Impact of Vertical Channel Thickness Non-Uniformity on DIBL in Stacked Nanosheet Transistors

Yi-Hsuan Peng ,Shou-Yung Chao ,Wei-Chen Tu
Department of Electrical Engineering,National Cheng Kung University
E-mail:wctu@gs.ncku.edu.tw

Abstract

This study investigates the impact of vertical channel thickness variation on the DIBL effect in stacked nanosheet transistors through TCAD simulations. The baseline thickness is 6 nm, with variations ranging from 4 nm to 9 nm. Simulated structures include cases where one, two, or all three nanosheet layers have non-uniform thickness.

Results and Dicussion

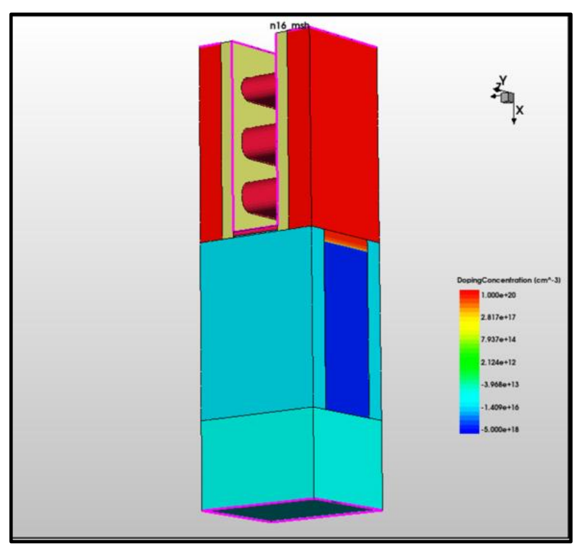

Fig. 1

Fig. 1 shows the 3D structure of the GAA nanosheet device.

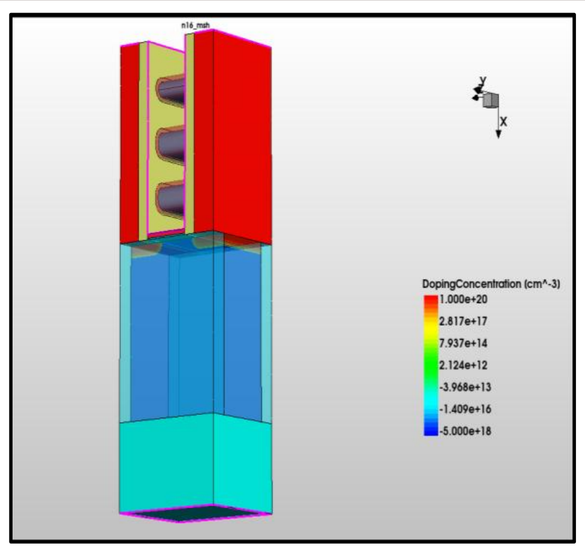

Fig. 2

Fig. 2 presents a partially transparent view of the GAA nanosheet structure, illustrating the internal layer configuration.

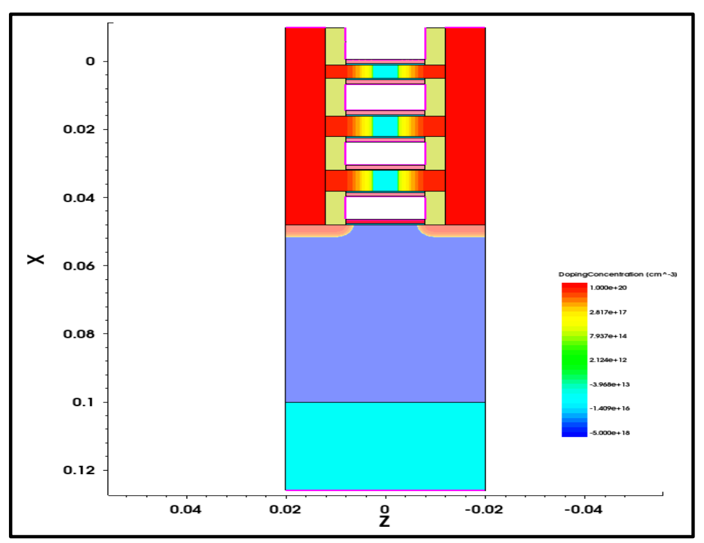

Fig. 3

Fig. 3 shows the X-Z cross-sectional view of the device at a fixed Y-axis, illustrating the doping concentration distribution in each region.

