Sapphire Removal By Polishing for Power GaN Devices

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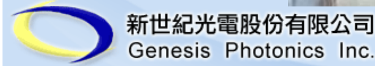
Industry



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Outline

1. Sapphire Removal for Power GaN LED Chips
2. Sapphire Removal by Polishing
3. Vertical GaN LEDs with Sapphire Removed by Polishing
4. Conclusions

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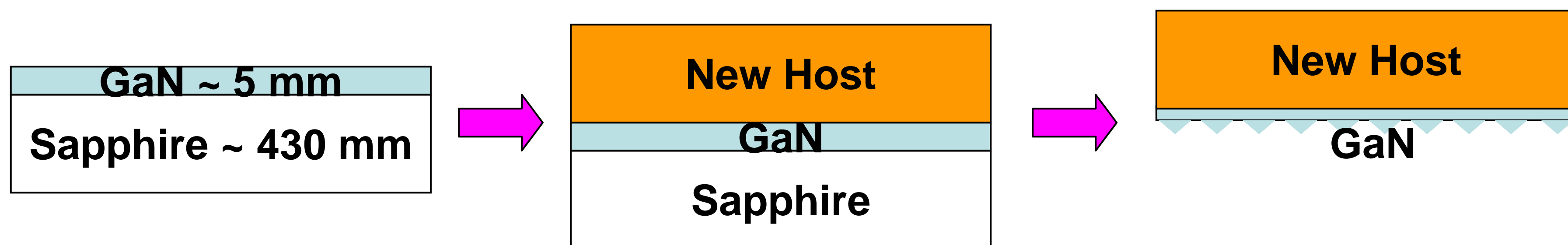
GaN and the Substrate



- **Intermate contact between new host and p-GaN :**
  ➔ Heatsink near the quantum well
  ➔ Uniform current distribution
- **Exposed n-GaN ➔ ideal surface texturing for light extraction**

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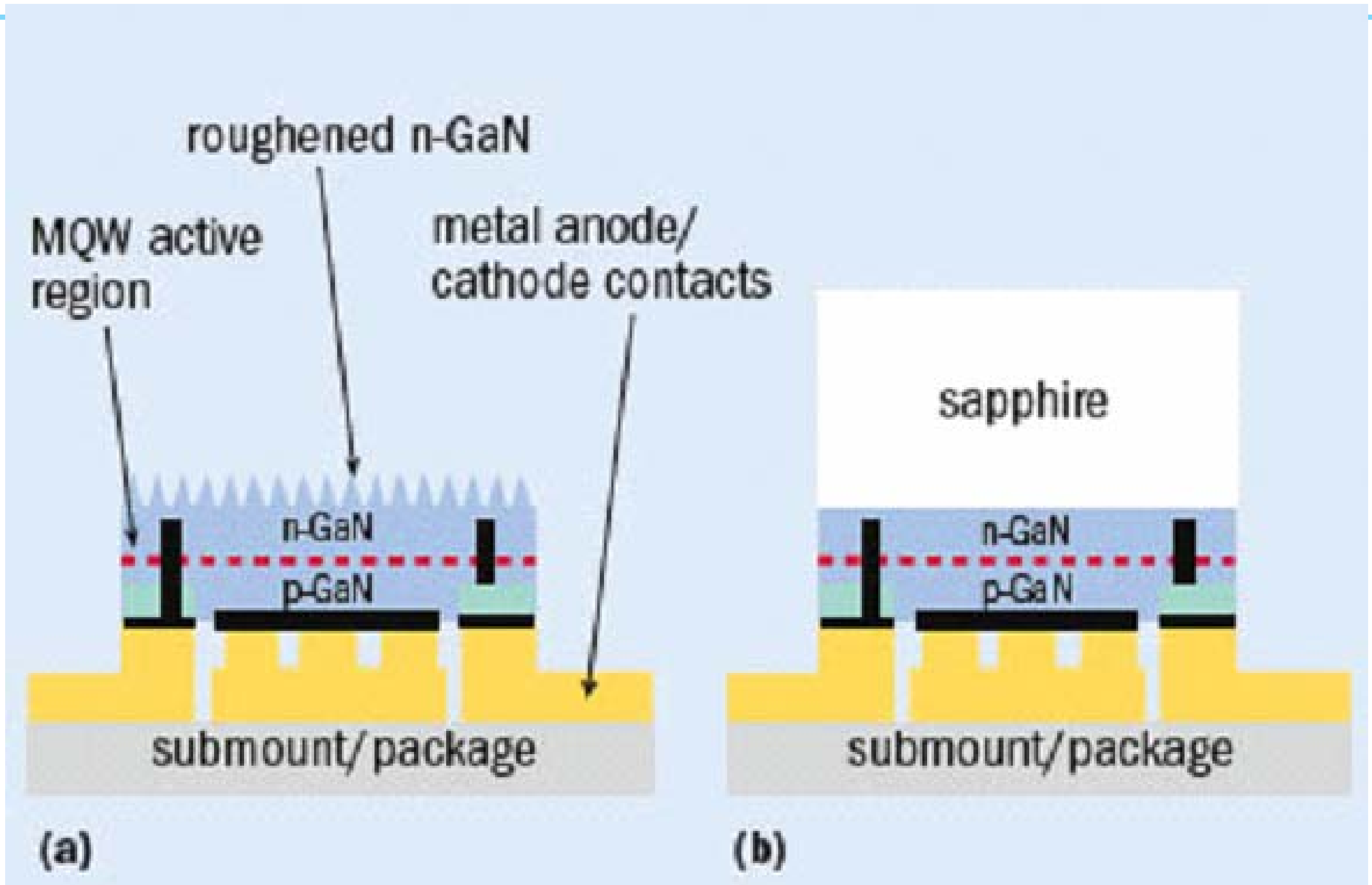
Power LEDs : Substrate Removal as a Key Technology

