Gallium Nitride (GaN) Based Transistors

CNSI

INSET
Internships in Nanosystems, Science, Engineering and Technology

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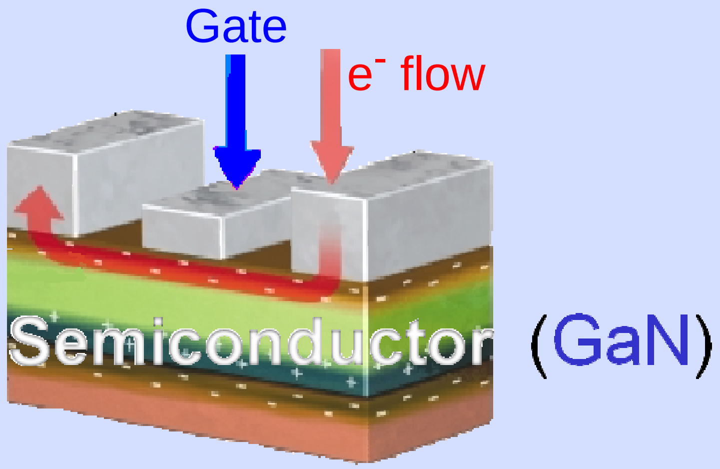
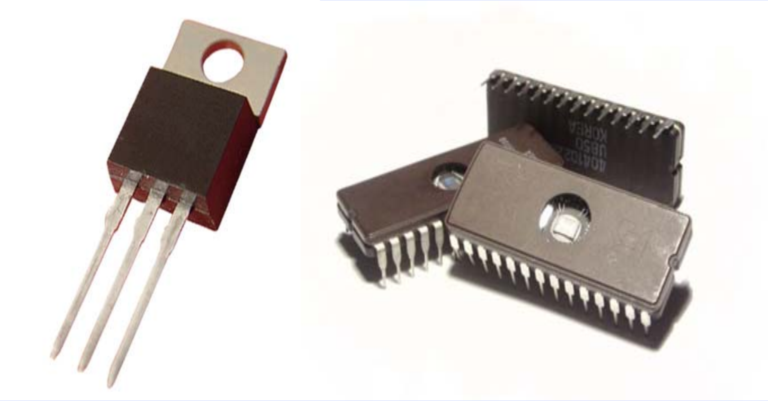
The Transistor



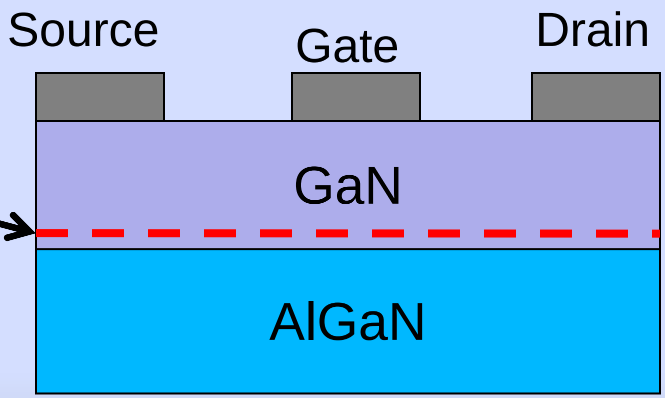
Mishra, U. Eastman, L. Toughest Transistor Yet, IEEE, Volume 39 May 2002

- Amplifier
- Switch



Why GaN?

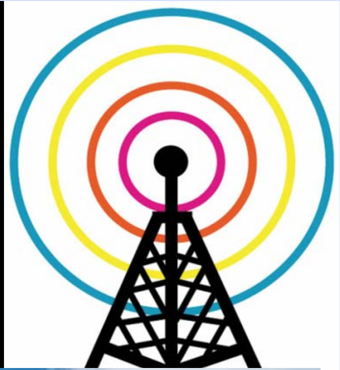
- Forms 2D Electron Gas (2DEG) making it a High Electron Mobility Transistor (HEMT)
- Tough
- High Thermal Conductivity
- High Breakdown Voltage



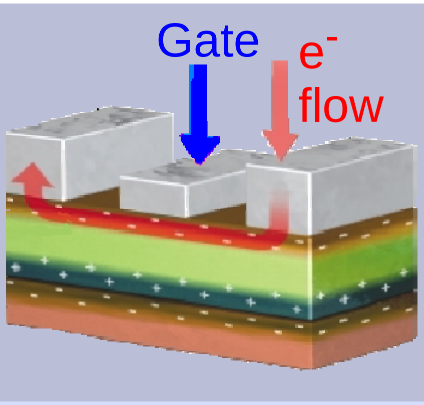
Why Do the Research?

