SEMINATEC 2026
XX Workshop on Semiconductors and Micro & Nanotechnology

XX Workshop on Semiconductors and Micro & Nano Technology

Poster nº: 44

Enhanced Split-CV method for mobility extraction minimizing VDS-effects

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Abstract: Carrier mobility is an important figure of merit for understanding transistor device physics. Unlike bias and current, mobility is extracted indirectly from measurements such as I-V and C-V characteristics. Consequently, the choice of extraction technique is important. While the split-C-V technique remains the gold standard for determining carrier mobility, studies by Liu et al. demonstrated that V_{DS} significantly impacts the extracted mobility in advanced devices with an EOT of approximately 1 nm. To address this, an improved methodology was proposed based on the arithmetic average of split-C-V results for positive and negative V_{DS} values. This paper proposes an alternative approach based on the geometric mean of these results, further reducing the impact of V_{DS} on the extracted mobility.

RESULTS AND DISCUSSION

The traditional split-C-V method relies on two primary measurements: the ID-VG characteristic at a low drain bias and the gate-to-channel capacitance (Cgc-VG)

$$Q_{inv}(V_G) = \int_{-\infty}^{V_G} C_{gc}(V)\,dV \qquad (1)$$

$$\mu_{eff} = \frac{L}{W} \cdot \frac{I_D(V_G)}{V_{DS} \cdot Q_{inv}(V_G)} \qquad (2)$$

Based on this standard approach, several studies have proposed methodologies to further refine extraction accuracy [1], [2], [3], [4]