Company	Drive Current (mA)	Substrate	Key Technology	Remarks
Epistar (Taiwan)	Up to 350	Sapphire		
Toyoda Gosei (Japan)	Up to 150	Sapphire		
Nichia (Japan)	Up to 350	Sapphire		
Osram (Germany)	Up to 1400	Sapphire	Vertical LED	Sapphire removed by laser liftoff
Cree (USA)	Up to 1000	SiC	Vertical LED	SiC substrate removed
Phillips Lumileds (USA/EU)	Up to 1500	Sapphire	Flip-chip	Sapphire removed by laser liftoff
ASTRI		Sapphire	Vertical LED	Sapphire removed by Polishing

Flip Chip LEDs



Flip chip packaging

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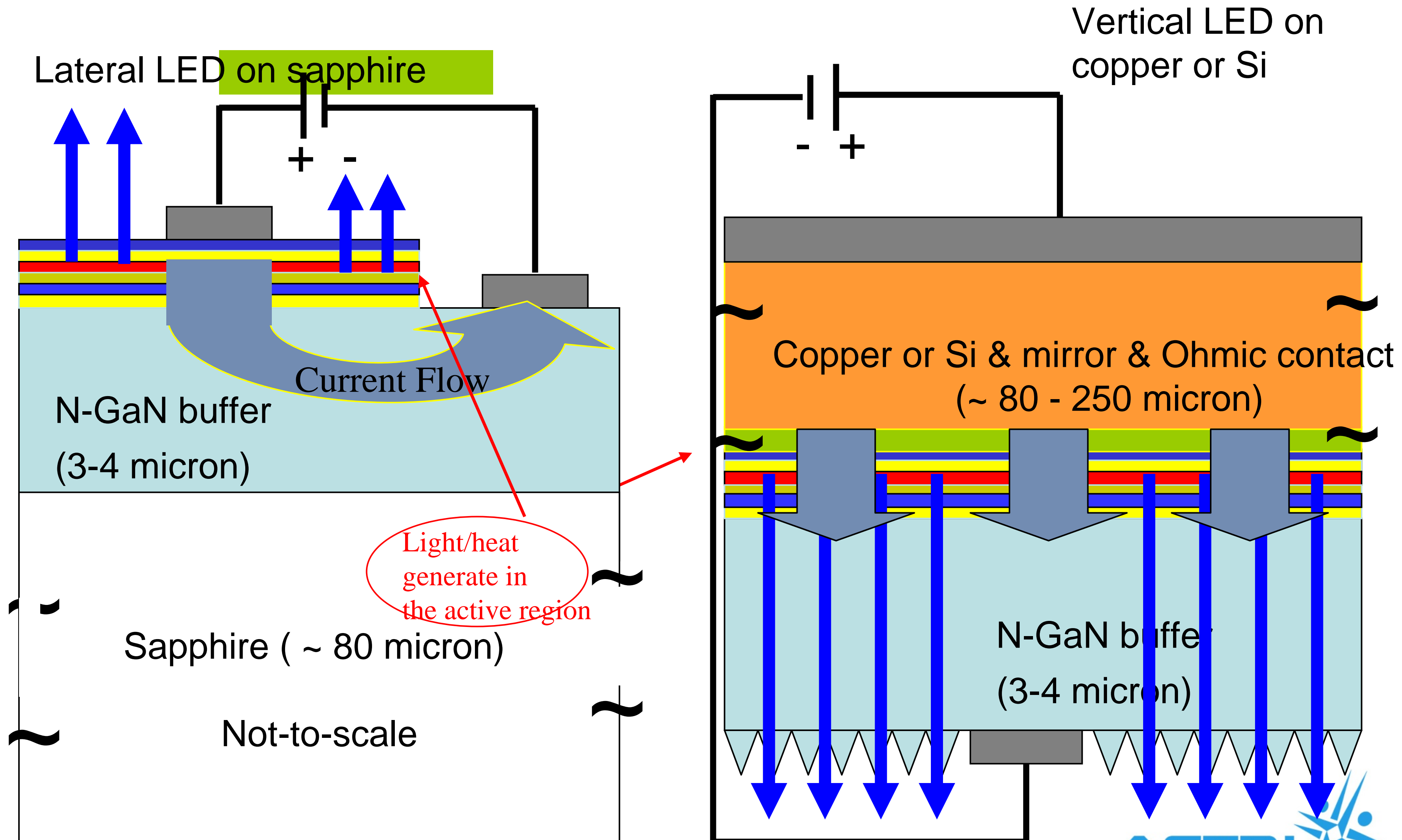
Power LEDs: Vertical LEDs with Sapphire Removed