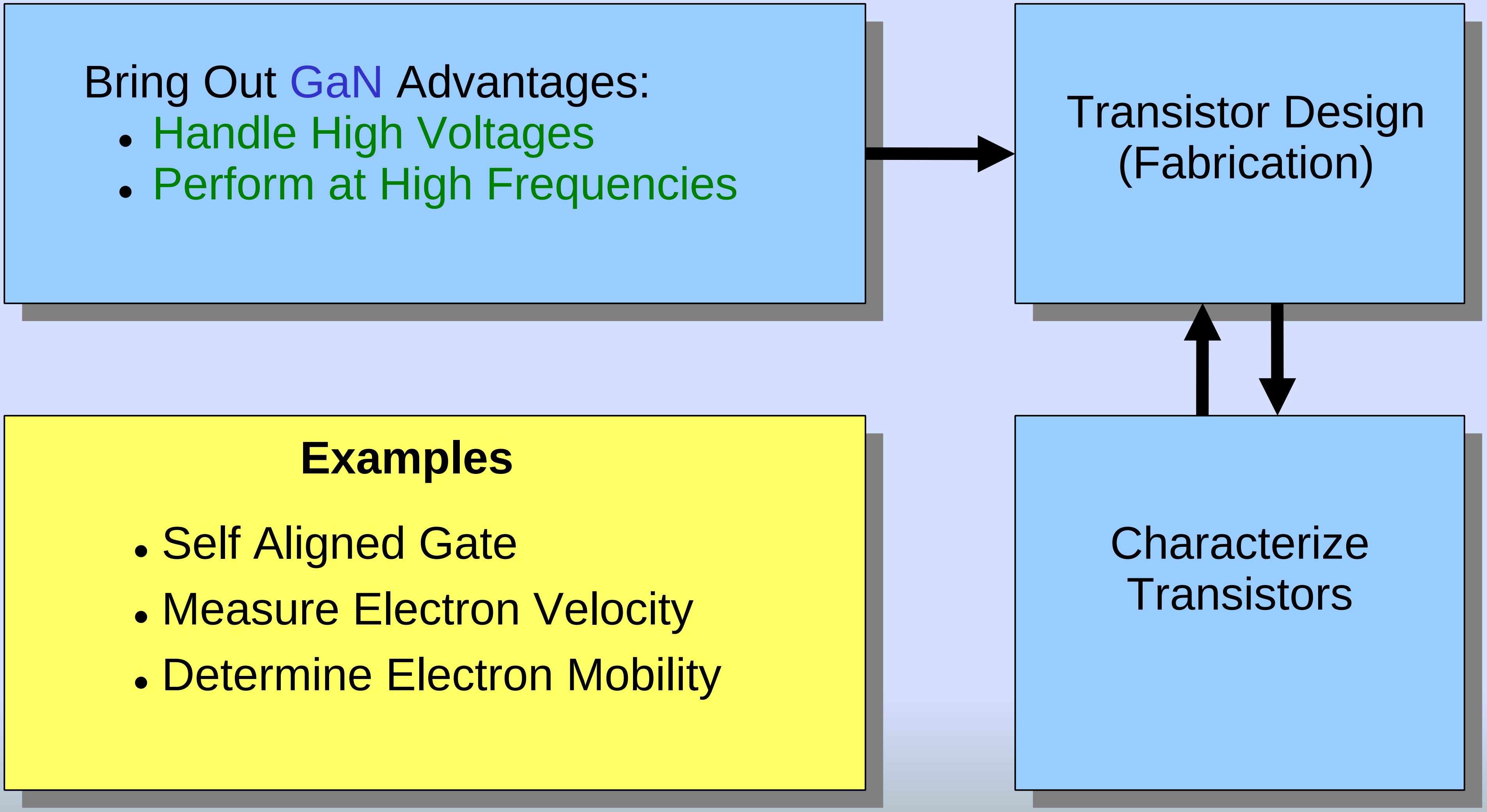
They Are *Everywhere*:

- Computers
- Stereos and TVs
- Wireless Internet
- Communication Infrastructure
- Hybrid Electric Cars
- The Electric Grid
- Defense Satellites and Radar


Research Goals





Bring Out GaN Advantages:

- Handle High Voltages
- Perform at High Frequencies

Transistor Design (Fabrication)

Characterize Transistors

Examples

- Self Aligned Gate
- Measure Electron Velocity
- Determine Electron Mobility

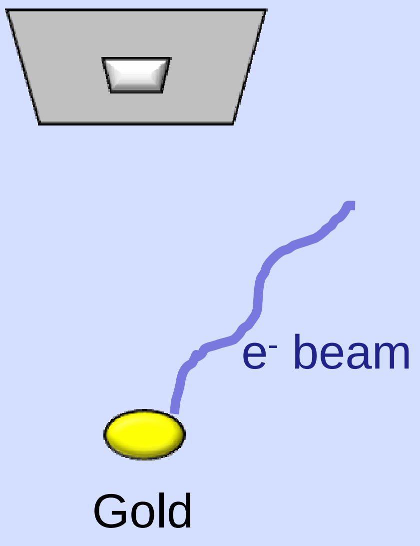
The Fabrication Process

Material Deposition

Photolithography

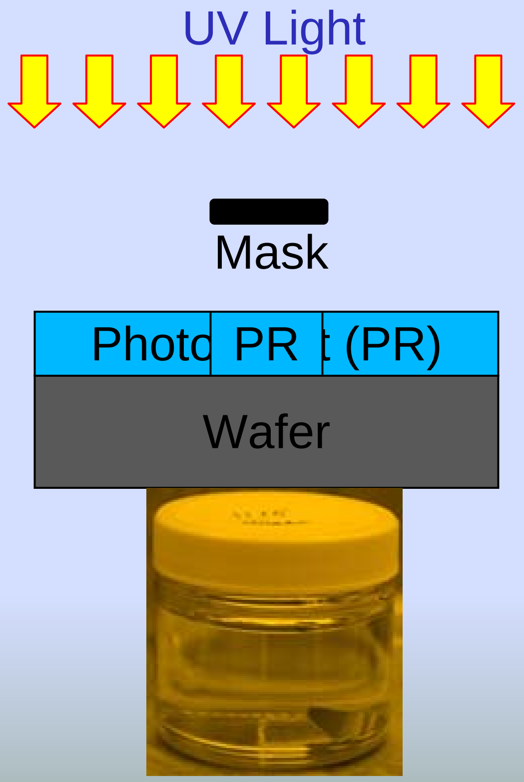
Etching

Annealing



e^- beam

Gold

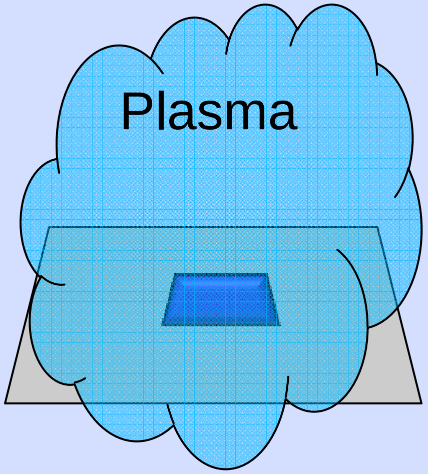


UV Light

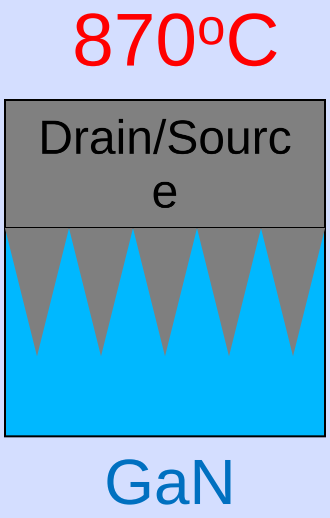
Mask

Photo PR t (PR)