Drain-Induced Barrier Lowering (DIBL)

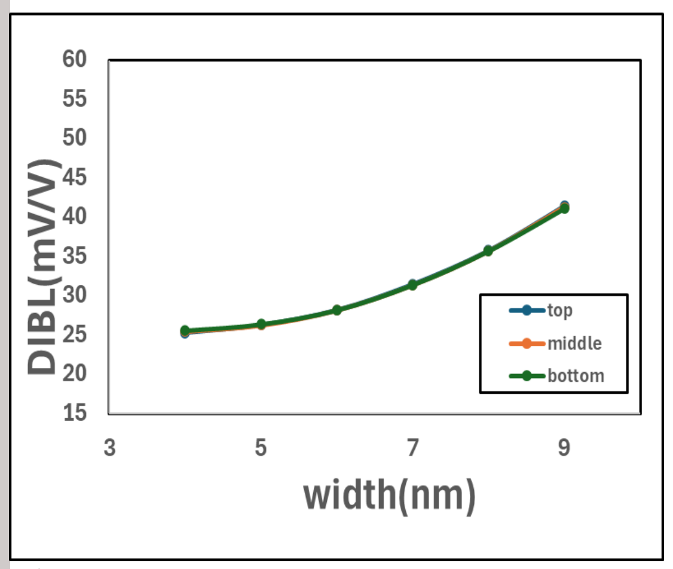

Fig. 4

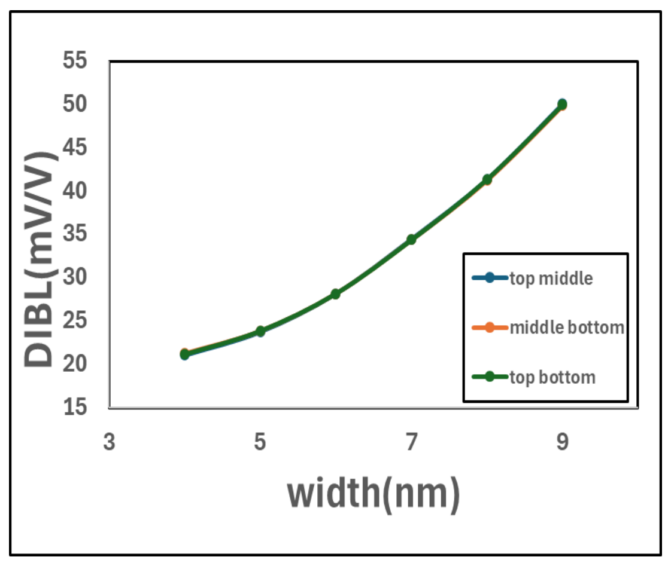

Fig. 5

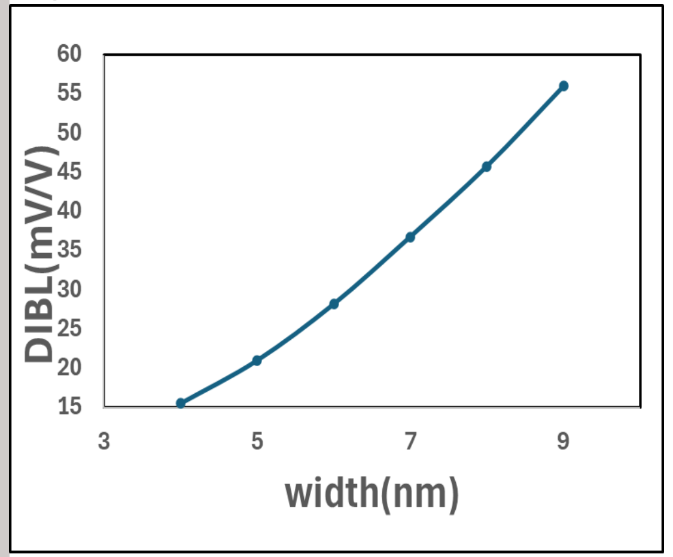

Fig. 6

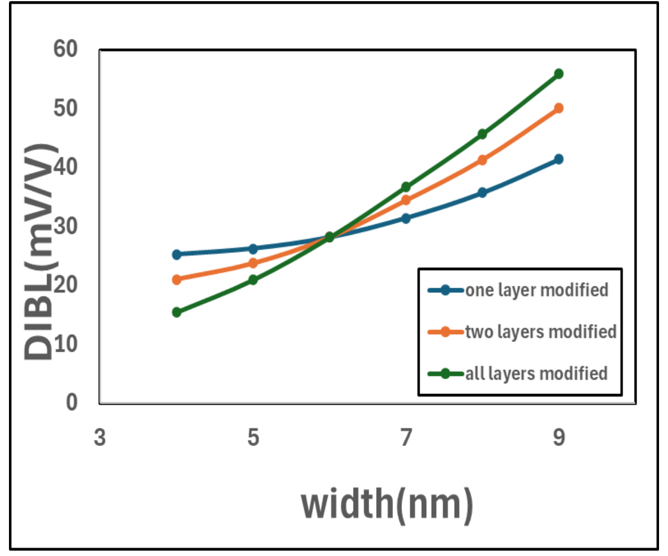

Fig. 7

Fig.4 DIBL variation when changing top, middle, or bottom layer.
Fig.5 DIBL values under different two-layer combinations.
Fig 6 DIBL under all-layer thickness changes.
Fig.7 Comparison of DIBL under one-, two-, and three-layer changes.

Explanation of the DIBL Mechanism:

When the thickness increases, the gate-to-channel distance becomes longer, weakening gate control. The drain-side field penetrates the channel more easily, increasing the DIBL value; conversely, reduced thickness lowers DIBL.

As more layers have thickness changes, the affected electric field region expands, leading to more significant DIBL variations.

