Investigation of DIBL Control in Nanosheet Transistors at Low-Voltage Operation

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Abstract

In this study, the nanosheet transistors operate under low-voltage conditions. When the active doping concentration increases from 1e17 cm^{-3} to 1e19 cm^{-3}, the DIBL decreases by 46.93%, the subthreshold swing (SS) decreases by 49.31%, and the current on/off ratio increases by a factor of 23.306. Additionally, when the metal gate work function (WF) increases from 4.34 eV to 4.40 eV, the SS decreases by 0.57%, and the current on/off ratio increases by a factor of 3.986.

Results and Discussion

Nanosheet-field transistor

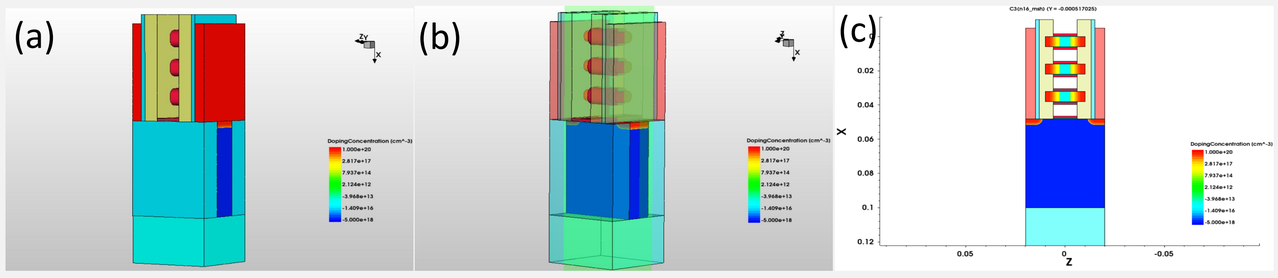

Fig 1. (a) 3D view of nanosheet-field transistor (b)The cross-section of nanosheet FET along y axis(c)The doping concentration distribution across the cross-sectional region of the nanosheet FET

DIBL

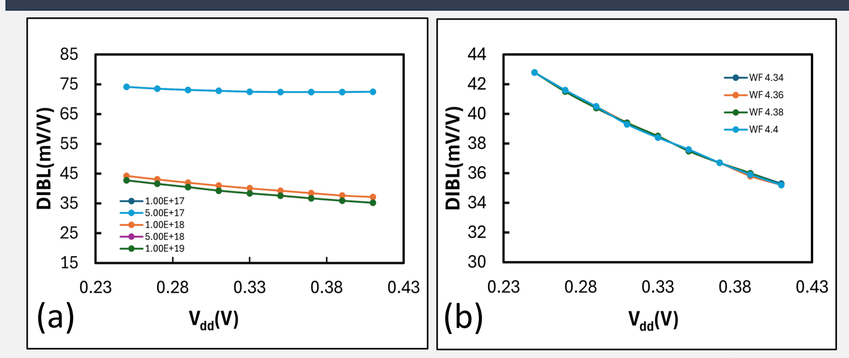

Fig 2. The DIBL variation with VDD (from 0.25V to 0.41V) under (a)different active doping concentration (b)different metal gate work function

Subthreshold Swing

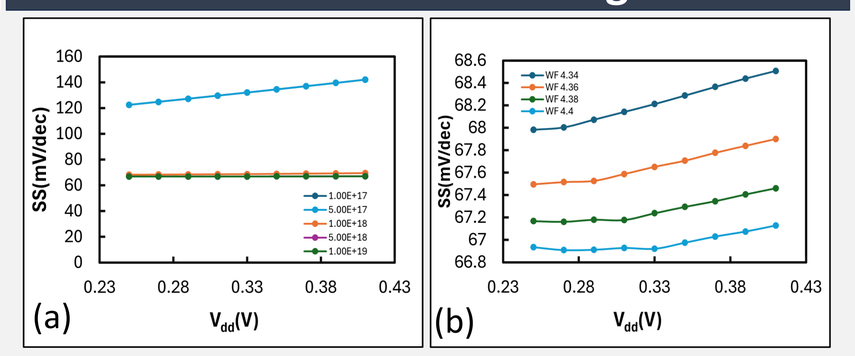

Fig 3. The SS variation with VDD (from 0.25V to 0.41V) under (a)different active doping concentration (b)different metal gate work function