Wafer



Plasma

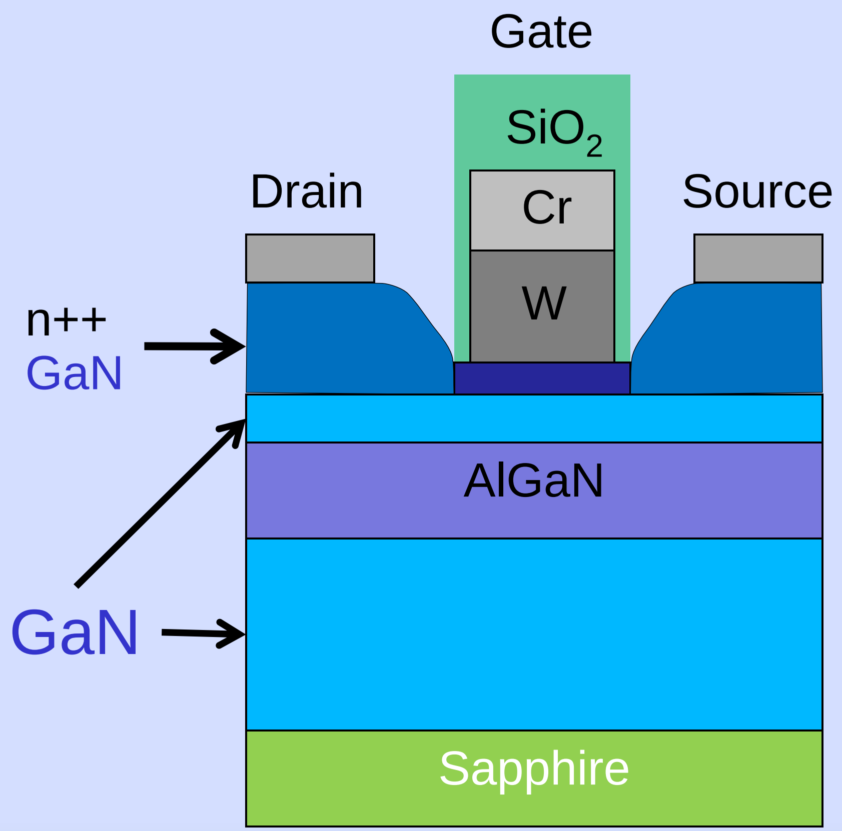


870^{o}C

Drain/Source

GaN

Self Aligned Gate Design

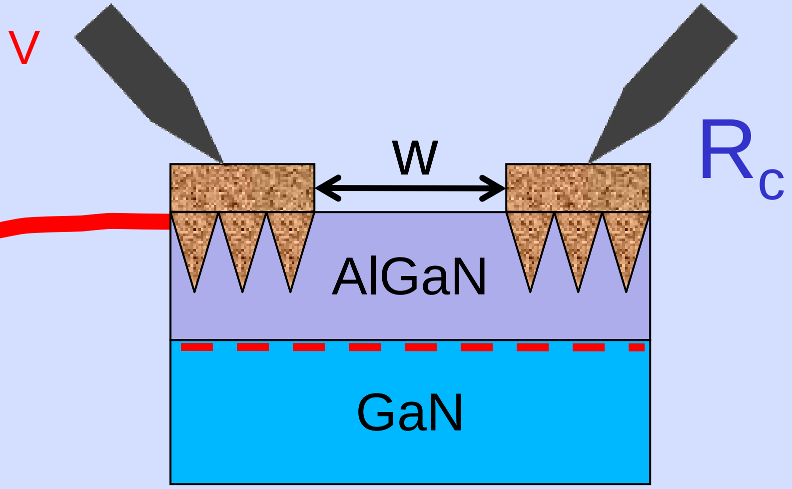


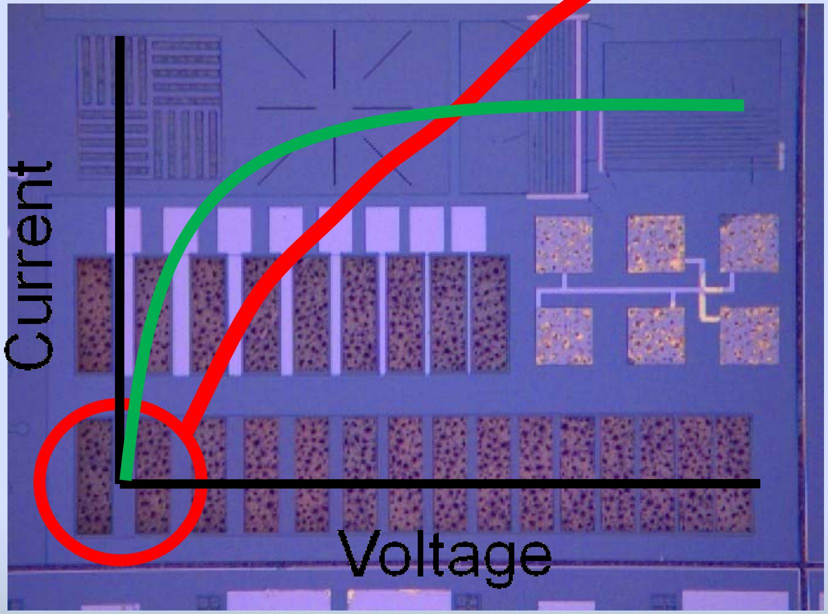
Advantages:

- Reduces distant between source and drain resulting in a small, fast device (Great high frequency performance).
- Reduces contact resistance with highly Silicon doped GaN terminals.

Transmission Line Measurement (TLM)

