

Analysis on effect of work function for the performance of Double gate MOSFET

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Abstract—Double gate Metal oxide field effect transistor is the most leading technology now days. This paper represents the study of the effect of the work function on the symmetric double gate MOSFET. The effect of work function of the two dimensional double gate MOSFET has been examined by two-dimensional tools. From the results of simulation it can be observed that by changing the work function of double gate MOSFET we are able to change the threshold voltage. So by setting the appropriate threshold voltage we can decrease the leakage power and as well as the short channel effects.

Keywords— Double gate MOSFET, Threshold voltage, leakage current, DIBL.

INTRODUCTION

To advancement the fabrication technology and satisfy the Moore's propagation law the metal oxide field effect transistor devices are continuously scaling down and it results high integration density and better performance. Due to the continuous scaling down of the devices some short channel effects is introduced which degrades the performance in terms of leakage power [1]. The double gate MOSFET having two gates and control the gates from the both side for better control of the channel, for this reason double gate MOSFET is superior to the conventional MOSFET .so it have better sub-threshold swing and higher current density. As the threshold voltage is degrades so the double gate MOSFET also suffer from short channel effects. Due to the continuous scaling down of the MOS devices the threshold voltage is decrease and as a results the short channel effect and leakage current is also increases. A metal gate technology can be overcome this limitation by providing the gate work function. Work function is the minimum energy required to liberate electron from the metal surface. So from the analysis and the simulation result it can observed that by changing the work function of metal gate we are able to set the appropriate threshold voltage which decreases the short channel effect and leakage current.[2]

An asymmetric double gate MOSFET also able to set appropriate threshold voltage by using n and p poly silicon gates in the DG devices. We can also set the threshold voltage by channel doping but it decreases the device performance due to the dopant fluctuations and carrier mobility [3]. A large channel doping results increasing band to band tunneling between body and drain and the asymmetric double gate MOSFET gives degraded performance. It emphasizes the need of gate work function as a alternative solutions [4]. With advancement of VLSI technology, leakage current need to be controlled which comes in to account due to the continuous scaling of the gate lengths, threshold voltages and the gate oxides as per the rules of scaling. In order to get effective control of the channel and minimizing the leakage current the metal gate is used for sub micron technology [5]. In order to reduce short channel effect metal gate electrode needs to a work function which can be tuned to a desired value. For any channel length metal gate work function has been increased and the threshold increases and at the same time leakage current decreases.[6][7].the threshold voltage sensitivity with the oxide thickness is not a serious issue for longer channel devices but in deep sub micron technology its effect cannot be neglected which put restriction on the gate oxide thickness value. The electrostatic potential along with the film thickness has been reduces when the film doping concentration and the source/drain thickness is increases.[8].

From the device design point of view the most important consideration or the gate electrode is work function of the material. Metal gate material chooses the best opportunity. For bulk or partially depleted SOI, the requirements on the threshold voltages and the need to use heavy dopants to control short-channel effects, the most suitable gate work-function values are close to the conduction and valence bands of silicon.[9]. The work was concentrated on the determination of threshold voltage directly but few limitation had been encountered.[10]. However, intrinsic channel DG MOSFETs need to rely solely on gate work function to achieve multiple threshold voltages on a chip due to the absence of body doping, which is an efficient tool to adjust the threshold voltage in DG MOSFETs with doped channels [11, 12].

DEVICE STRUCTURE:

To study the effect of work function on double gate MOSFET the cross sectional view of DG MOSFET is shown in fig (1)

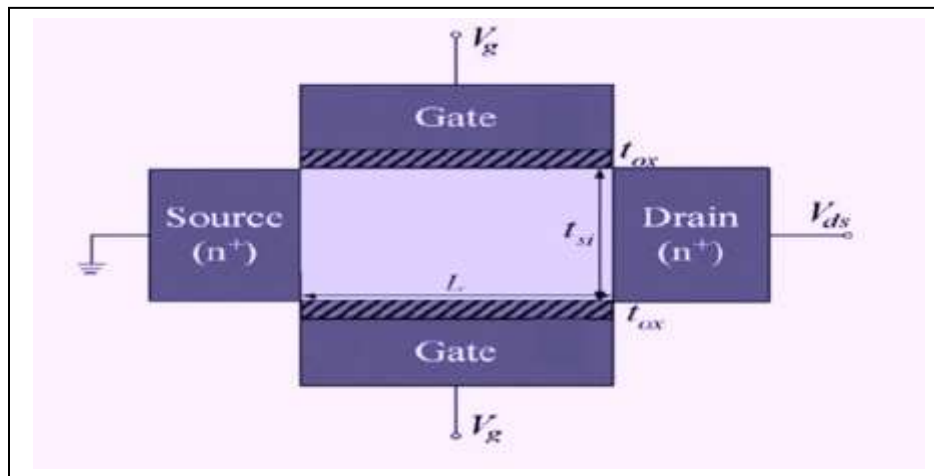


Fig:1 structure of DG MOSFET

To neglect the degradation of carrier mobility and more threshold variation we consider light channel doping concentration. The channel doping concentration is 1×10^{-16} . And the silicon film thickness is 20nm and the oxide thickness is 2nm. Here we consider the n channel device and simulated this with different work function of double gate MOSFET. We consider molybdenum metal as a gate metal because it gives a very wide range of work function. As molybdenum has low resistivity and high melting point it exhibits work function near to 5eV [4]. With high dose of nitrogen implantation the work function of molybdenum can be significantly reduced. To adjust the molybdenum gate work function in a controllable way without degrading the transistor performance a nitrogen implantation can be used.

