A28 Electron Mobility Modeling of AlN/GaN MIS-HEMTs With Embedded Source Field-Plate Structures

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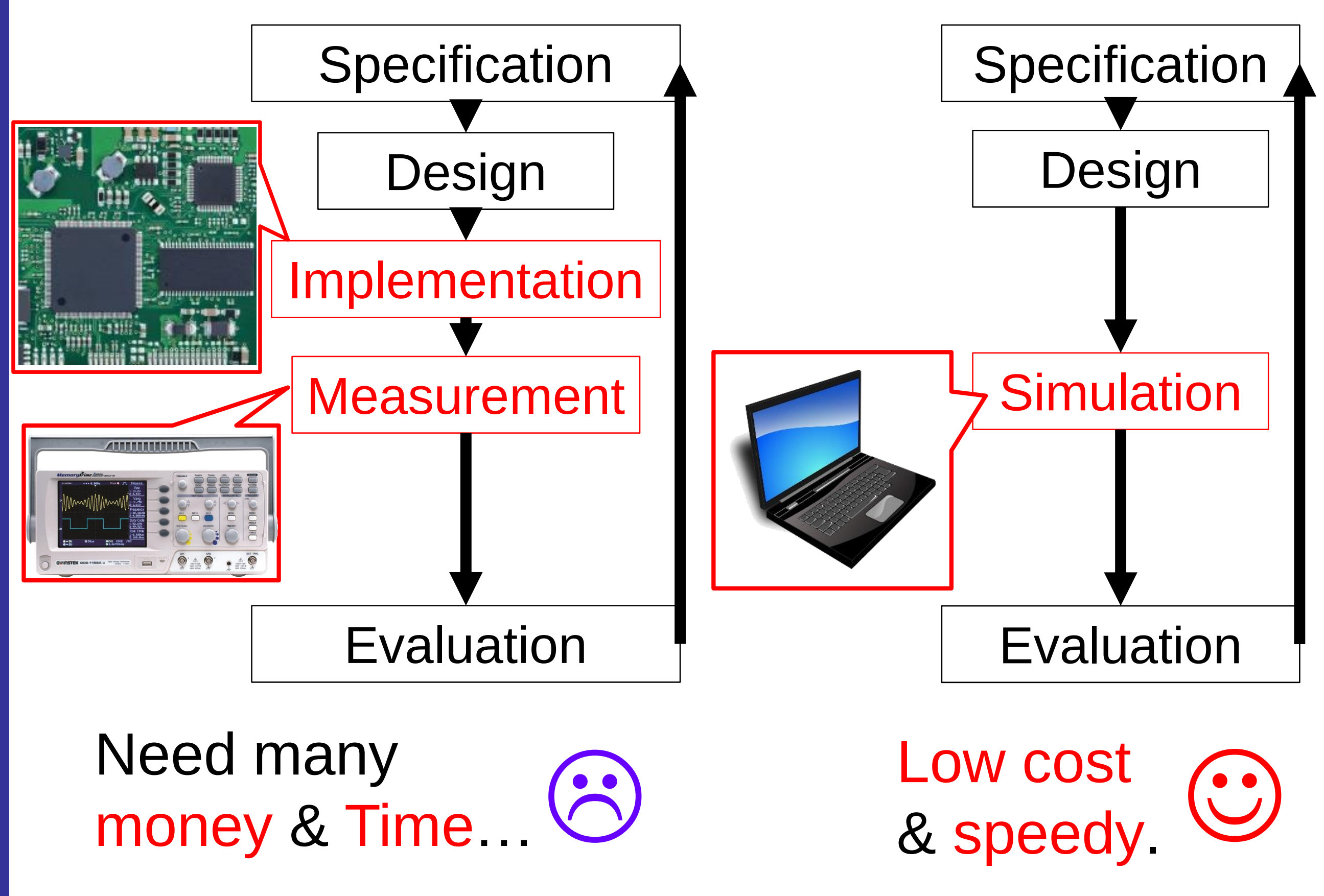
Introduction