Purpose:
Measure e$^-$ Velocity
And Mobility

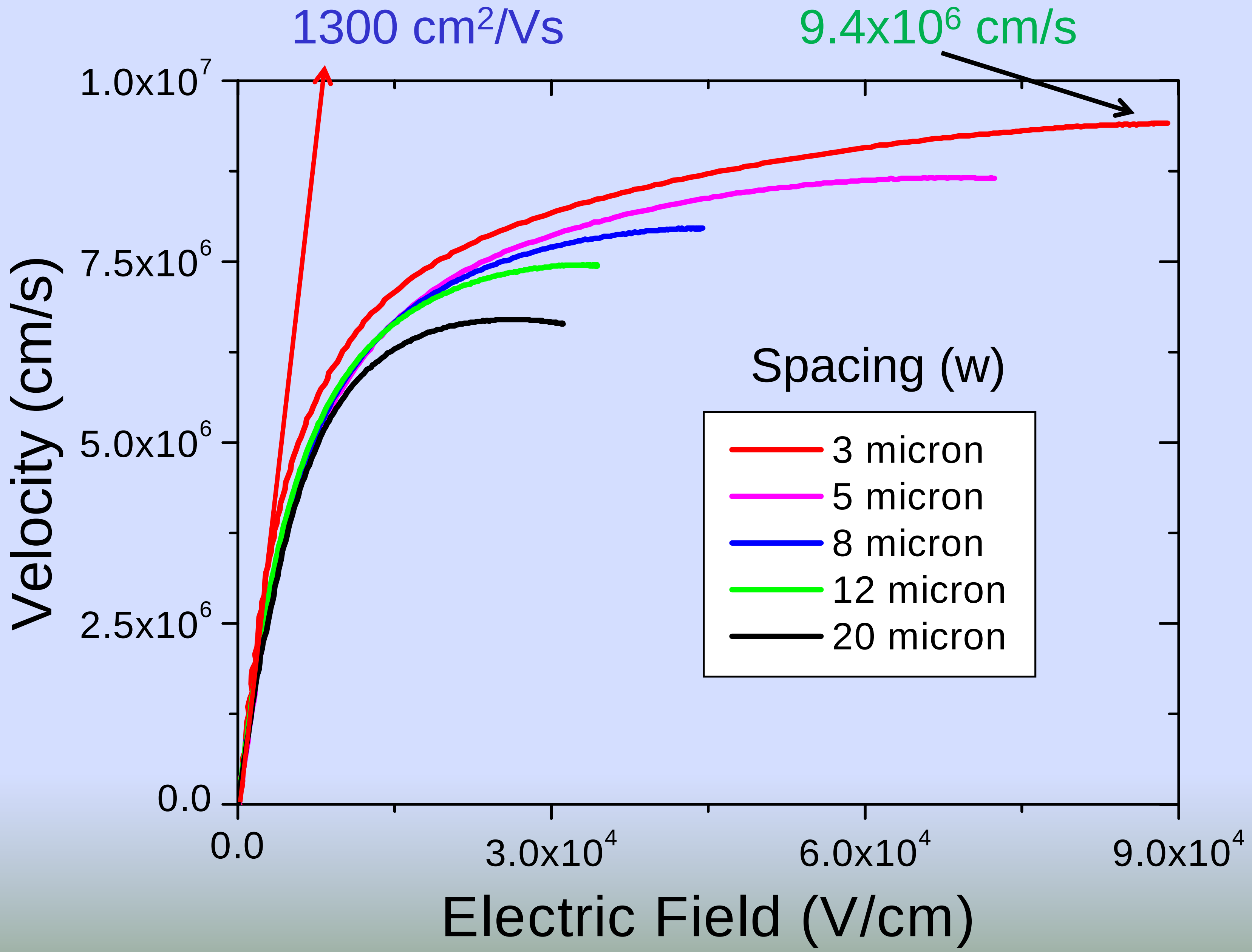




Analysis:

Current = qn_sv	E = (V – IR_c)/w
q = e$^-$ charge n_s = charge density v = e$^-$ velocity	I = current

