# Optimal Thickness in 2D van der Waals Multilayers with Vertical Double Side Contacts

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Two-dimensional (2D) van der Waals (vdW) materials inherently possess an interlayer resistance between adjacent layers, which significantly influences their carrier distribution across the thickness of the material, particularly in relation to the positioning of the metal electrodes. Herein, by considering the Thomas-Fermi charge screening theory and a resistive network model, we systematically explore the thickness-dependent effective carrier density profile for the bottom contact, top contact, and vertical double-sided contact (VDC), where the top and bottom contact electrodes are connected. VDC provides the least resistive conducting paths for carriers within 2D vdW multilayers by suppressing interlayer resistance effects, resulting in a spatial redistribution of carrier density along the thickness under varying electrostatic vertical and lateral bias conditions, and consequently establishing separate bottom and top channels. The highest effective mobility, particularly for VDC, was observed at approximately 10 nm, highlighting the pivotal role of the bottom channel in the high electron accumulation regime as the thickness increases. To validate our computational results, several back-gated *n*-type $WSe_2$ transistors with thicknesses ranging from 4 to 244 nm were fabricated. Superior electrical properties, including carrier mobility, conductivity, and a high on/off current ratio, were observed at thicknesses of 8–10 nm, in excellent agreement with our numerical calculations. Our findings provide valuable insights for the advancement of next-generation electronic transistors based on 2D vdW multilayers.

*This study was supported by the International Research & Development Program of the National Research Foundation of Korea (NRF), funded by the Ministry of Science and ICT [No. RS-2023-00254934], an NRF grant funded by the Korean government [No. NRF-RS-2025-00514053], and Samsung Display.*

## References

[1] Das, S. et al., Rapid Research Letters (2013) pp. 268–273.

## Figures

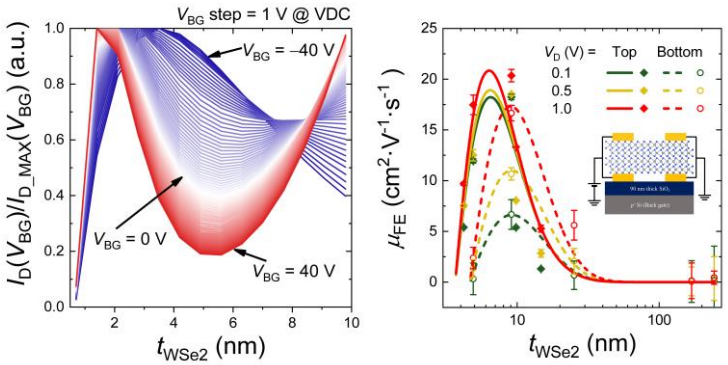


**Figure 1:** Numerically simulated thickness-dependent $I_D(V_{BG})/I_{D\_MAX}(V_{BG})$ of 10 nm-thick $WSe_2$ under VDC, using a $V_{BG}$ range of - 40 to 40 V in 1 V steps, with $R_{int}$ = 50 kΩ·μm. And $\mu_{FE}$ for top- and bottom-channels at $V_D$ = 0.1 V, 0.5 V, and 1 V as a function of $t_{WSe2}$. The error bars for $\mu_{FE}$ represent the standard deviation from the mean $\mu_{FE}$.