Ion/Ioff

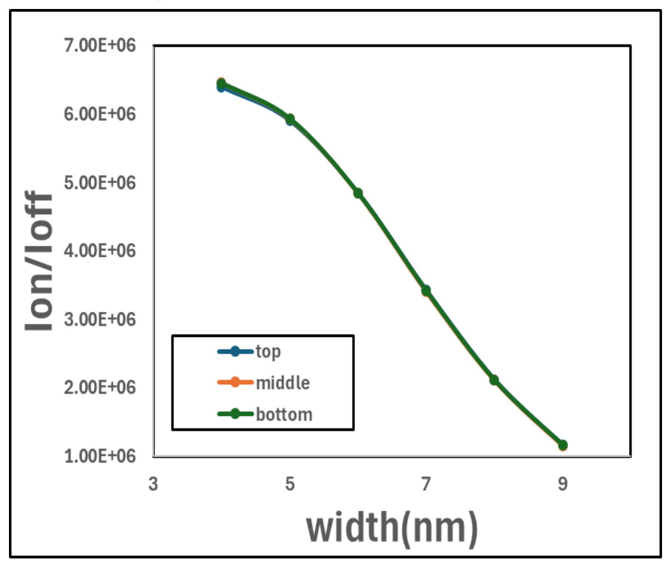

Fig. 8

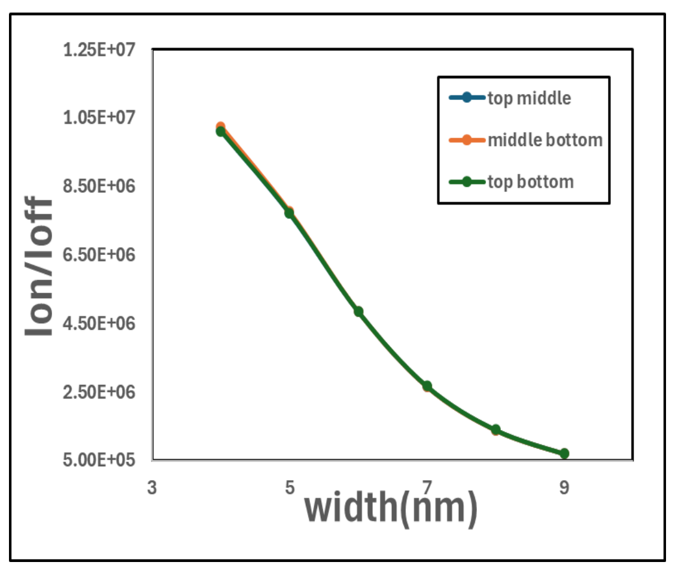

Fig. 9

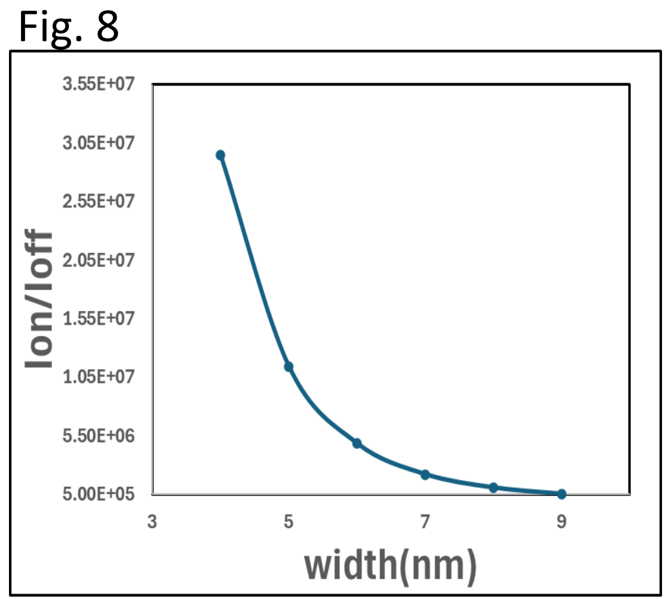

Fig. 10

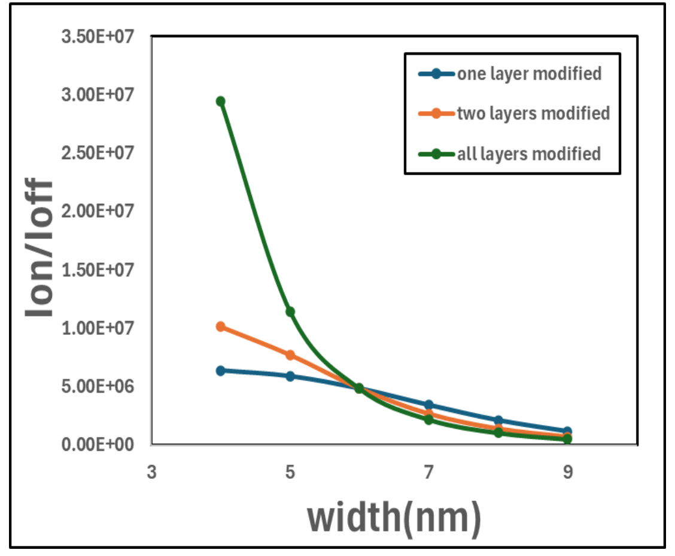

Fig. 11

Fig.9 Ion/Ioff variation when changing top, middle, or bottom layer.
Fig.10 Ion/Ioff values under different two-layer combinations.
Fig 11 Ion/Ioff under all-layer thickness changes.
Fig.12 Comparison of Ion/Ioff under one-, two-, and three-layer changes.

Explanation of the Ion/Ioff Mechanism:

When the thickness increases, gate control weakens and the barrier lowers, making drain field penetration easier, which raises Ioff and reduces the Ion/Ioff ratio; conversely, when it decreases, the barrier rises, lowering Ioff and increasing the Ion/Ioff ratio.More layers with thickness changes expand the affected field region, causing more significant Ion/Ioff variation.