TLM Results



$1300 \text{ cm}^2/\text{Vs}$

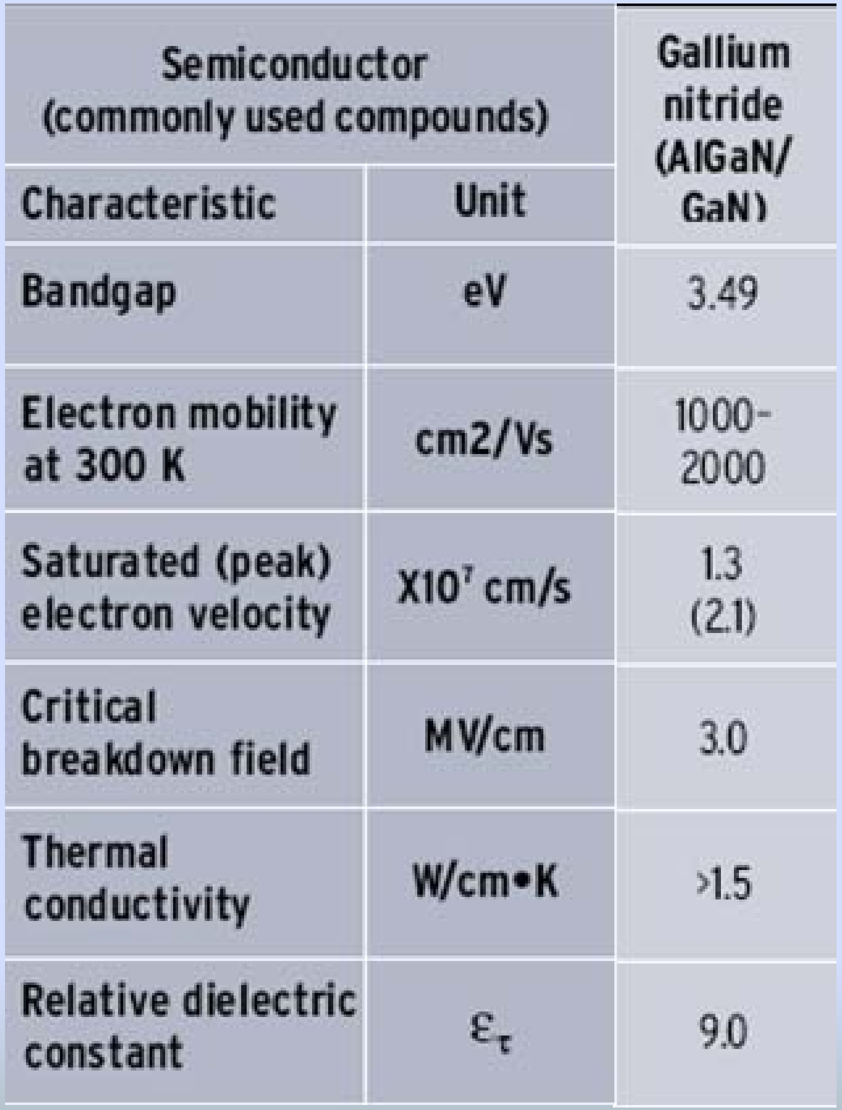
$9.4\text{x}10^6$ cm/s

In Perspective

Mobility:
1300 cm^2/Vs

Velocity:
9.4x10^6 cm/s

Test: 3 micron
Target: <100nm



Semiconductor (commonly used compounds)		Gallium nitride (AlGaN/GaN)
Characteristic	Unit	
Bandgap	eV	3.49
Electron mobility at 300 K	cm2/Vs	1000-2000
Saturated (peak) electron velocity	X10^7 cm/s	1.3 (2.1)
Critical breakdown field	MV/cm	3.0
Thermal conductivity	W/cm•K	>1.5
Relative dielectric constant	ε_r	9.0