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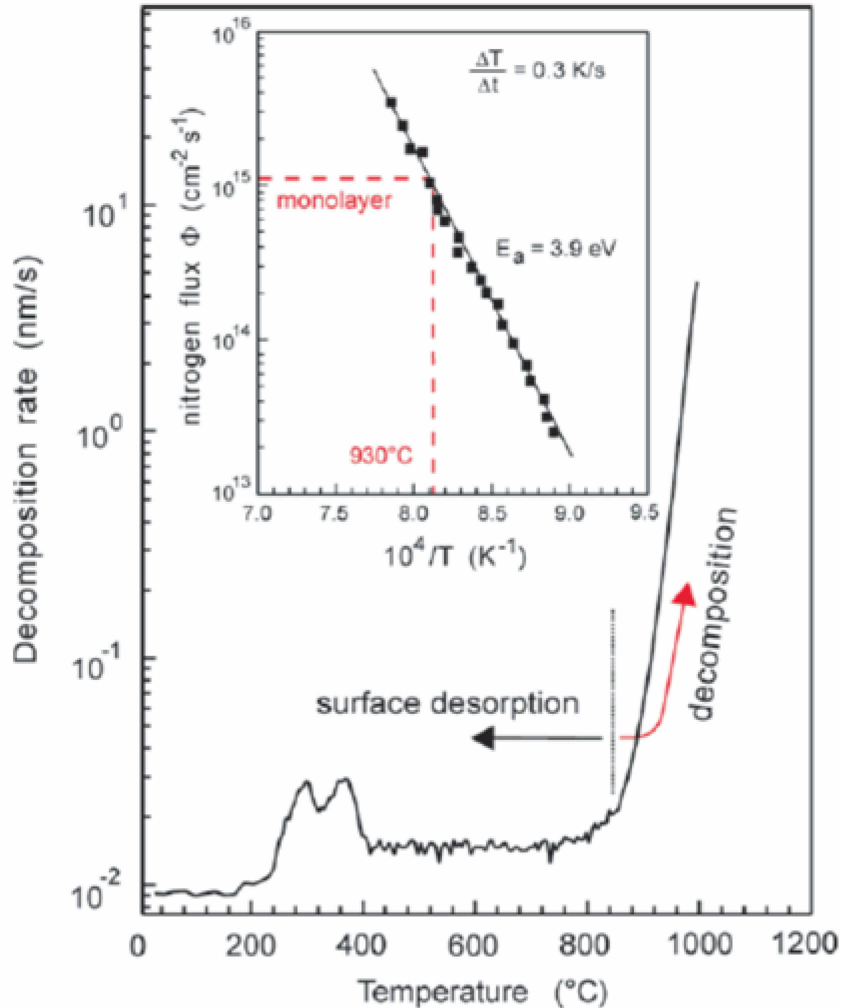
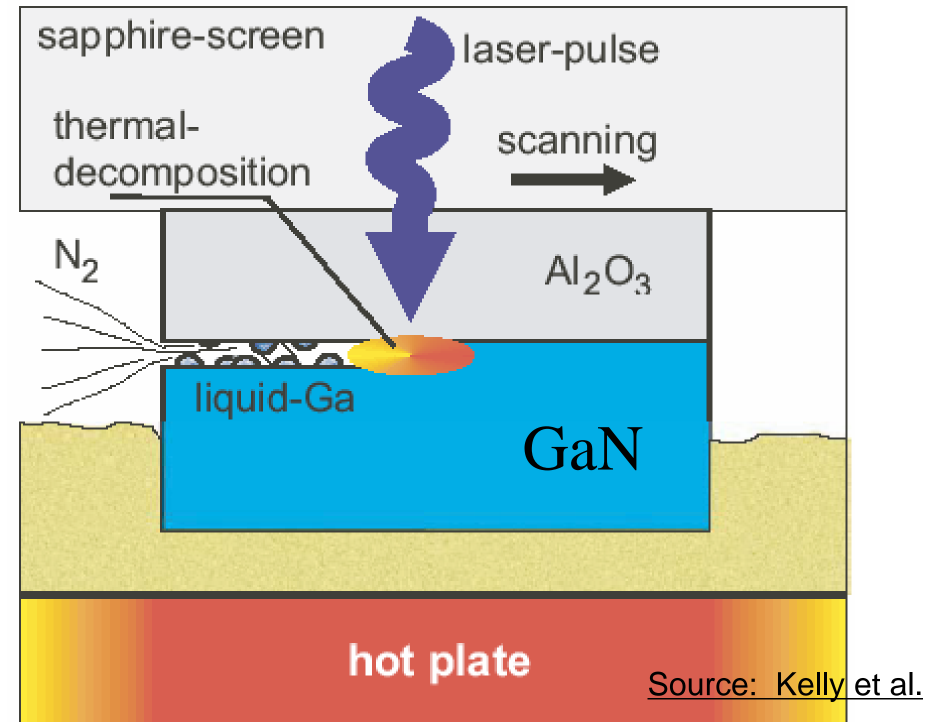
Removal of Sapphire by Laser Liftoff