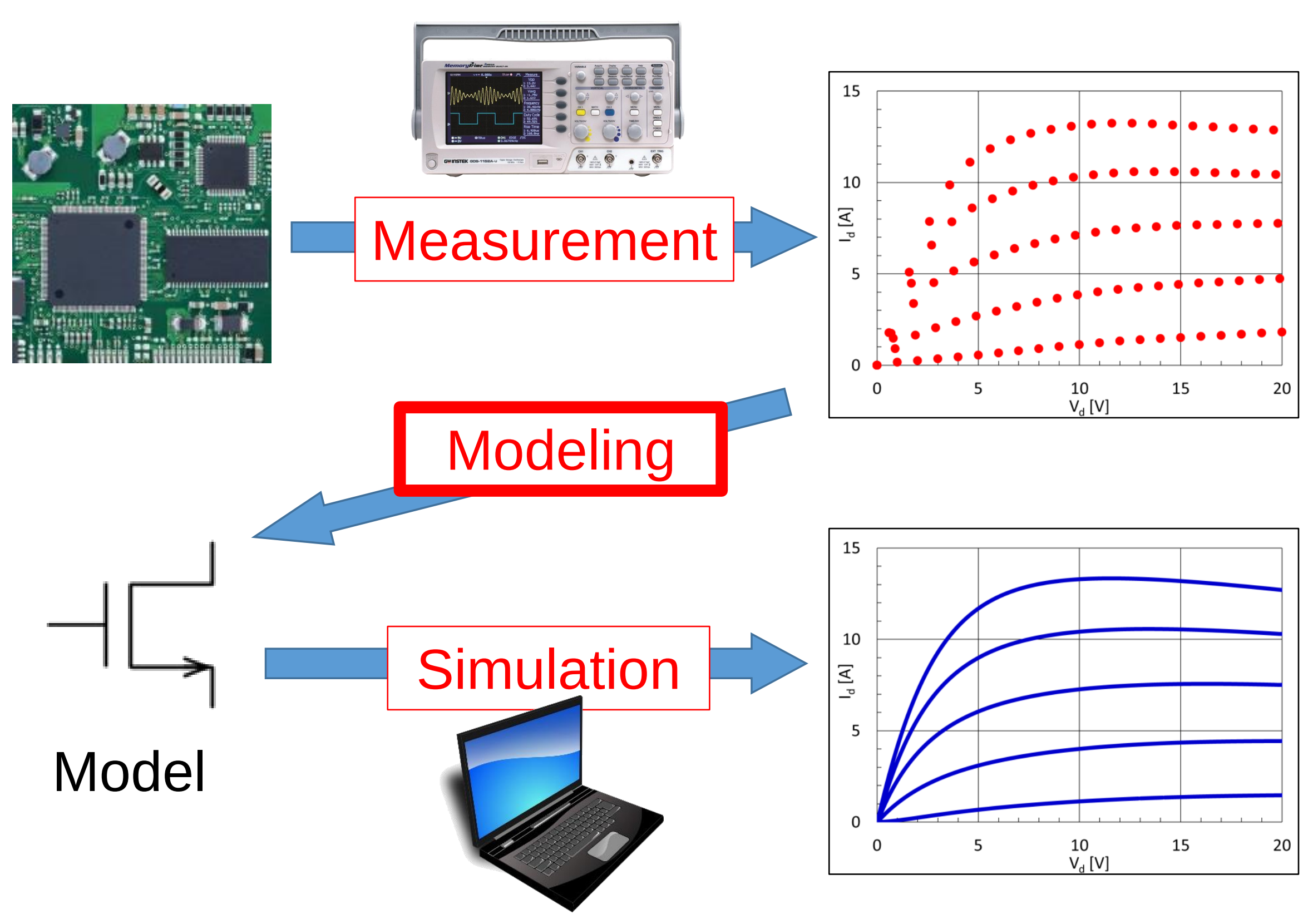
Electronic circuit simulator



Need many money & Time… ☹

Low cost & speedy. ☺

Device Modeling



Research Background

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Gallium Nitride(GaN) is used in spotlights as the material of semiconductor.

Blue LED

Especially, GaN HEMT is expected to be used for high power applications.