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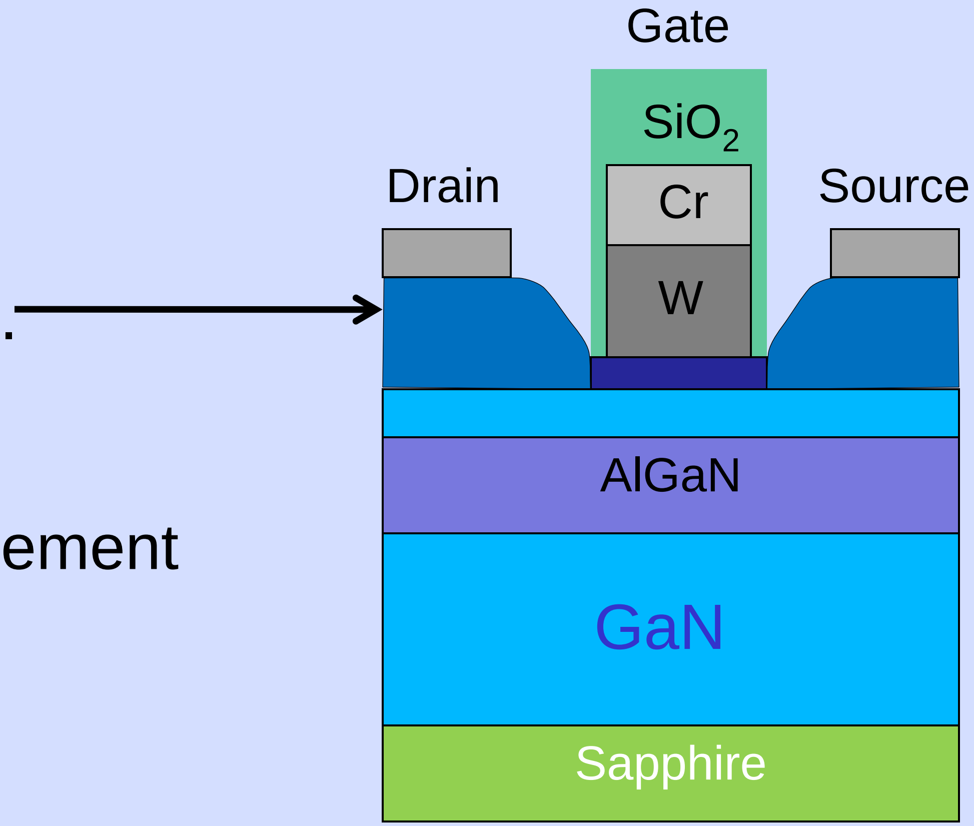
Future Plans

- Improve regrowth process.
- Use Indium Nitride for the terminals.
- Develop methods for better measurement of sidewall thickness and quality.
- Compare results to Nitrogen faced design.



Summary

Accomplishments:

- Learned and help perform fabrication processes in clean room.
- Gained knowledge of semiconductor device physics.
- Performed tests and collected valuable data on transistor performance.
- Gained communication and technical skills.
- Learned what graduate research is like.