Thermal decomposition of GaN



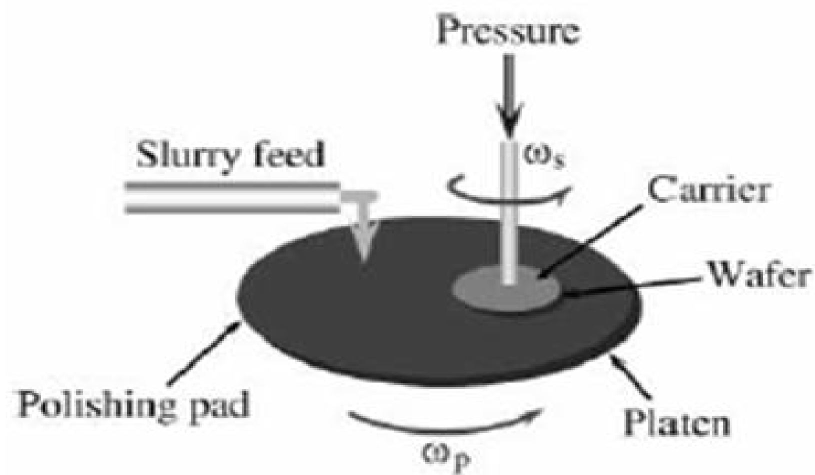
Source: Kelly et al.

Issues:

- Patents
- Technical challenges

Sapphire Removal by Polishing

Multiple wafers can be processed in batch.



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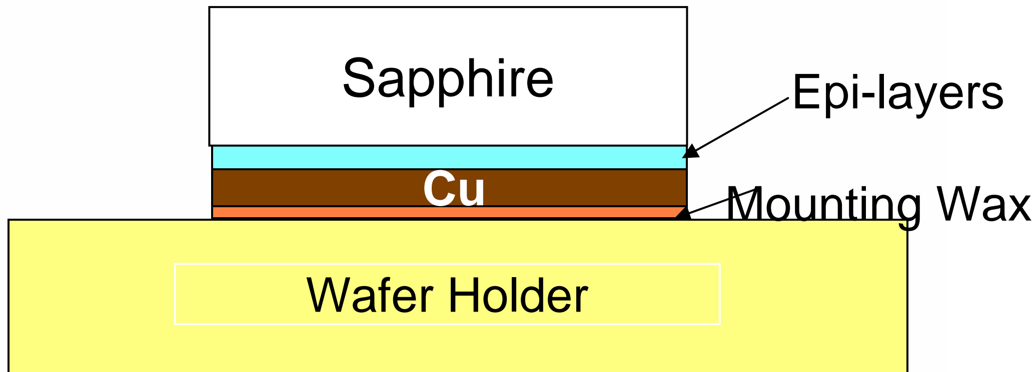
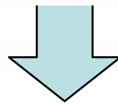
Sapphire Removal by Conventional Mechanical Polishing