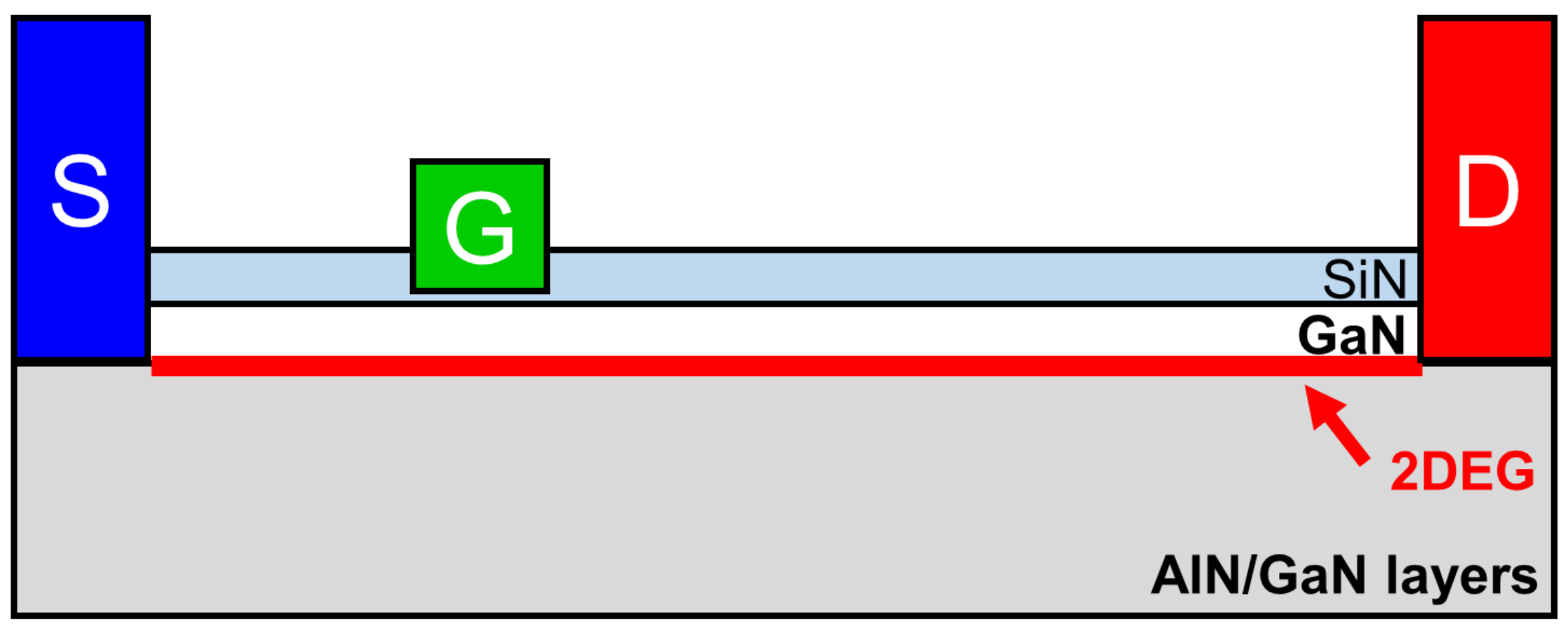
Drain currents of GaN HEMTs are **normally-on**.

➔ NOT suitable for switching devices.

