LED Processing for GaN-based Materials

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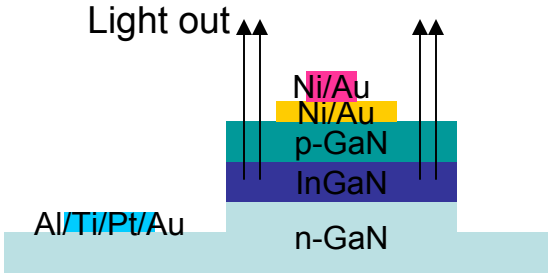
Outline

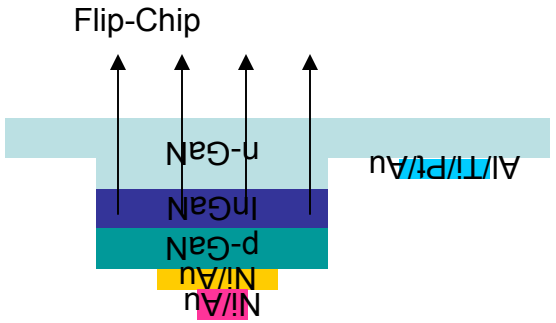
- Overview
- Material Issues
- Equipment
- Fabrication steps
- Conclusion

Overview

- LEDs are a useful way of characterizing material quality.
- Basic LED fabrication is relatively simple
  - Large features
  - Simple structure (patterns)
  - 4-5 mask steps



- Light extraction for High Brightness
  - Need transparent contacts
  - Flip-chip designs
    - Better light extraction
    - harder fabrication
  - GaN has high index of refraction
    - Internal reflections at interface with epoxy or air
    - Some techniques exist to counter
      - Chip shaping
      - Surface roughening



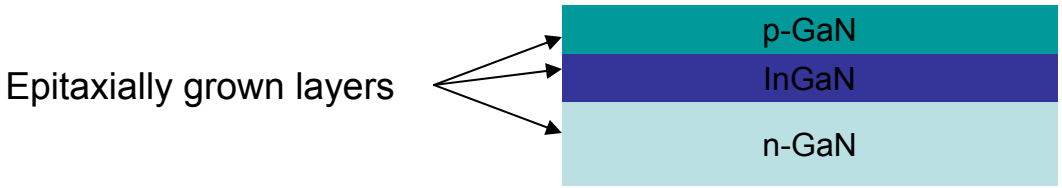
Issues With GaN-based Material Processing

- GaN-based materials present a number of processing challenges
  - poor p-type doping (Mg)
  - difficulty in achieving reliable low-resistance p-ohmic contacts
  - high temperatures needed for implant activation
  - lack of efficient wet etch process
  - generally low dry etch rates
  - low selectivity over etching masks
  - dry etch damage
- Chemistry is not as well or widely understood as Si

Doping

- Typical Dopants
  - N-type
    - Si
    - E_a~30 meV
  - P-type
    - Mg
    - E_a~170 meV

- Epitaxial Growth Doping is preferred to Ion Implantation
  - No implantation damage
  - Better p-type doping
  - Better defined regions



Dry Etching

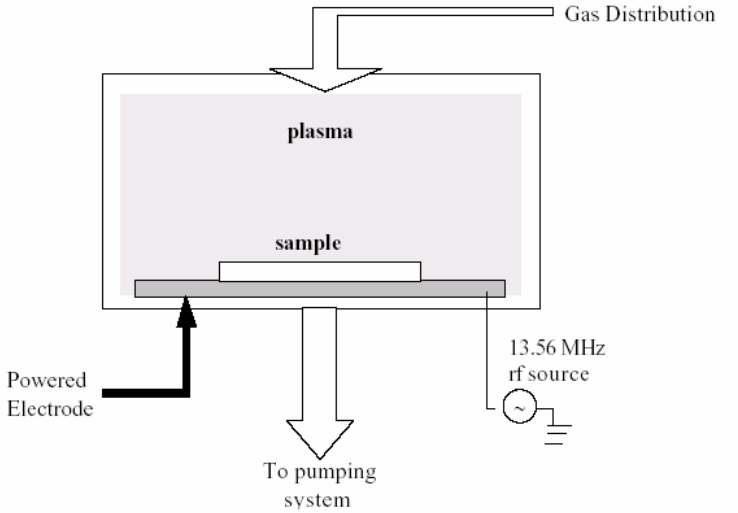
- Physical sputtering
- Chemical reaction
- Ion-assisted plasma etching - combination of the two

- Commonly used techniques
  - Reactive Ion Etching (RIE)
  - Inductively coupled Plasma (ICP)
  - Electron cyclotron resonance (ECR)