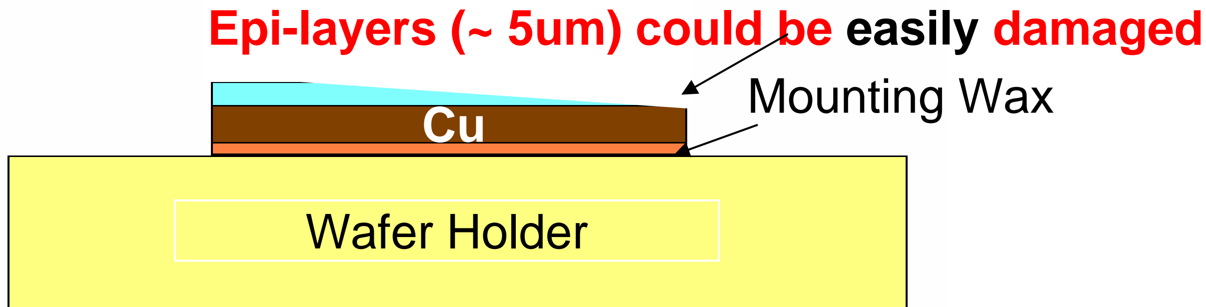


Wafer Mounting



Conventional Polishing

Epi-layers (~ 5um) could be easily damaged



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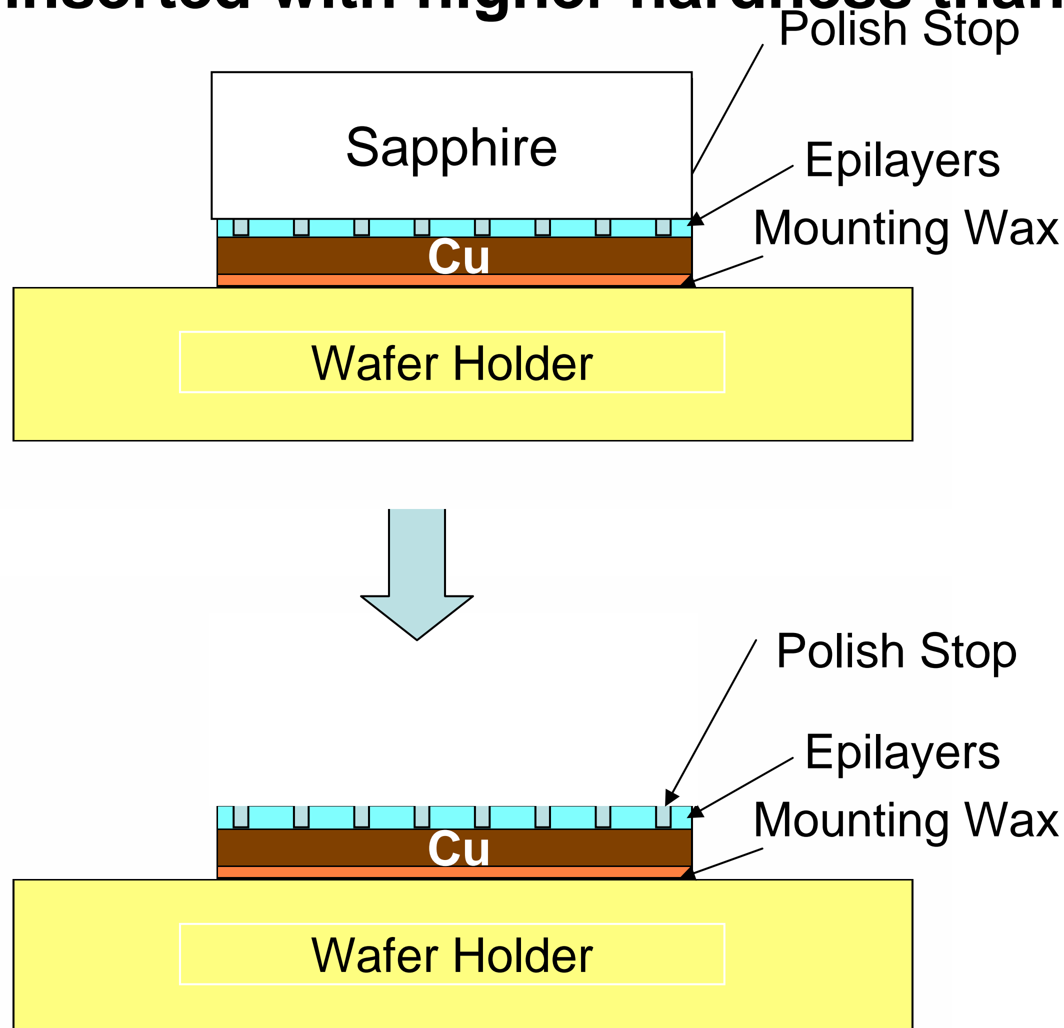
Sapphire Removal by Novel Method (with polish stop)

Polish stop inserted with higher hardness than GaN!



