threshold voltage of polysilicon obtain from I_D-V_{GS} curve was analyzed.

Simulation

In brief, the SILVACO TCAD is semiconductor process and device simulation and design tool. It consists of ATHENA and ATLAS. The simulation is begun by write the program of building the PMOS device in the ATHENA. The program's focus upon the simulation of fabrication process. Fig.2 below shows the processing steps for build PMOS structure using ATHENA. Once the device is built with ATHENA and
by changing the p-type doping with different level of dose in the ATHENA, ATLAS can be used to simulate the I-V curves for the PMOS. To obtain the I_D-V_{GS} curve, the drain voltage, V_{DS} was setting to -0.1V. In this simulation part, the device parameters such as threshold voltage, sheet resistance and leakage current can be achieved. To obtain I_D-V_{DS} curve, the gate voltage, V_{GS} was setting to -1.1V, -2.2V, -3.3V and -4.4V respectively.

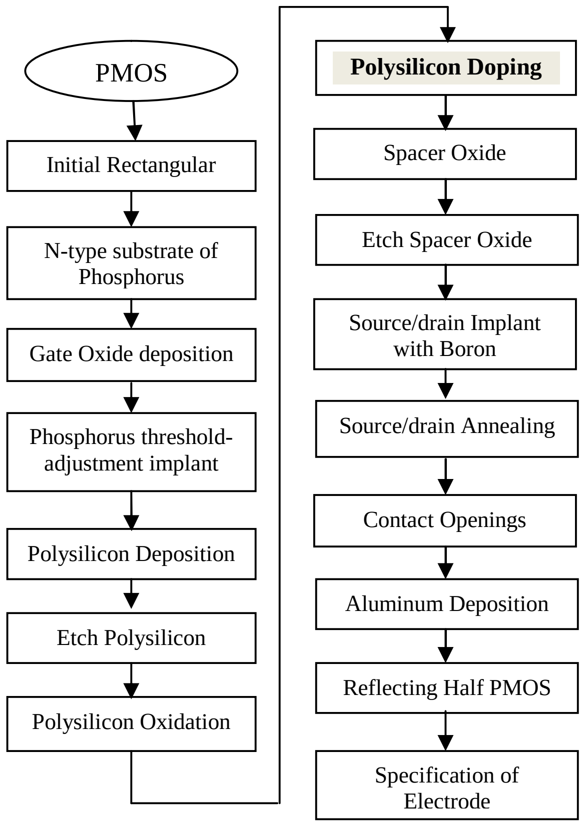

Fig.2 Processing steps for build PMOS structure using ATHENA.

Result and discussion

I-V Characteristics

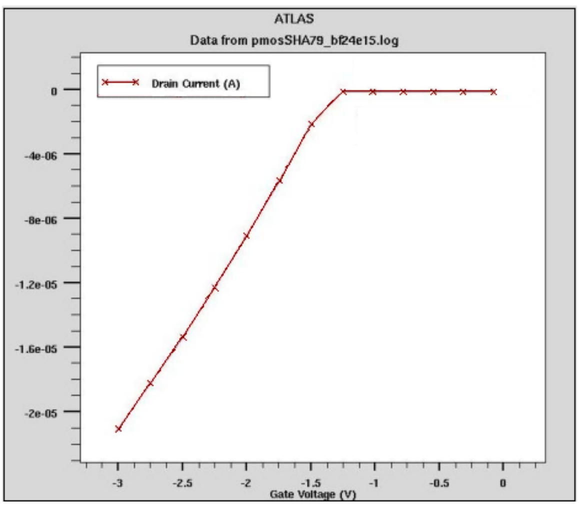

Fig.3 I_D-V_{GS} curve for BF_2 at dose 10^{15}(atoms/cm^3)