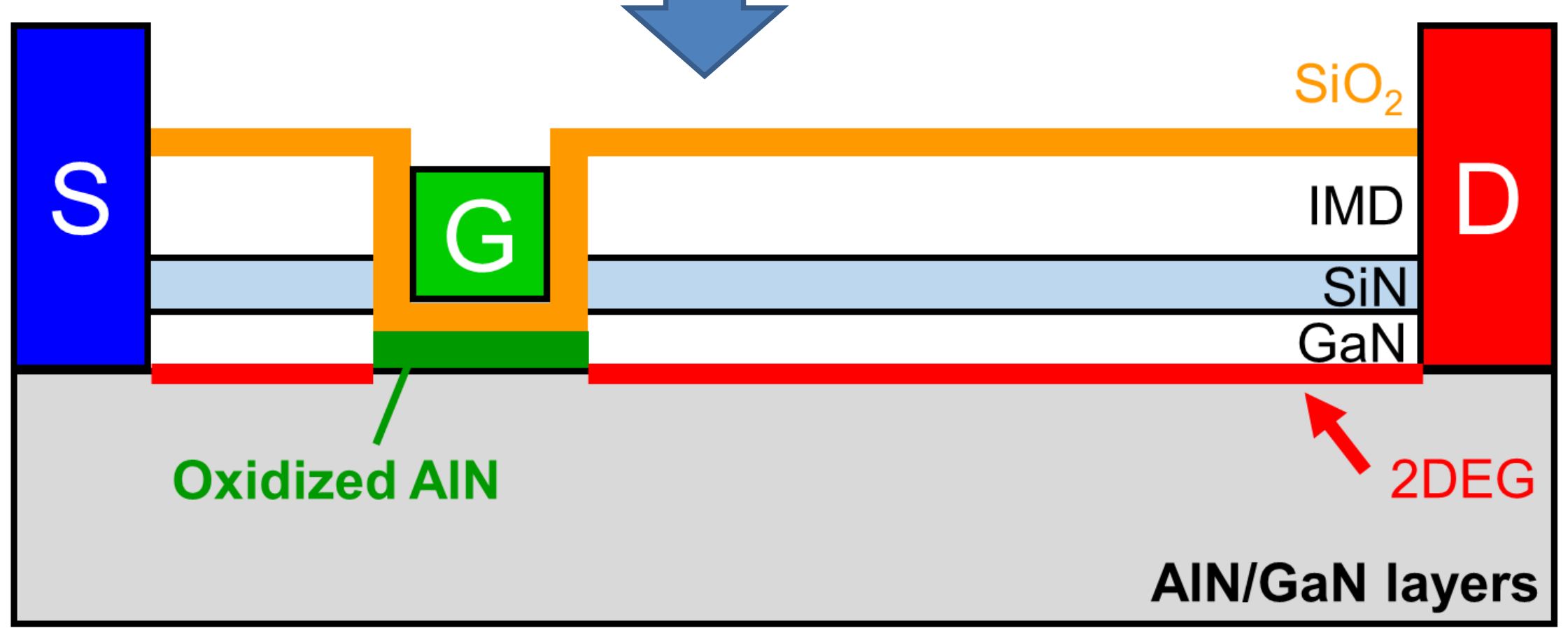
Research Objective

Research & develop the drain current model of normally-off GaN-MIS HEMTs

Device Structure



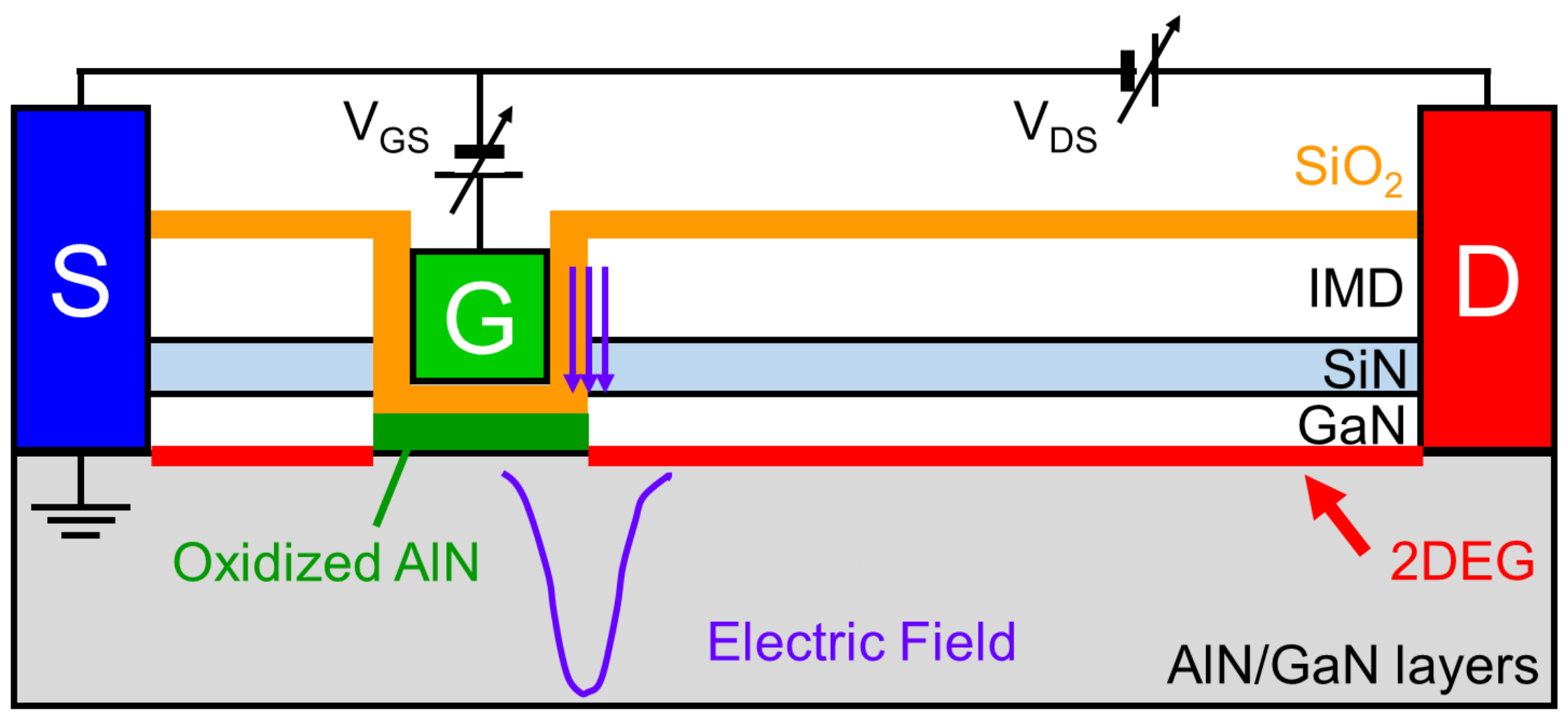