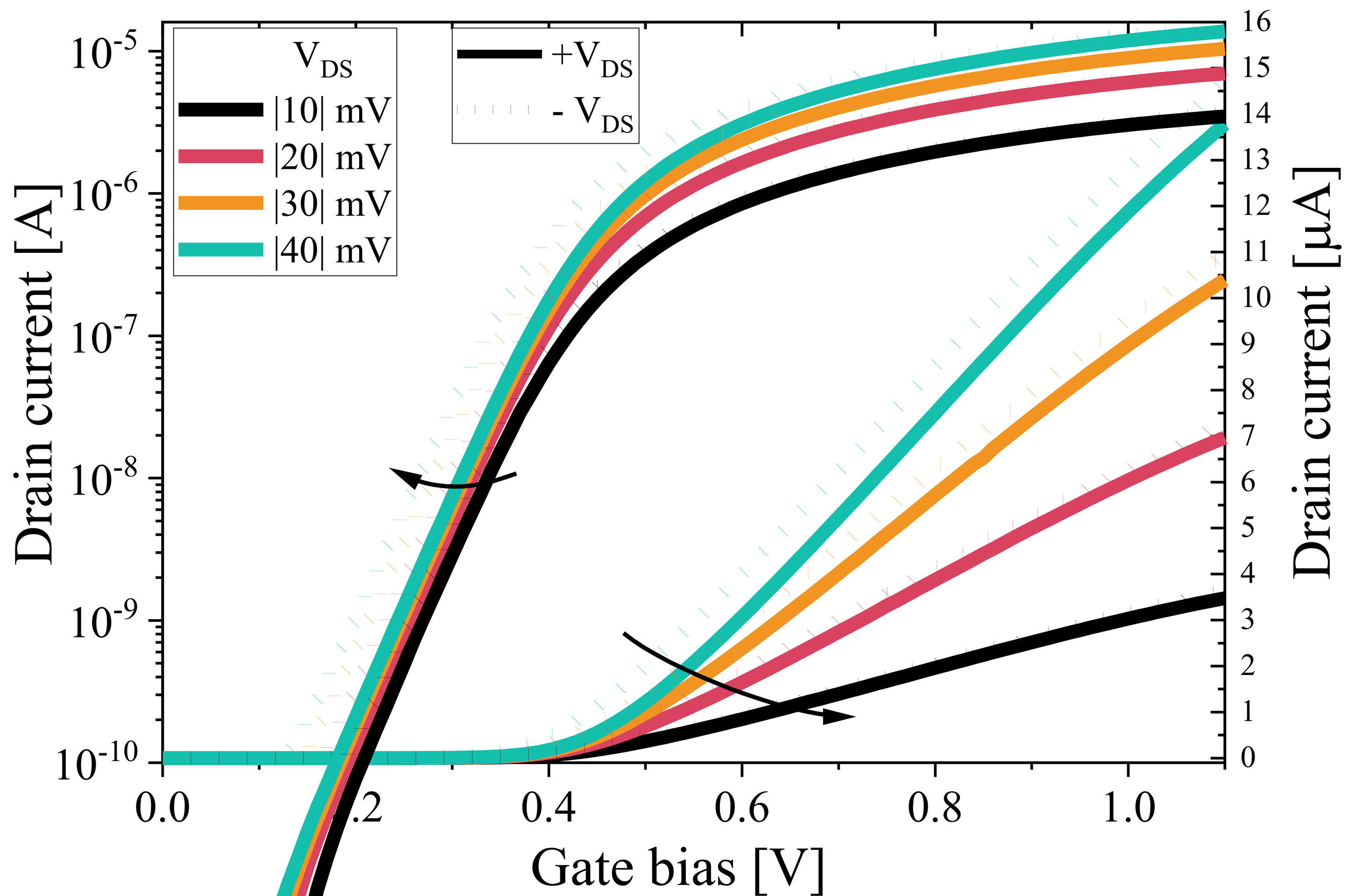

Fig. 1. Drain current as a function of the gate bias for a wide range of drain bias, from -40 mV to +40 mV.

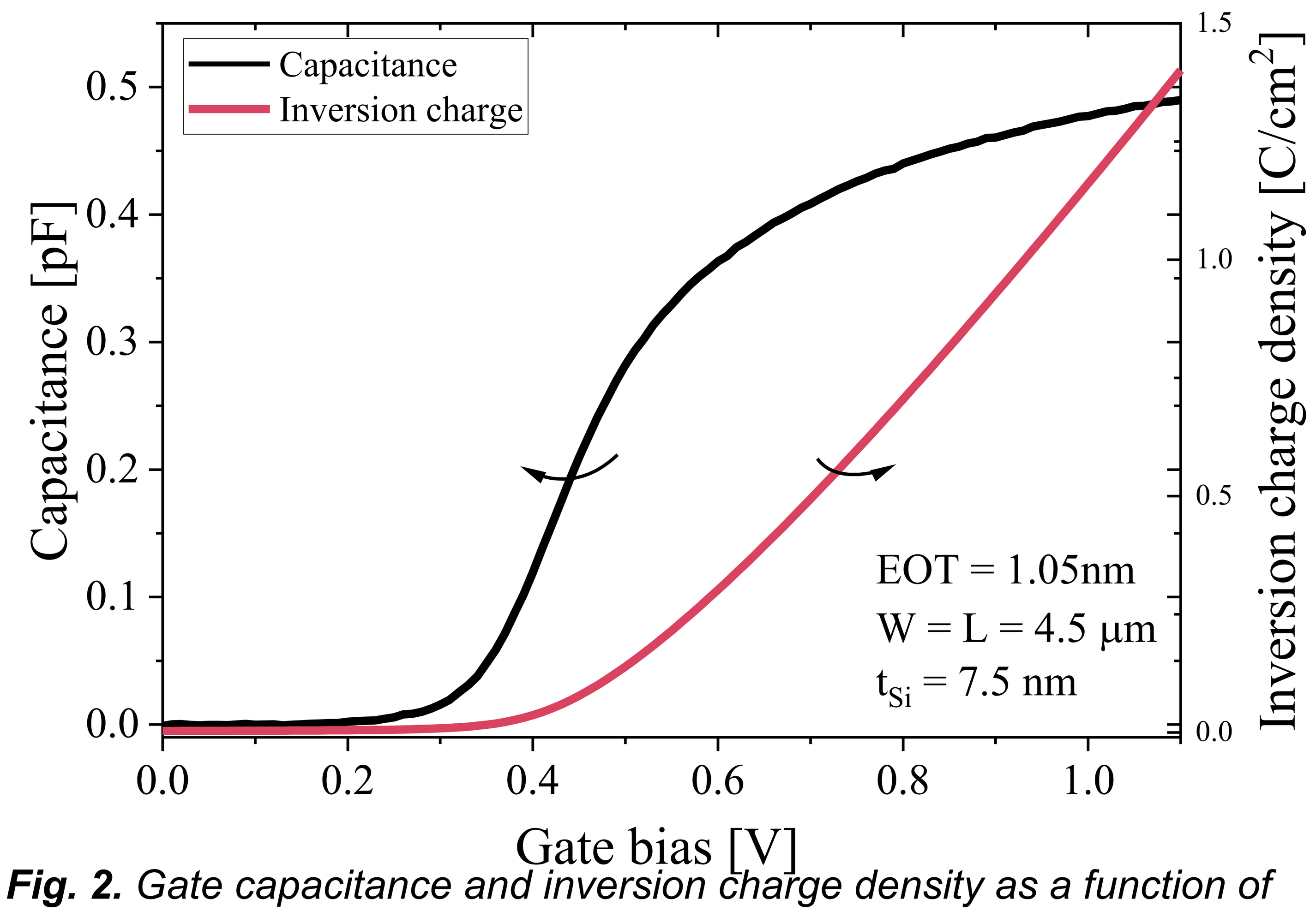

Fig. 2. Gate capacitance and inversion charge density as a function of gate bias.