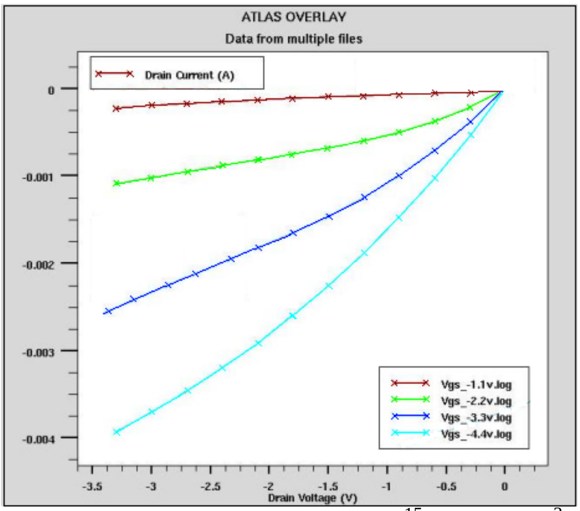

Fig.4 I_D-V_{DS} curve for BF_2 at dose 10^{15} (atoms/cm^3)

The relationship of the current and voltage for PMOS was measured for I_D-V_{GS} and I_D-V_{DS} curves. Fig.3 shows the I_D-V_{GS} curve for BF_2 doping at dose 10^{15} (atoms/cm^3). The drain current started to decrease linearly with gate voltage when the V_G is less than -1.125V. This phenomenon happened because the current is allowed to flow from source to drain after gate voltage exceeds threshold voltage. In this case, since the negative gate voltage was injected into the device, so the more negatively gate voltage is needed to ON the device.

Fig.4 shows the I_D-V_{DS} curve for BF_2 doping at dose 10^{15} (atoms/cm^3). It shows the level of saturation current allowed in the device for the PMOS at applied gate of -1.1V, -2.2V, -3.3V and -4.4V respectively. The current is nearly zero when the gate voltage is below the threshold voltage.

The overlay of I_D-V_{GS} curve in Fig.5 below shows the BF_2 doping at dose from 10^{14} to 10^{19} (atoms/cm^3) has produce the better performance of the device with suitable dose for PMOS applications. The threshold voltage of BF_2 doping are between 1.3V to 1.0V.

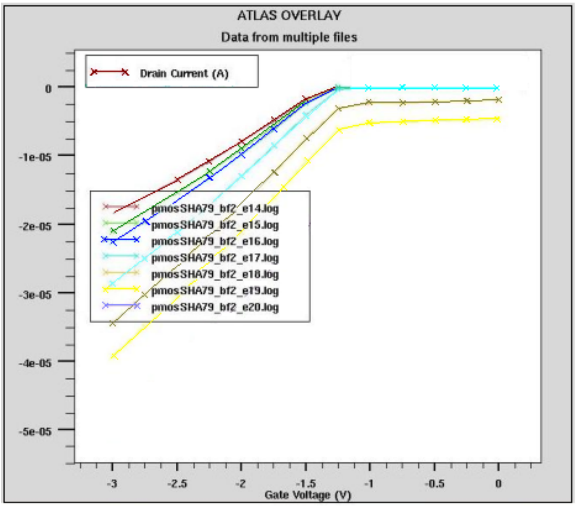

Fig.5 The overlay graph of I_D-V_{GS} curve for BF_2 doping at dose 10^{14} to 10^{19} (atoms/cm^3)

Resistivity,Conductivity and Leakage Current

The value of sheet resistance can be extracted form the I-V curve. The resistivity of polysilicon is significantly influenced by the doping levels. By adding more dopant into polysilicon will reduce the resisitivity. As shown in Fig. 6, the resistivity,ρ will gradually decrease as a concentration of dopant increase for dose from 10^{11} to 10^{20} (atoms/cm^3). At lower dose concentration of 10^{11} (atoms/cm^3), the BF_2 and has the lowest resistivity at 0.2824 (Ω-m).