Employ MIS gate structure



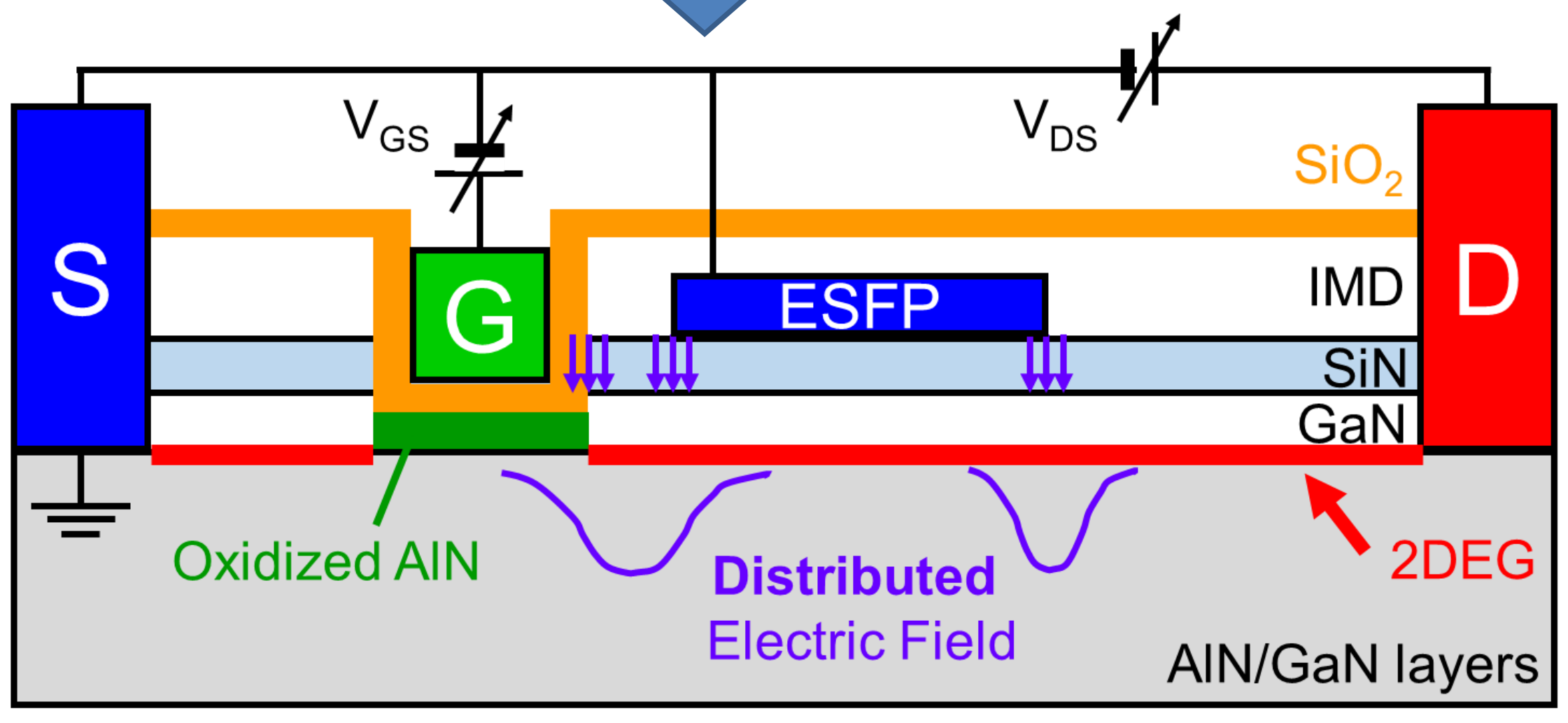
Drain-source current : Normally-on ☹

Normally-off ☺

Apply for switching circuits



Add Embedded Source Field-Plate (ESFP)



