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High Voltage Regrown GaN P-N Diodes Enabled by Defect and Doping Control

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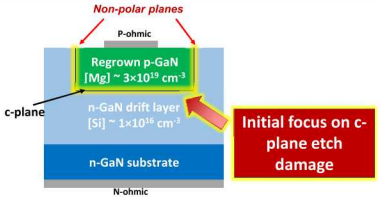
GaN electronics for domestic energy security

Goal: Demonstrate 1.2 kV GaN diodes using selective area regrowth

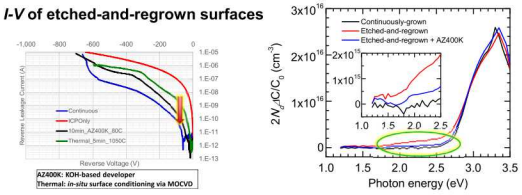
Challenge: Regrown GaN diodes exhibit current leakage and premature breakdown.

Problem and Methodology

- Examining etched-and-regrown approach for selective area doping
- GaN typically requires dry etching methods damage the regrowth surface
- Incorporation of defects at the regrown junction increases leakage
- Use Deep Level Optical Spectroscopy (DLOS) to quantify defect properties and concentration at regrowth interface
- Quantify correlation between defect mitigation and reduced leakage

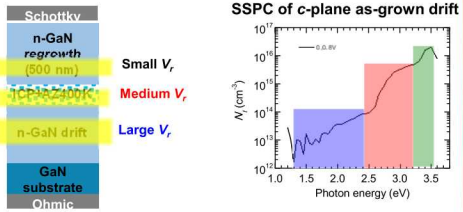


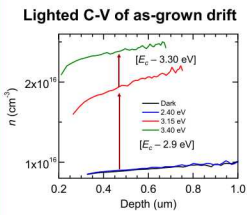
I-V of etched-and-regrown surfaces

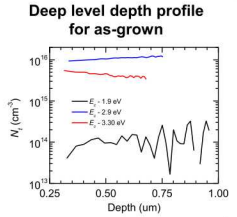


	[E_c – 1.90 eV] (cm^{-3})	[E_c – 2.90 eV] (cm^{-3})	[E_c – 3.2 eV] (cm^{-3})
Continuously-grown	-	2.0×10^{16}	6.0×10^{15}
Etched-and-regrown	$\mathbf{1.8 \times 10^{15}}$	1.7×10^{16}	5.3×10^{15}
Etched-and-regrown + AZ400K	$\mathbf{5.0 \times 10^{14}}$	2.1×10^{16}	5.0×10^{15}

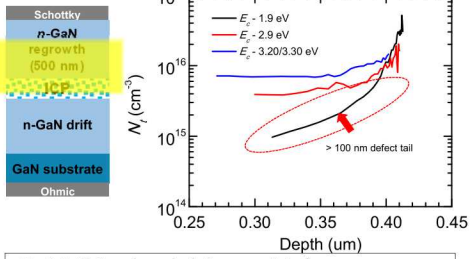
Depth-profiling of deep level defects





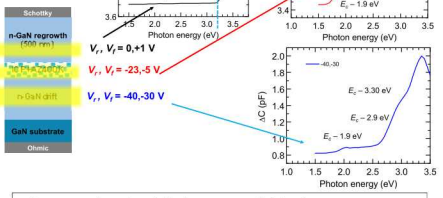


- Steady-state photocapacitance measures deep level density
- Bias-dependent depth sensitivity enables profiling slices of drift
- Lighted capacitance-voltage aggregates slices into a depth profile

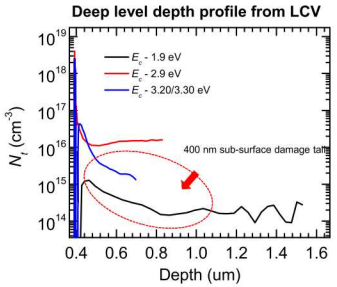


- E_c – 1.9 eV strongly peaked at regrown interface
- Suggests it is an etch-enhanced defect
- Elevated [E_c – 1.9 eV] extending into regrown drift

Defect mitigation via AZ400K

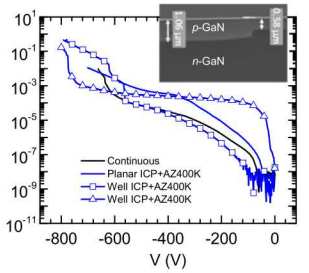


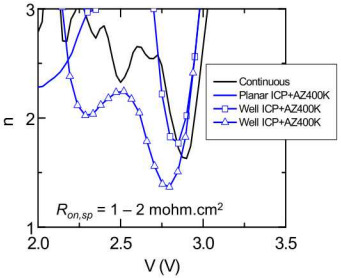
- As-grown deep levels below regrowth interface
- E_c – 1.9 eV becomes dominant at regrowth interface
- E_c – 1.9 eV strongly mitigated above regrowth interface



- Defect concentration indicates sub-surface damage etch damage
- AZ400K improves crystal quality above regrowth interface but apparently not below

Impact of defect mitigation on selective area regrowth





- AZ400K-treated diodes regrown in 0.5 um deep wells show forward and reverse characteristics equivalent to continuously-grown diodes
- Demonstrates that AZ400K mitigates both *c*-plane and sidewall etch damage sufficiently well to achieve good electrical performance

Summary and Conclusions

- **Deep level defect spectroscopy quantitatively correlated defects with the etched-and-regrown interface**
- **Etch-enhanced defects can be mitigated above the regrowth interface using AZ400K post-ICP**
- **AZ400K leaves remnant sub-surface damage**
- **AZ400K treat sufficient to achieve forward and reverse characteristics similar to continuously-grown diodes**

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