Subthreshold Swing (SS)

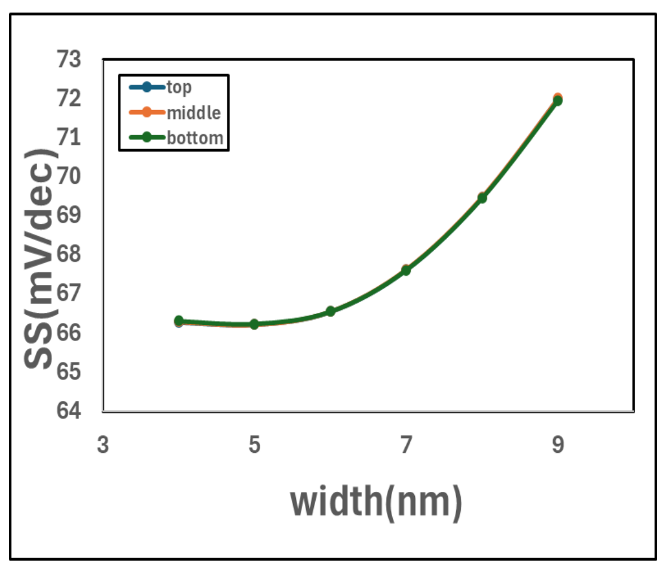

Fig. 12

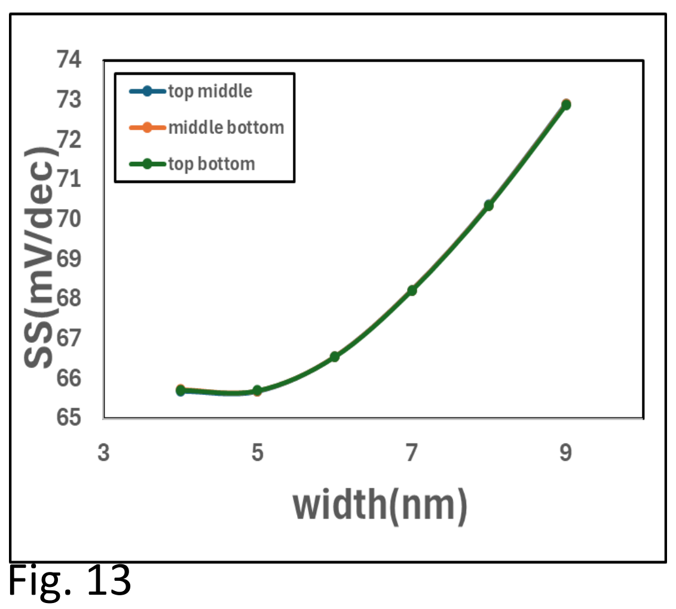

Fig. 13

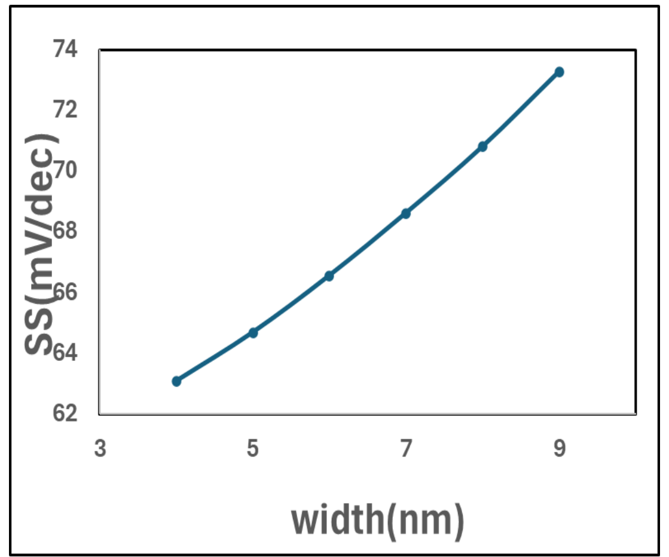

Fig. 14

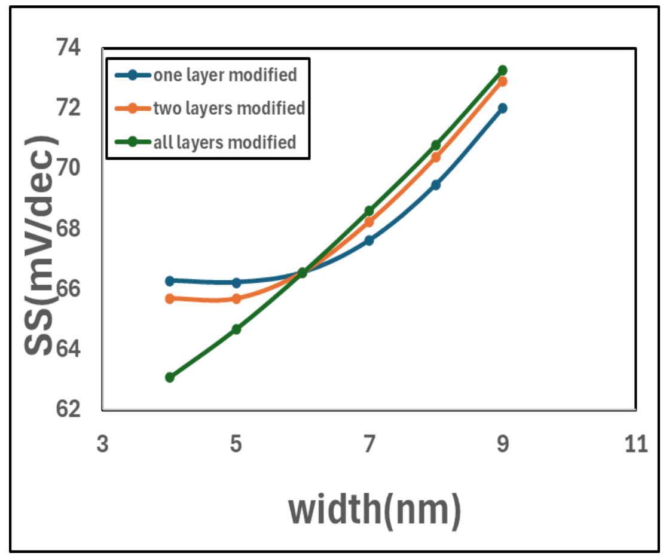

Fig. 15

Fig.12 SS variation when changing top, middle, or bottom layer.
Fig.13 SS values under different two-layer combinations.
Fig 14 SS under all-layer thickness changes.
Fig.15 Comparison of SS under one-, two-, and three-layer changes.

Explanation of the SS Mechanism:

When the thickness increases, gate control weakens and the channel responds less to gate voltage changes, requiring a larger voltage to raise the current by one order, thus increasing SS; conversely, reduced thickness lowers SS.

More layers with thickness changes expand the affected field region, causing more significant SS variation.

ID-VG

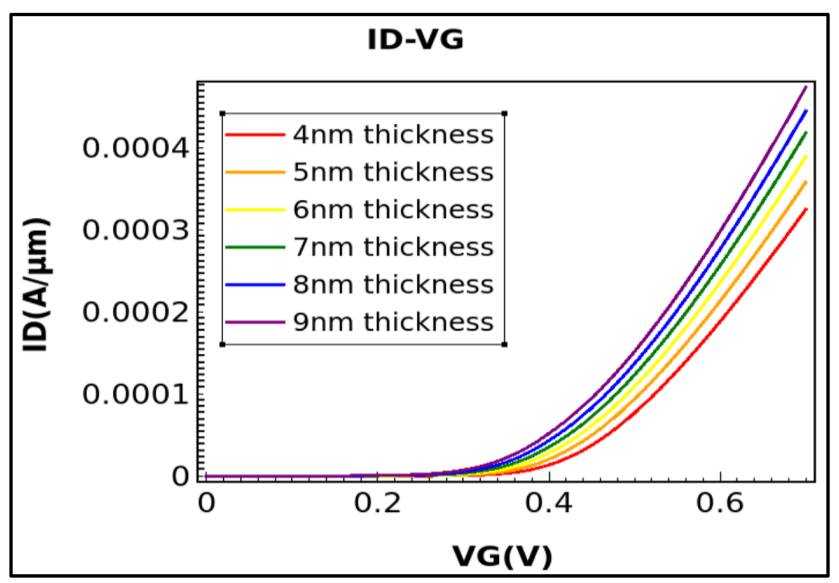

Fig. 16

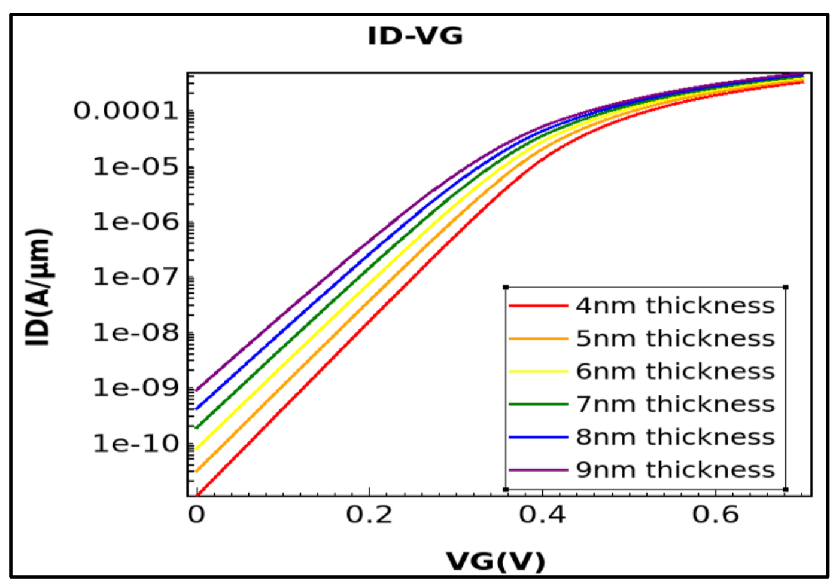

Fig. 17

Fig. 16 shows the ID–VG characteristics under different nanosheet thicknesses (4–9 nm).
Fig. 17 shows the logarithmic scale version of the same set of simulation results.