Acknowledgements

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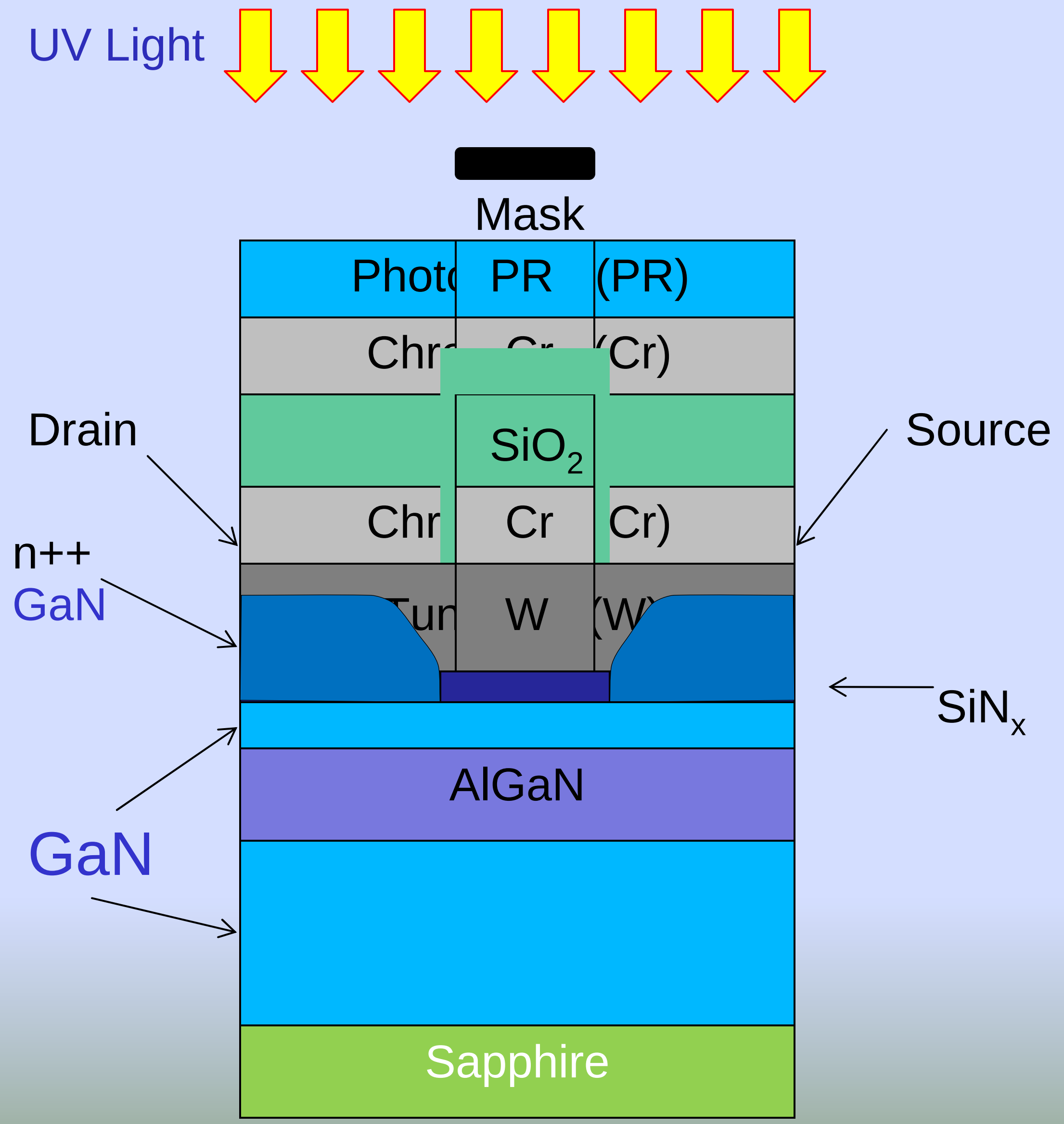
The Nanofab

Thank You!

Self Aligned Gate Process



Goals:

- Reduce resistivity with highly doped GaN terminals.
- Bring Source and Drain close together resulting in a very fast device (great high frequency performance)

Process:

Photolithography
Deposition
Etching