Metal source/drain technology for nanoscale MOSFET & high speed flash applications

Moongyu Jang1, Myungsim Jun1, Yangkyu Choi2 and Seongjin Choi1, 2
1 Electronics & Telecommunications Research Institute (ETRI), Daejeon, Korea
2 Korean Advanced Institute of Science & Technology (KAIST), Daejeon, Korea
jangmg@etri.re.kr

Abstract
Metallic source/drain technology is widely investigated including MOSFETs, single electron transistors, flash memories and thin film transistors. Due to the existence of Schottky barrier between metallic silicide and silicon, the subthreshold swing characteristic is enhanced and the source/drain parasitic resistance is reduced giving the improvement of device characteristics. Also, due to the tunneling process through the Schottky barrier, the flash memory characteristic is dramatically enhanced.

Introduction
As the feature sizes of the conventional field-effect-transistors (FETs) continue to shrink into the nanometer regime, physical and technological problems such as short-channel effects and dopant fluctuation issues are significant emerging problems. Tunnel transistors with metallic source and drain structures have attracted attentions because the aforementioned problems could be overcome. For example, in nanotube/nanowire devices, such CNT FETs, silicon and ZnO nanowire FETs, etc, metallic electrodes (Au, Ti, TiN, etc.) are widely being used as the source and drain materials. In metallic source & drain devices, the main charge transport mechanism is tunneling through the Schottky barrier existing between the metal and semiconductor interfaces.

In this paper, various sizes of Schottky barrier MOSFETs (SB-MOSFETs) are manufactured down to 7nm using erbium-silicide and platinum silicide for n-/p-type transistors. Also, the short channel characteristics of SB-MOSFETs are analyzed using SS characteristics to check the scalability. Moreover, the low temperature (7K) behavior is also investigated to check the possibility as single electron transistor.

Here, also, we demonstrate a new type of Flash memory cell based on the structure of dopant-segregated Schottky-barrier (DSSB) MOSFET. The hot carriers intrinsically generated from the shallow DSSB source/drain junctions can be utilized for the advancement of both the NAND and the NOR type Flash memory cell. With the aid of these hot carriers that possess improved probability to be trapped into a charge storage node such as polysilicon layer in the floating gate memory device or the nitride layer in the SONOS memory device, the DSSB MOSFET shows very fast programming time at low programming voltage, compared to conventional MOSFET based on p-n S/D junctions. Besides, the superior scalability resulting from the abrupt and shallow junctions are also achieved without the constraint of the parasitic resistance due to metallic silicided material. Furthermore, the DSSB thin film transistor based on polycrystalline silicon for the application of 3-D stackable memory will be reported.

Results and Discussions
Erbium and platinum are chosen as source/drain metal of n/p-type SB-MOSFETs, because of its low Schottky barrier height for electrons and holes, respectively. Devices are fabricated with the procedures as following. After gate etching, 15nm thin spacer is made using 900 °C thermal oxidation method. Erbium-silicide and platinum-silicide are formed on low doped (NSUB=10¹⁵cm⁻³) SOI layer by annealing at 500°C for 10min using rapid thermal annealing method. The remained erbium and platinum are removed using sulfuric Peroxide mixture (SPM) and aqua regia for 10min, respectively. Fig. 1 shows the diode characteristics of ErSi₁.⁷ on p-sub and PtSi on n-sub, respectively. The extracted Schottky barrier height of ErSi₁.⁷ for hole is 0.77eV and PtSi for electron is 0.87eV which corresponds to 0.36eV for electron and 0.25eV for hole, respectively.

![Fig. 1. Schottky diode I-V characteristics](image-url)

Fig. 2 shows I_DSVGS and I_DSVDS characteristics of the 20 μm long channel n/p-type SB-MOSFETs. The gate oxide and spacer thickness is 5nm and 15nm, respectively. Both the n/p-type SB-MOSFETs show high on/off current ratio, larger than Ion/Ioff>10⁵ with low leakage current (I_LKG<100 pA/μm). The on/off ratio and the leakage current level is the highest and lowest values compared with previously published data in SB-MOSFETs. Also, DIBL is almost suppressed in both n/p-type SB-MOSFETs and the SS value is 60mV/decade both in n-type & p-type SB-MOSFETs, reaching the theoretical limit value in MOSFETs.
of Schottky barrier which causes the injection of more energetic carrier at the edge of source region due to the tunneling process through the Schottky barrier.

Conclusions

In summary, metallic source/drain technology is widely investigated including MOSFETs, single electron transistors, flash memories and thin film transistors. The metallic source/drain structured devices are a very promising candidate for future nano-electronics applications of the logic and Flash memory device since they enable the continuation of device scaling.

References