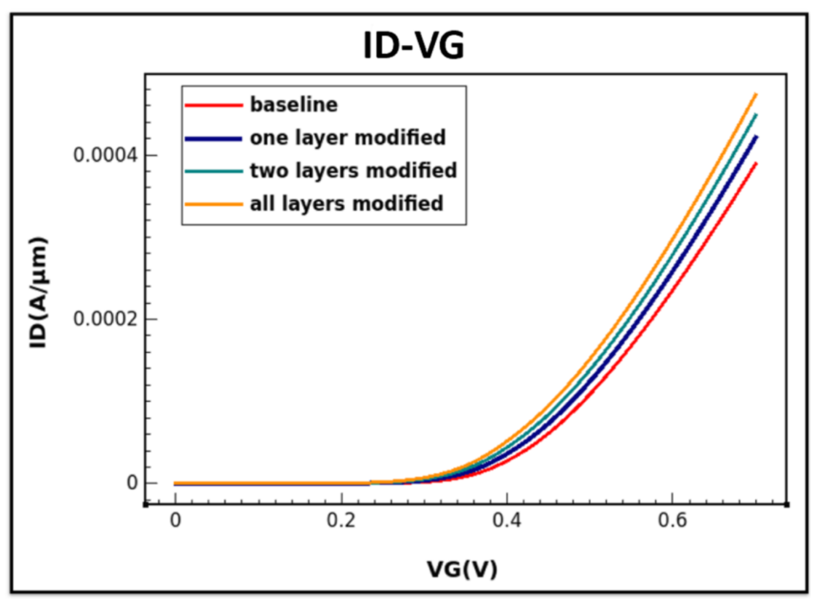

Fig. 18

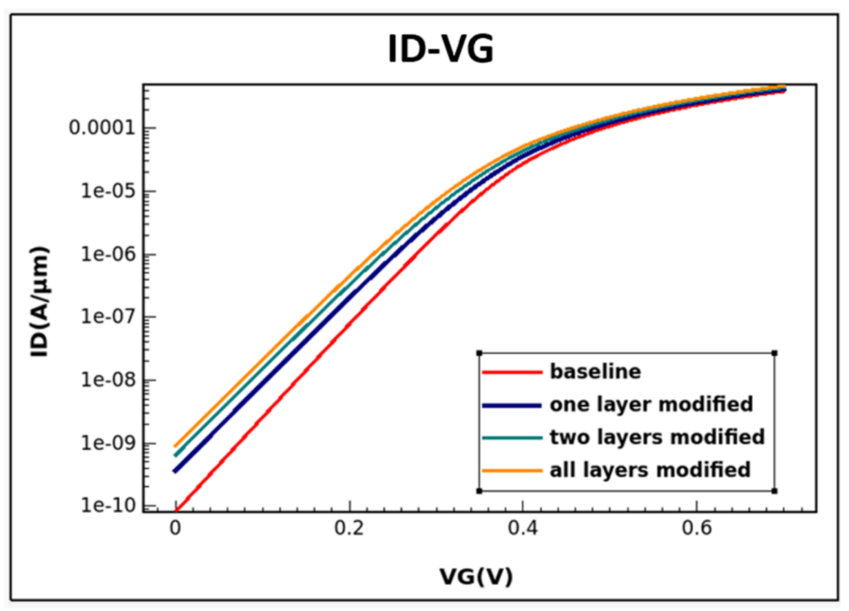

Fig. 19

Fig. 18 shows the ID–VG characteristics for devices with different numbers of modified nanosheet layers (one, two, all), compared with the baseline.
Fig. 19 presents the logarithmic scale version of the same data set.

Conclusion

1. When nanosheet thickness increases, gate control weakens, causing higher DIBL and SS, increased Ioff, and lower Ion/Ioff ratio; conversely, when thickness decreases, gate control strengthens, reducing DIBL and SS, lowering Ioff, and raising Ion/Ioff ratio.
2. As the number of modified nanosheet layers increases, the variations in DIBL, SS, and Ion/Ioff ratio become more significant.