From Figure 3, it is noticeable that the drain bias impacts the carrier mobility, with the negative bias overestimating the mobility and the positive drain bias underestimating the mobility

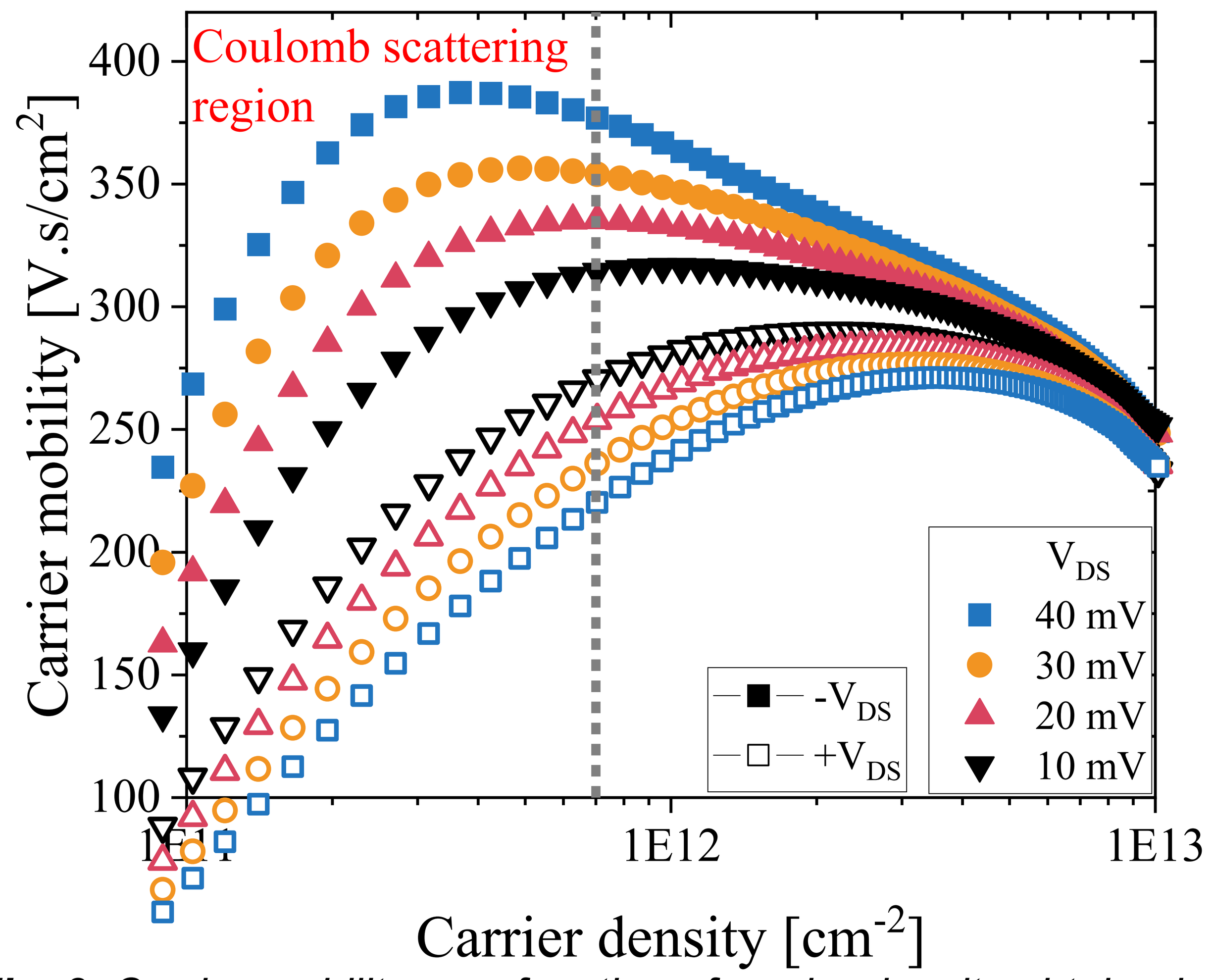

Fig. 3. Carrier mobility as a function of carrier density obtained with drain bias from -40 mV to +40 mV