Electric Field : Concentrate ☹

Distributed ☺

For high breakdown voltage

Electron Mobility Model

New Electron Mobility Model

$$\boxed{\mu_{eff} = \frac{\mu_0 \cdot U_{Leff}}{1 + U_{Gate} \cdot U_{SFP}}}$$

Effective channel length

$$U_{Leff} = 1.0 - UP \cdot e^{-L_{eff}/LP}$$

Gate voltage

$$U_{Gate} = UA\left(\frac{V_{gs} + 2 \cdot V_{th}}{T_{fm}}\right) + UB\left(\frac{V_{gs} + 2 \cdot V_{th}}{T_{fm}}\right)^2$$

Source field plate

$$U_{SFP} = 1 + \underline{USFP} \cdot V_{ds}$$

Surface Electric field

$$\mu_s = \frac{\mu_{eff}}{\sqrt{1 + \left(\frac{E_x}{E_c}\right)^2}} = \frac{\mu_{eff}}{\sqrt{1 + \theta_{sat}^2 \cdot \psi_{ds}^2}}$$

Temperature_

$$\mu_{eff\_temp} = \mu_s \Big/ \left(\frac{T_{dev}}{T_{nom}}\right)^{\varepsilon}$$

MIT Virtual Source Model

Drift Current

$$\boxed{I_{ds} = W \cdot Q_{i,x0} \cdot v_x \cdot F_{sat}}$$

Gate width

Charge

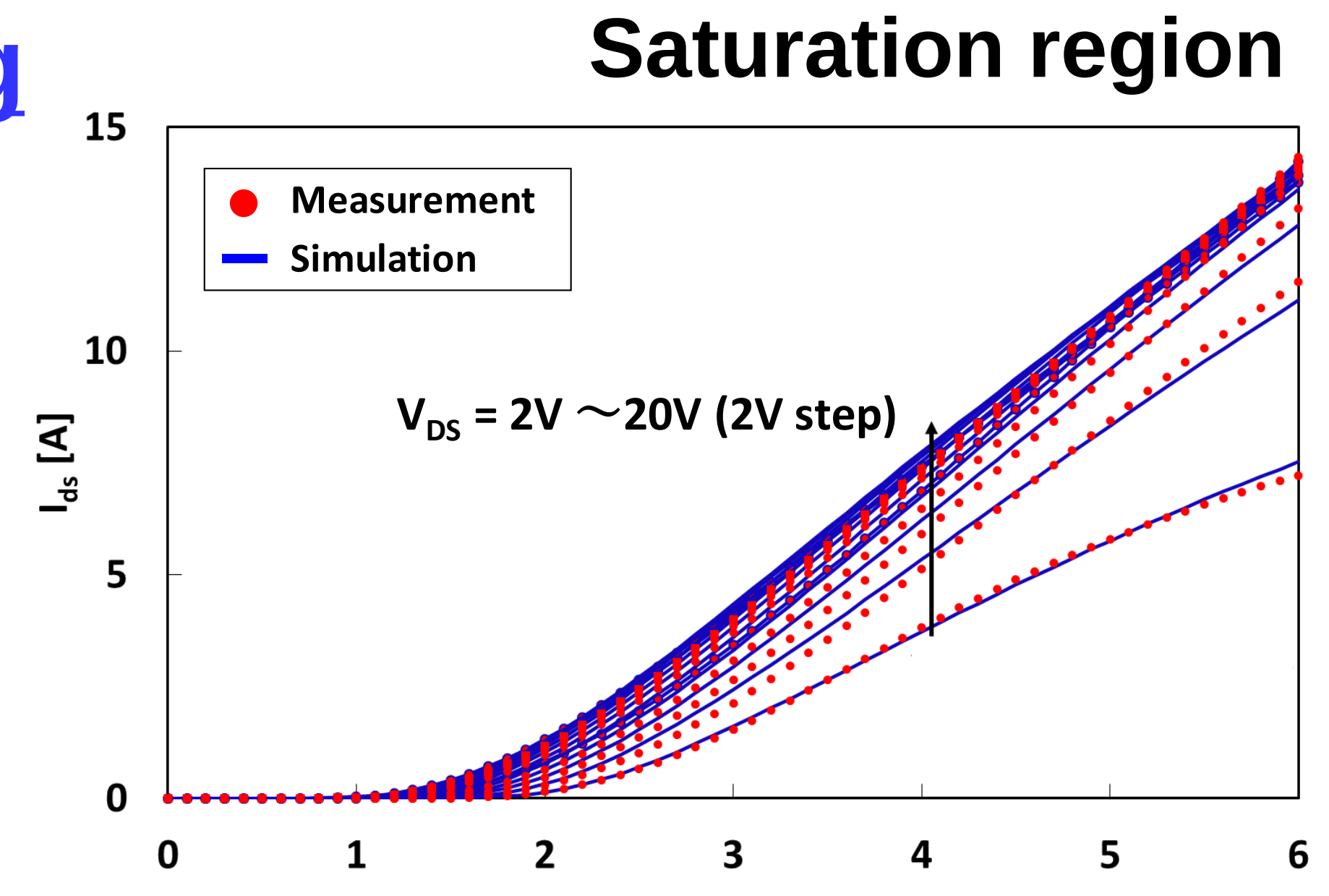
Drift speed of carrier

Empirical function

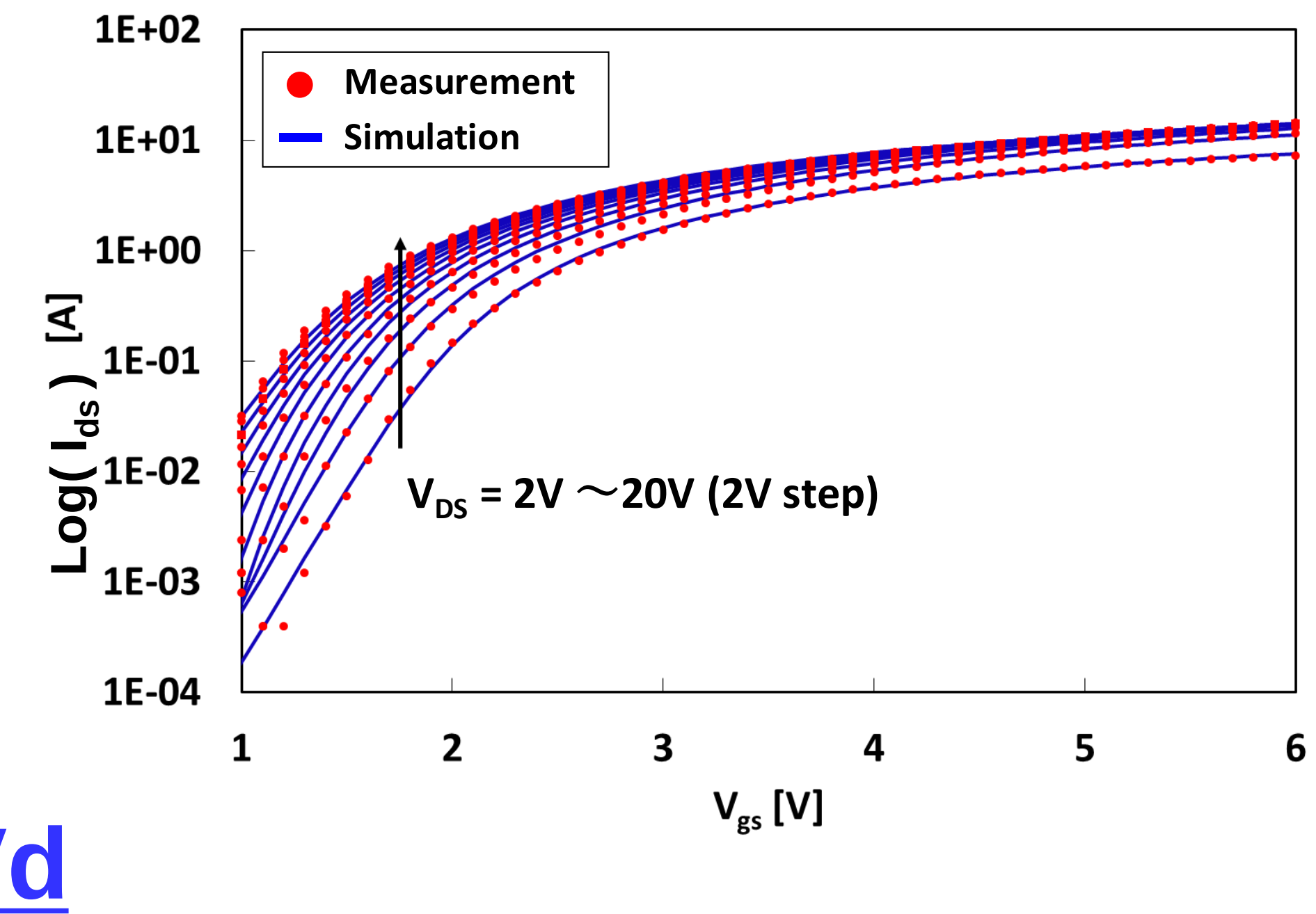
Measurement & Simulations

Id vs Vg

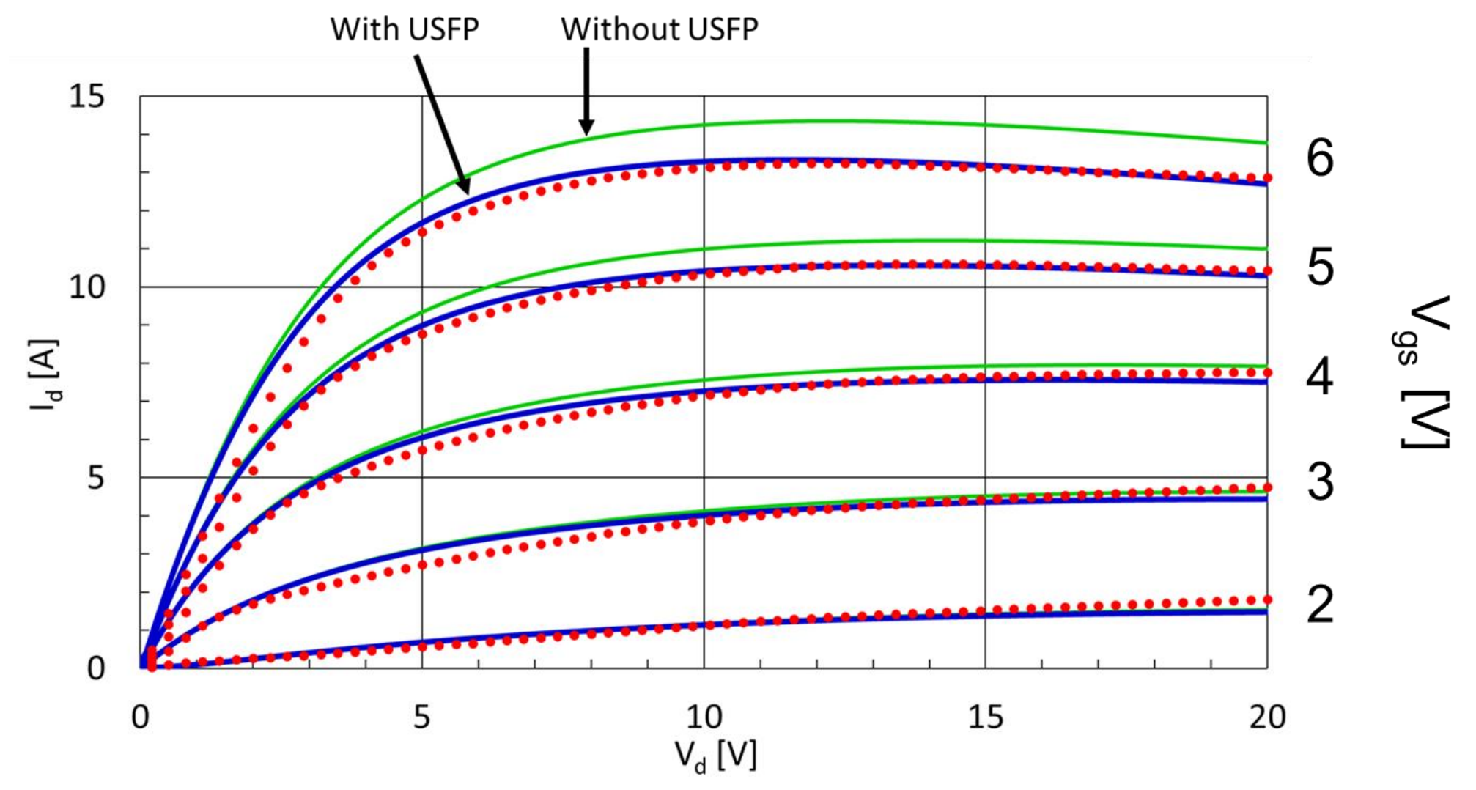
Saturation region



Log(Id) vs Vg



Id vs Vd



- Excellent agreements
- Characterization of ESFP dependencies

Summary

Conclusion

- The electron mobility model for drain current simulations of GaN MIS-HEMTs has been developed.
- The model has been implemented in MIT Virtual Source model with modifications of Verilog-A source codes.
- The results of HSPICE simulations showed excellent agreements with the measurements.

Future work

- Develop Scalable model for gate length and width, gate fingers, and the number of cells
- Support small signal AC and transient behaviors

Reference

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[4] H. Aoki, "Dynamic Characterization of a-Si TFT-LCD Pixels," IEEE Trans. Electron Devices, vol. 43, no.1, pp.31-39, 1996.
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