Current Ratio

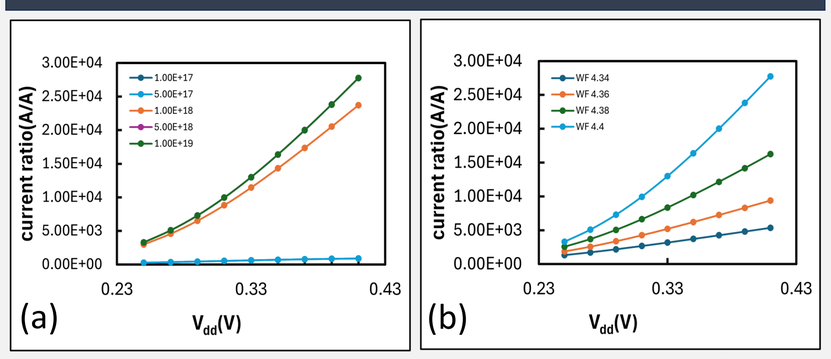

Fig 4. The current ratio variation with VDD (from 0.25V to 0.41V) under (a)different active doping concentration (b)different metal gate work function

Id-Vg curve

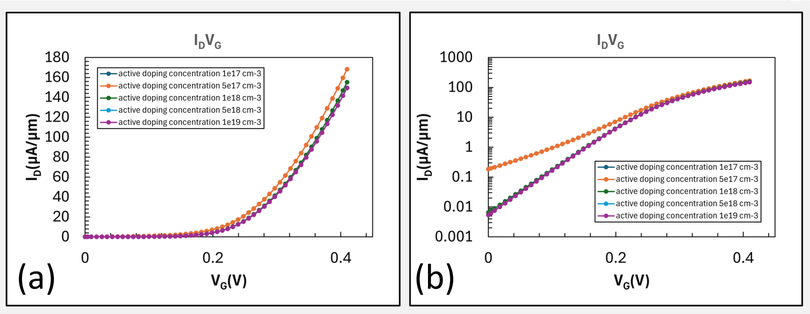

Fig 5. (a)The Id-Vg (drain current-gate voltage) curve under different active doping concentration, and (b)shows the Log-Scale Id-Vg plot

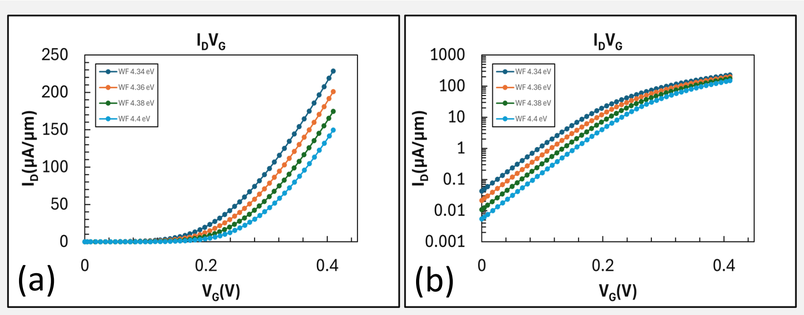

Fig 6. (a)The Id-Vg (drain current-gate voltage) curve under different metal gate work function, and (b)shows the Log-Scale Id-Vg plot

Id-Vd curve

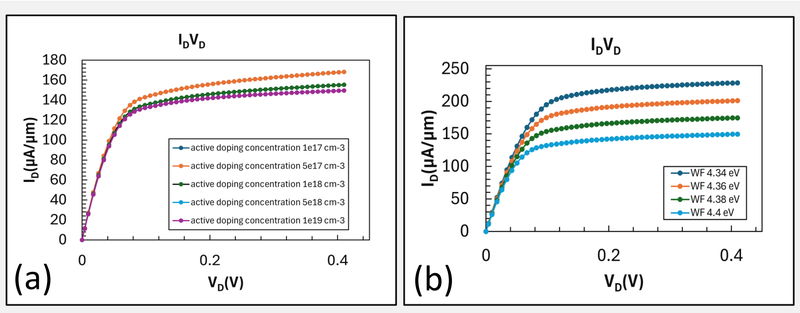

Fig 7. (a)The Id-Vd (drain current-drain voltage) curve under different active doping concentration(b) different metal gate work function

Conclusions

1. It shows that the higher active doping concentration tends to exhibit lower DIBL effect, large Subthreshold Swing (SS), and a bigger current ratio. The results means the higher active concentration has better electrical behavior.
2. Although the difference of four different metal gate work function (WF) in DIBL is not significant, it can still be observed that the higher WF leads to a smaller SS and a larger current ratio. This indicates that device with higher WF exhibits superior electrical performance.
3. The Id-Vg curve rises slowly under higher active doping concentration, which confirms the result of the first conclusion. The Id-Vg curve of different WF reveals that the device with higher WF turn on at a higher gate voltage, making it more suitable for low power design.
4. This study successfully shows that the higher active doping concentration and WF can reduce DIBL effect and enhance SS and current ratio at low-voltage operation.