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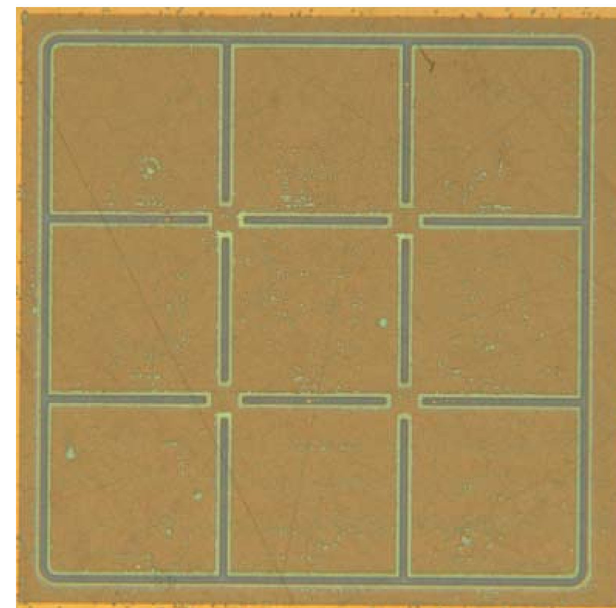
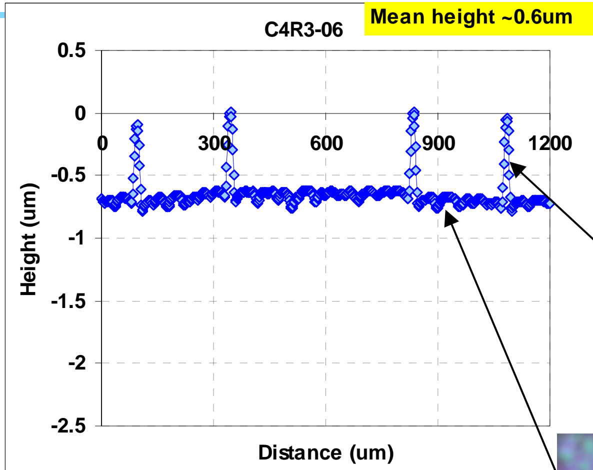
Grinding and Lapping

- Grinding to remove ~ 90 % sapphire
- Lapping to remove ~ 6 % sapphire

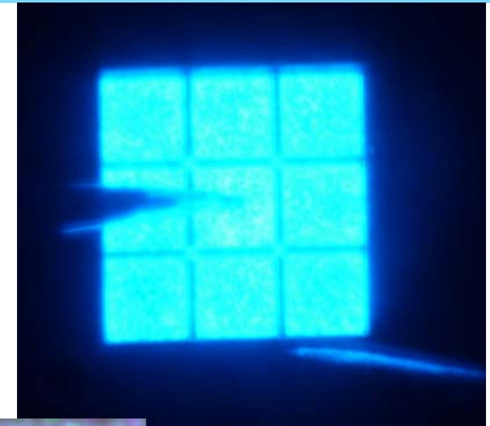


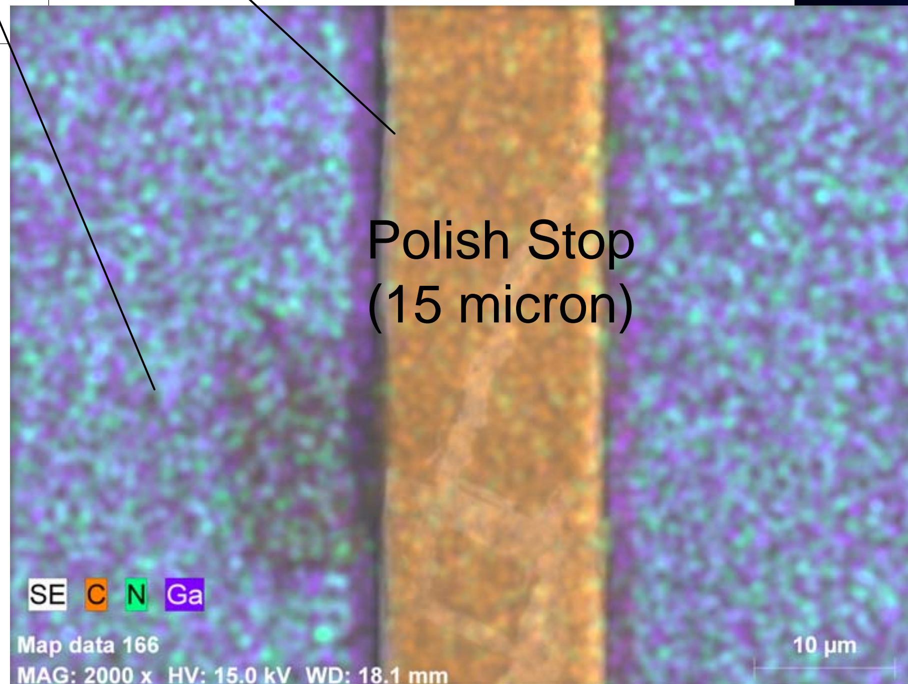
Final Removal of Sapphire by Polishing



Remaining GaN thickness:

3.8 ± 0.6 micron





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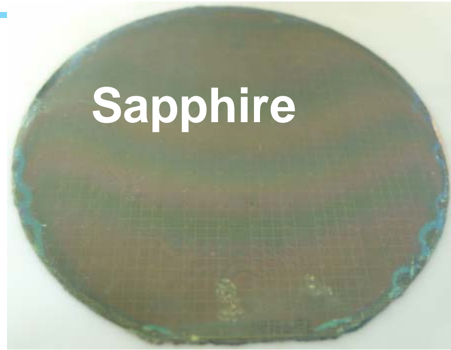
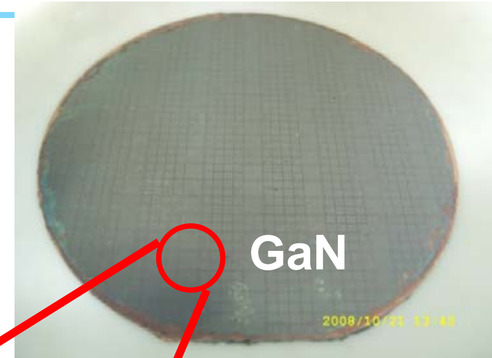
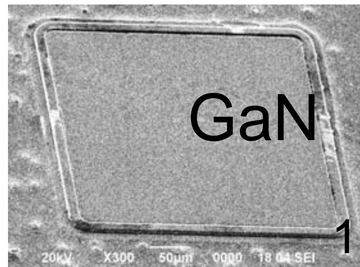
Removal of Sapphire by Polishing



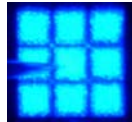


In Process

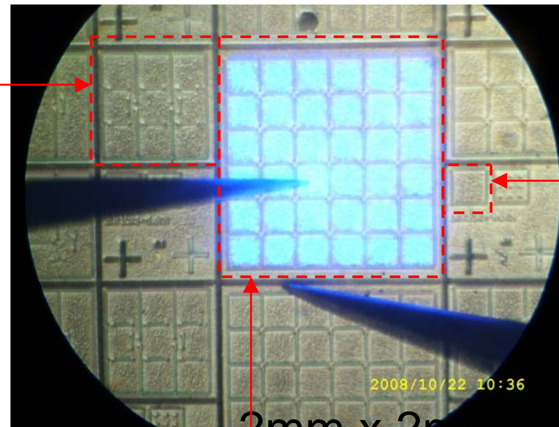
Sapphire Removed
(After Process)



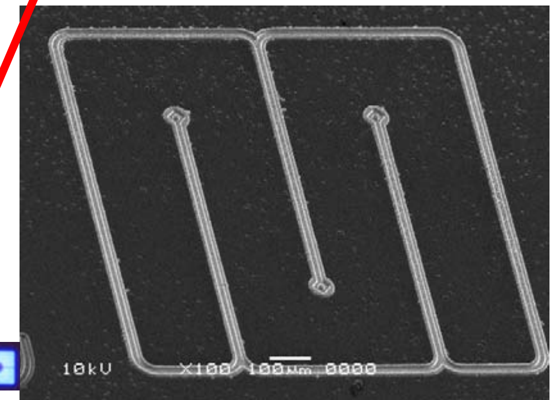
SEM



1mm x 1mm



2mm x 2mm



0.35 mm x 0.35 mm

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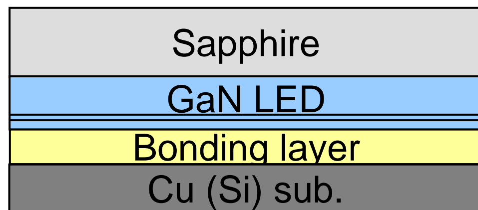
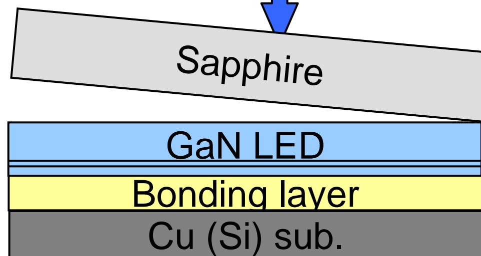
Generic LED Fabrication Process

Semiconductor Epitaxial Layers

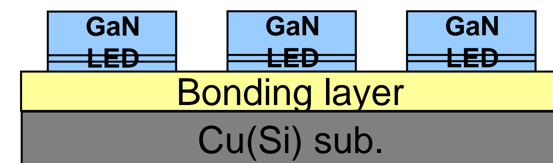
Cu-electroplating or Wafer Bonding



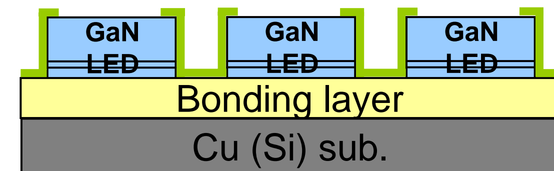


Sapphire Removal by Laser Liftoff or CMP (ASTRI)