The comparison suggests that the geometric mean is more effective at neutralizing the VDS impact across the Ninv range. This improvement is attributed to the power-law behavior of the mobility curve in the low-density region

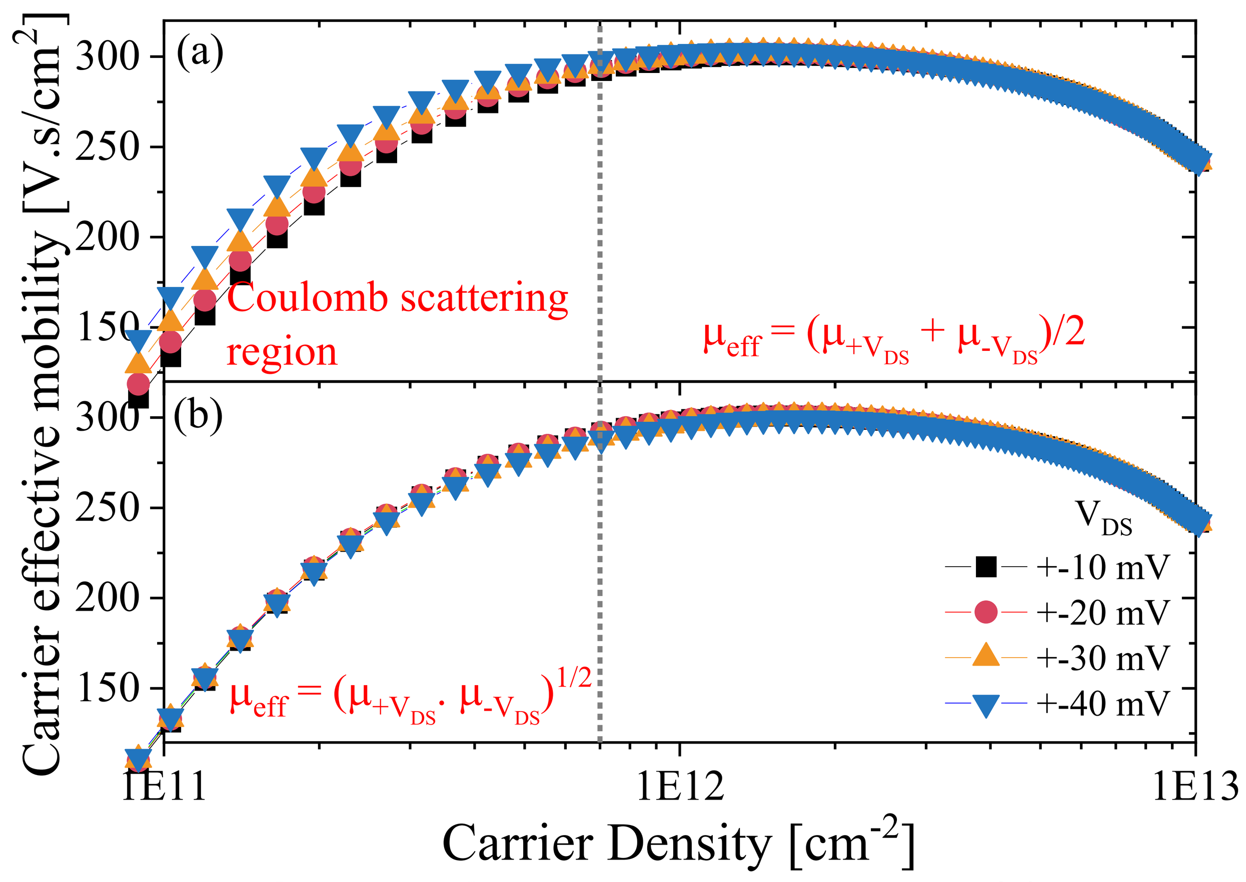

Fig. 4. Carrier mobility as a function of carrier density calculated (a) using a simple average and (b) using a geometric mean

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ACKNOWLEDGEMENTS

(The research work presented in this paper was partly carried out in the framework of the Fames Pilot Line of the Chips JU, funded by Horizon Europe grant 101182279 and the ANR NextGen project ANR-22-NEXTG-001 of the France 2030 initiative and the support of CEA-Leti, CNPq and CAPES for financial support.

Organizers: Feec Unicamp, UNICAMP, IEEE Advancing Technology for Humanity, Electron Devices Society

Support: INCT NAMITEC, SBMicro Sociedade Brasileira de Microeletrônica