RIE

- Most popular etching technique
- Chlorine-based plasma
- Good Anisotropy

- Some problems with photoresist being attacked by the plasma



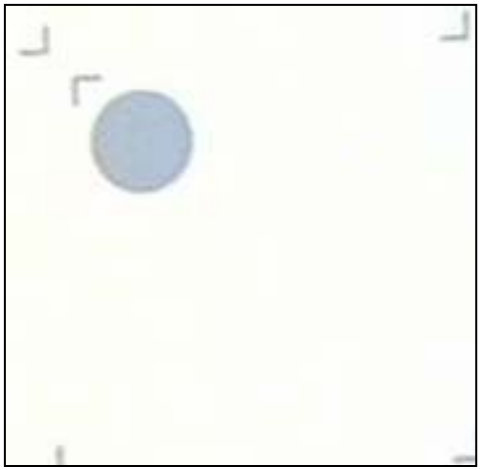
Metal Evaporation

- Filament Evaporator
- Electron Beam Evaporator
  - Preferred to filament
  - Good directionality
- Ni/Au p-type contacts
- Al/Ti/Pt/Au n-type contacts

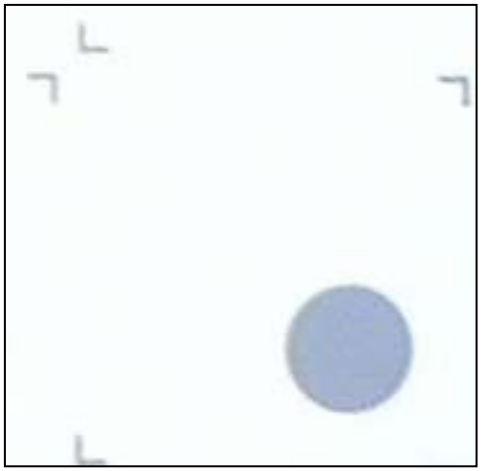
Example Mask

Mesa

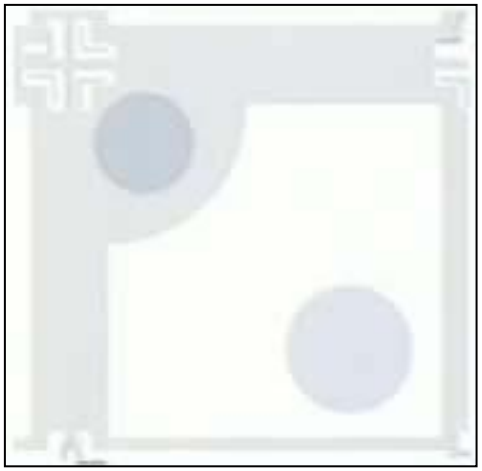
N Contact



P Bonding pad



Overlayed



Mesa Etch

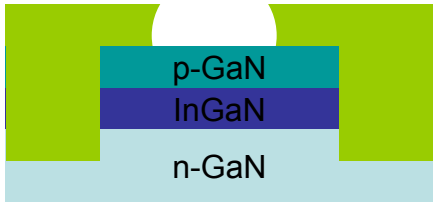
Photolithography

RIE

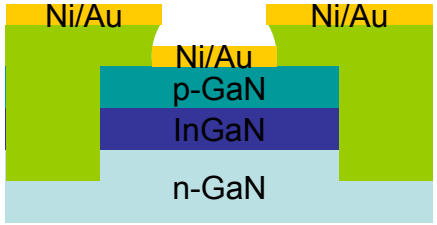
PR strip

Transparent Contact

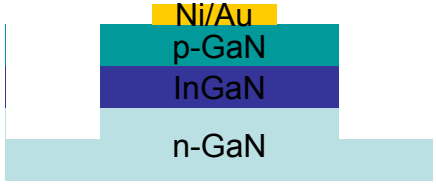
Photolithography



Evaporation



Metal Lift-off

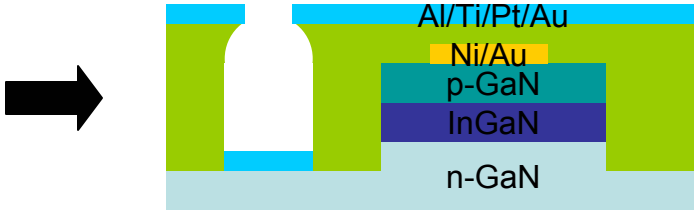


The metal may now be oxidized to improve contact quality
This contact is required for good current spreading