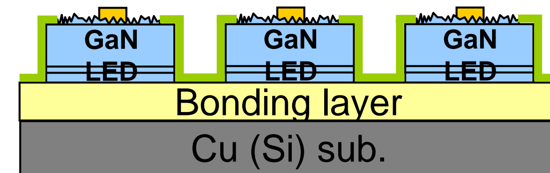
Isolation



SiO2 Passivation



Surface Roughness & Electrode



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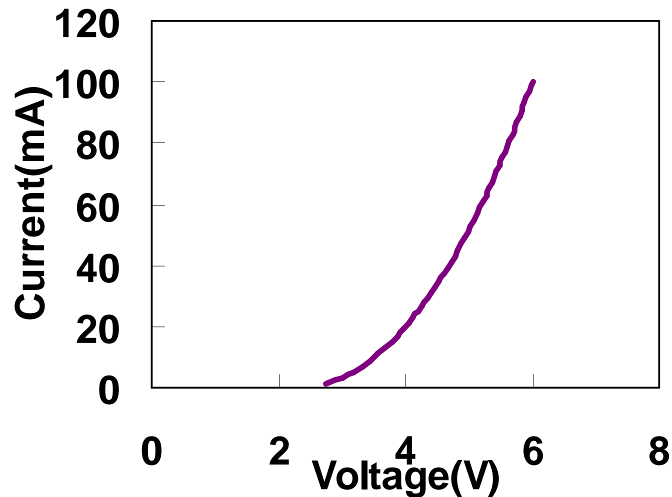
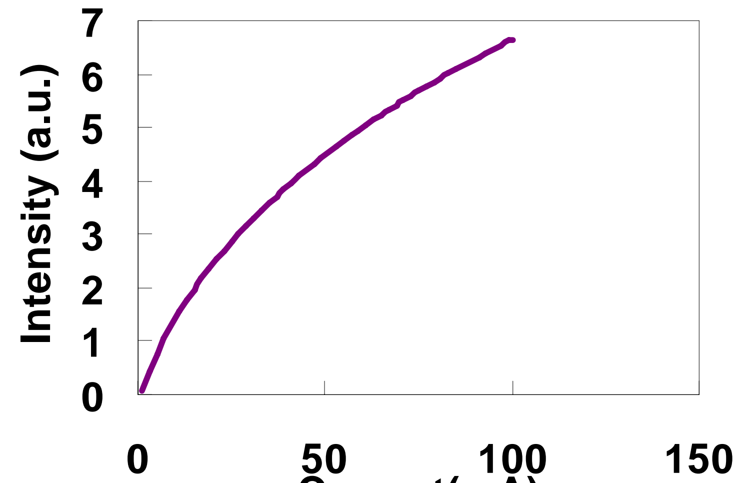
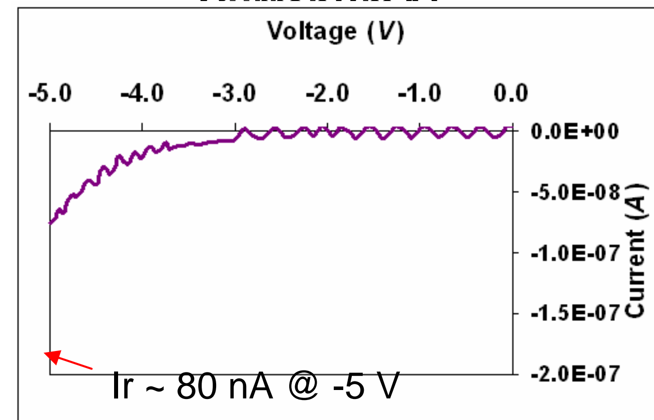
Preliminary Electrical and Optical Characteristics





Data for a typical
0.35 mm x 0.35 mm
Chip after sapphire removal



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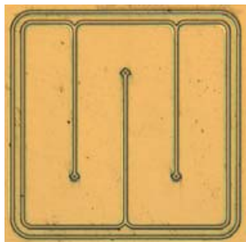
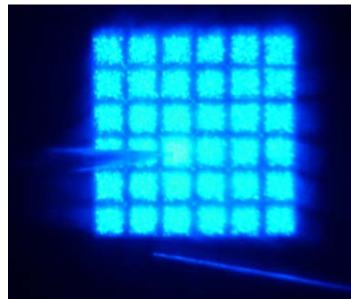
Conclusions

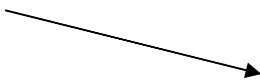




LED mesa   0.35mm x 0.35 mm   2mm x 2mm

Wafers: sapphire totally removed,
Copper is the new host substrate.

No.:
F021
F041
F060
F065
F066
F070
F073
F074
F075
F076
F078



Thank You !!

- **This method has the potential to be used for making vertical LED chips, although a lot of more work needs to be done.**

- **Hong Kong ASTRI welcomes partners to jointly develop this method.**