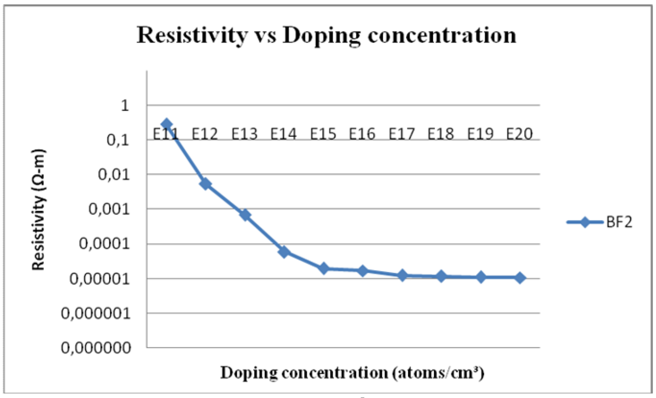

Fig.6 Resistivity at various doping concentration

Fig.7 shows a correlation between conductivity at various doping concentration. The level of dose in the polysilicon makes a large difference in conductivity, more doping leads to higher conductivity.

The relationship of leakage current with various doping concentration for various doping concentration are shown in Fig.8. It can be seen that the leakage current of polysilicon is increases directly with the increase of level of dose from 10^{11} to 10^{20} (atoms/cm^3).

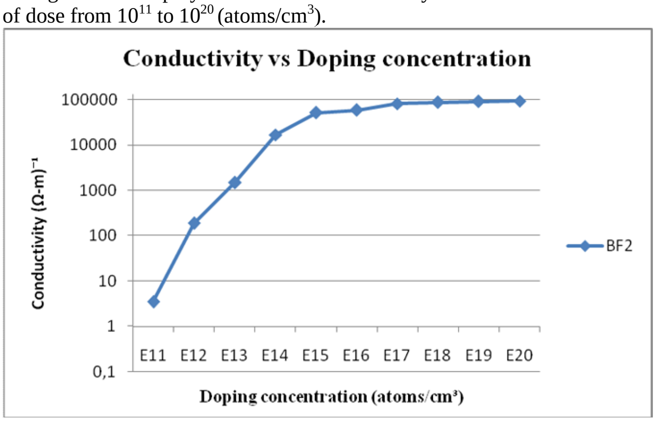

Fig.7 Conductivity at various doping concentration

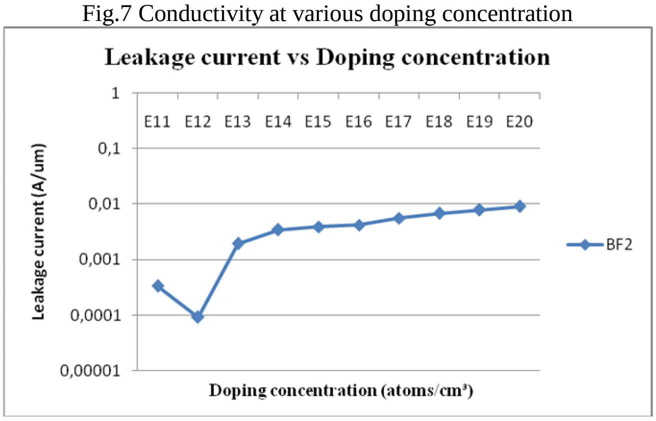

Fig.8 Leakage current at various doping concentration

Conclusion

In this paper, the effect of various concentration of BF_2 has been studied using SILVACO's TCAD software. It is found that, the threshold voltage, resistivity, conductivity and leakage current has effect the characteristics of PMOS device. It can be concluded that, by increasing the doping concentration from 10^{11} to 10^{20} (atoms/cm^3), has result highest threshold voltage, greater conductivity, higher leakage current and lower resistivity.

References

[1]W.C.O'Mara, R.B.Herring and L.P.Hunt, Preparation Properties of Polycrystalline Silicon Films, Noyes Publications, pp.698-699, 1990.
[2]Abdullah Omar, Sharaifah Kamariah and Ibrahim Ahmad, An Alternative Doping Technique of Polysilicon Gate for Sub-micron CMOS/BICMOS devices, MIMOS Semiconductor, MIMOS Berhad, pp.388-392, 2004.
[3]S.M.Sze, VLSI Technology, Mc-Graw Hill International, pp.99-105, 1983.
[4]Sandhya Gupta, Effects of Underlying Dielectrics on Boron Implanted Polysilicon in Presence of Fluorine, Solid-State Electronics, Vol 47, pp.307-313, 2003.