N-Layer

Photolithography

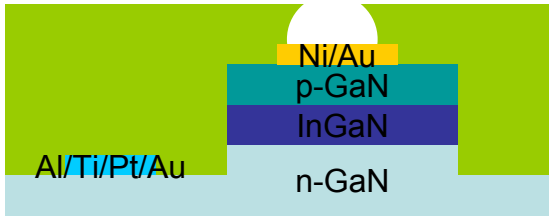
Evaporation



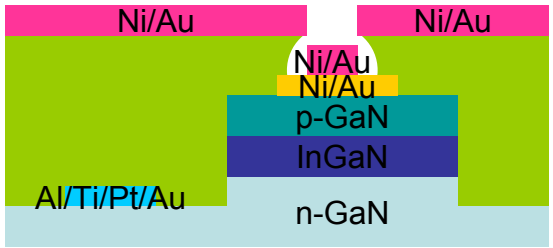
Metal Lift-off

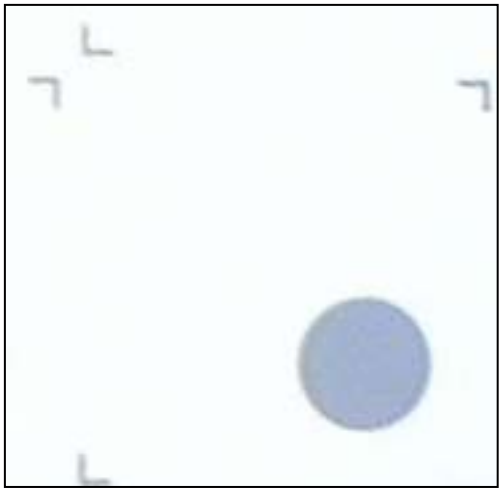
P-Bonding Pad

Photolithography

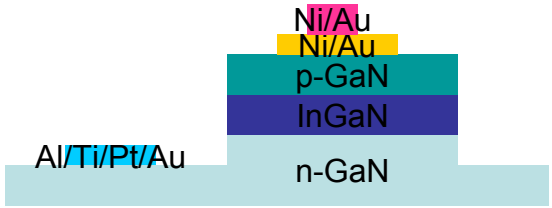


Evaporation

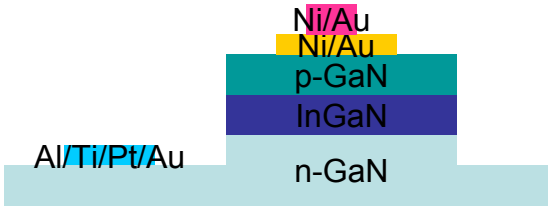


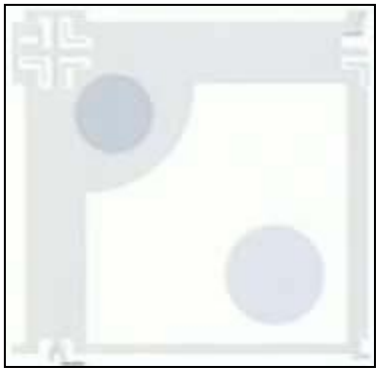


Metal Lift-off

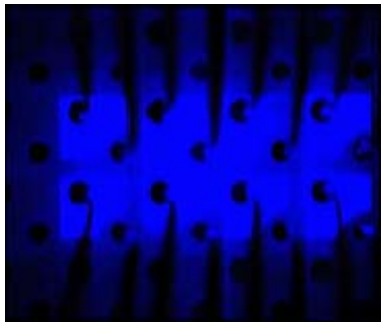


Final Structure

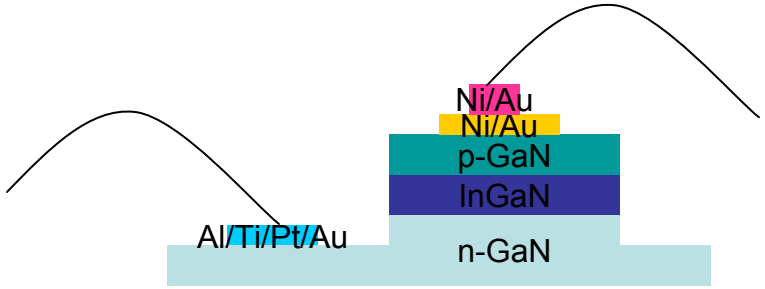


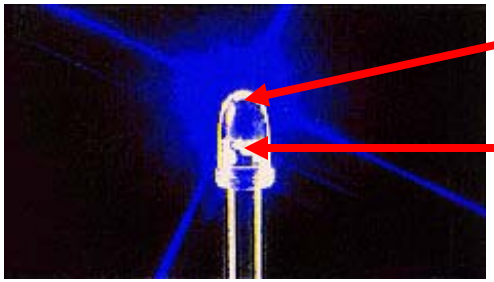


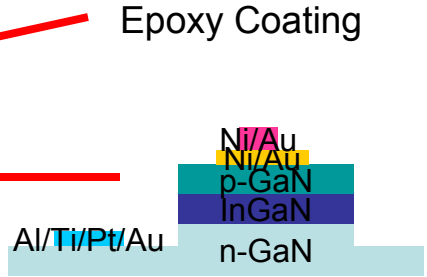
Wiring and Packaging



Wired wafer







Typical 5mm Packaging

Conclusion

- Simplicity of process depends on device use
- GaN-based materials require different fabrication techniques than Si
- Metal Lift-off is important in this process, thus proper lithography is required