RESULTS AND ANALYSIS:

As shown in the table no 1 that the double gate MOSFET with work function 4.8 have lower drain induced barrier lowering high threshold voltage and low leakage current compared to the device with work function 4.4eV and 4.6eV respectively. This is because to invert the channel higher gate to source voltage (V_{gs}) is required. The double gate MOSFET which have work function 4.4eV has maximum drain current (I_{dmax}) as compared to the other devices which have work function 4.6eV and 4.8eV respectively but they have higher DIBL effect and higher leakage current. The drain induced barrier lowering (DIBL) is defined as the difference in threshold voltages when the drain current is varies from 0.1 V to 1 V. so by selecting work function of metal gate we can set the desired threshold voltage. The variation of drain current as a function of gate voltage shown in the figure 2. We can observe that double gate MOSFET having work function 4.8 eV has higher threshold voltage but have lower drain current compared to the other devices. As we can set appropriate threshold voltage by providing different work function to the metal gate. So in this way we can also reduce leakage current as leakage current is affected.

Table: 1 comparison of different parameter of double gate MOSFET with different work function

Device Name	Leakage current	Maximum Drain current	Threshold voltage	DIBL(mV/V)
DGMOSFET with work function 4.4 eV	4.2μA/μm	2.3 ma	0.16 V	78.8
DGMOSFET with work function 4.6 eV	3.4μA/μm	1.8ma	0.24 V	44.3
DGMOSFET with work function 4.8 eV	0.8nA/μm	1.3 ma	0.46 V	17.2

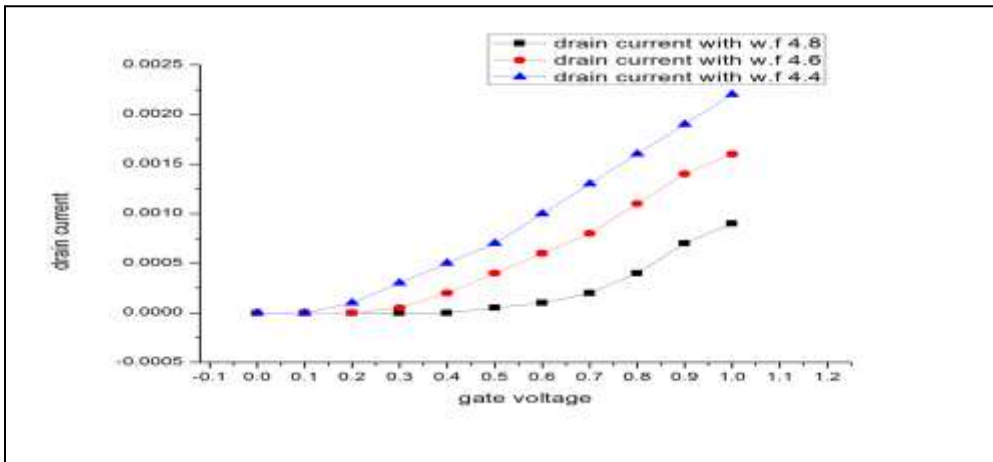


Fig: 2 drain current as a function of gate voltage

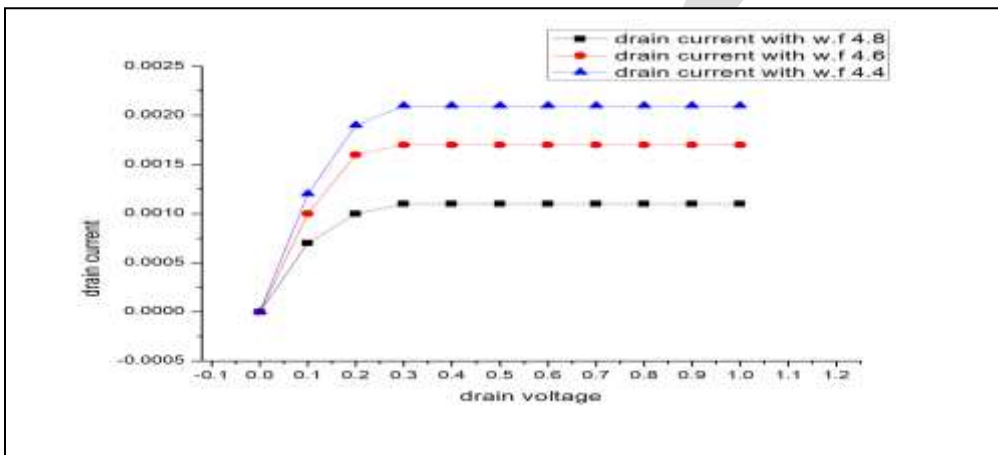


Fig: 3 drain current as a function of drain voltage

From the figure 3 we can observe that the device having work function $4.4eV$ has higher drain current as compared to the devices having work function $4.6eV$ and $4.8eV$ respectively. But the device having work function $4.8eV$ gives the better performance in terms of low leakage current and reduced short channel effect.

CONCLUSION

To increase the device speed and the packing density the device is continuously scaling down but due to this continuously scaling down some short channel effects is occur and the device performance is degrades in terms of leakage current. So to continue this scaling process it is need to introduce a structure which gives better performance in submicron technology. Channel doping is concepts by which we can set desired threshold voltage but it degrade the device performance in terms of carrier mobility and dopant fluctuations. But by the concept of work function we can set appropriate threshold voltage and as well as better device performance as compared to channel doping. Molybdenum is the most attractive because of its compatibility with CMOS. The work function of the molybdenum is altered by nitrogen implantation without hamper or degrading the device performances. so it can be concluded that we can set appropriate threshold voltage by set different work function

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