MOCVD Technology for LED

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Outline

- Introduction
- Basic MOCVD Technology
- Advantages of Showerhead MOCVD Reactor
- The Planetary Reactor
- LED Processing
- Conclusion
Example of Products with LEDs

Samsung LED-TV 9000 Series • LED Monitor Dell G2410 • LED Toshiba Portégé R500

Audi R8 LED Headlight • Nimbus LED Ceiling Light 12 W • LED Street Lighting
MOCVD = Metalorganic Chemical Vapor Deposition
Compound Semiconductor Systems

- Leading edge design to manufacturing
- Flexible wafer configuration from 2”-300 mm
- Configurable common platform
- Integrated automated solutions
- Customized turn-key solutions
- Proven industry standard & market leader
MOCVD Source Comparison

Group V
Ammonia bottle, capacity: 26.5 kg

Group III
TMGa Bubbler, 100 g
Transport of gases within tubes
Switch by valve
Control via MFC, pressure controller

For metalorganic sources

Bubbler containing MO source
(e.g. TMGa, TMIn, TMAI)

Each bubbler is placed in a thermally controlled bath (Lauda bath)
Integrated Concept Design

- Reactor Cabinet
Basic MOCVD Process in Reactor

(Metalorganic Vapor Phase Epitaxy)

Gas blending

H₂, N₂  10-1000 mbar

TMGa, AsH₃, (CH₃)₃Ga

TMIn, TMAI, PH₃

TMGa, NH₃

Reactor

Ga(CH₃)₃ + ASH₃ → GaAs + 3CH₄

50 rpm

GaAs, InP Substrate, T_D ~ 400-1000°C

Scrubbing System

H₂

high purity, precise mixing

crystal quality, homogeneity

safety

production oriented → low cost of ownership
Cross section of an epitaxial wafer

Cross section of a human hair
Diameter: 100 micron

Epitaxial layers
group III and V elements
thickness: 0.02 micron to 4 micron

Substrate wafer
normally made from Gallium Arsenide (GaAs)
or Indium Phosphide (InP)

(1 micron = 1/1000 mm)
A cross section of a light emitting diode (LED)

Substrat-Wafer (ca. 5 cm diameter)

0.00001 mm thin layers like GaN, GaInN

This wafer will be separated to ca. 10,000 single LED-Chips

Light
Advantage of going large

Maximum reactor utilisation

- 42x2"
  Area: 100% ref.
  Yield: 100% ref.

- 11x4"
  Area: 101%
  Yield: 110%*

- 6x6"
  Area: 125%
  Yield: 140%*

Same MOCVD reactor allows up to 40% increase in productivity

* 2 mm edge exclusion
Showerhead Principle (19x2")

- High Efficiency
- Vertical Flow Design
  w/o Discontinuity in the Center
- Robust Design

CoO
Yield
Uptime
Close Coupled Showerhead: The Concept

Carrier and MO into upper showerhead
Carrier and Hydrides into lower showerhead

Ga Distribution ➔ MMGa Distribution

Growth-rate ➔ intrinsic uniform
Thickness uniformity of an LED structure on 200 mm diameter sapphire

- Thickness mappings showing thickness uniformity of $\sigma = 2.6\%$ (with 4 mm edge exclusion).
- Thickness uniformity dominated by high temperature GaN layers.
42x2” Nitride Reactor After Fully Loaded Run

Total wafer area 42x2“ = 851cm²
AIXTRON G5HT: Larger Chamber

- 56x2 inch / 14x4 inch / 8x6 inch / 5x8 inch
- Capacity Increase: + 33%*
- Compared to AIX2800G4 HT

G5 HT
- Increased throughput
- Large wafers (4", 6", 8")
- No particles
- Continuous production
- Higher yield
- Automation
- Reduced footprint
- Cost of ownership ↓
Sapphire ~430 µm
(0.3deg off-cut from 0001)

4 µm Undoped GaN

2 µm GaN:Si(5x10¹⁸)

100 nm GaN:Mg

40nm AlGaN:Mg

2x u-InGaN QWs (2.5nm) + u-GaN QBs (12nm)

3x u-InGaN QWs (2.5nm) + GaN:Si(5x10¹⁷) QBs (12nm)

QWs @ ~740°C, QBs @ ~860°C

~25nm GaN Nucleation layer

Growth Pressure

900mBar 2μm/hr

400mBar

266mBar

90nm GaN:Mg

400mBar 4μm/hr

400mBar 4μm/hr
Photoluminescence

Recombination between conduction and valance band

- $e$: electron
- $h$: defect electron / hole
- $eh$: exciton / electron-hole pair
- $D$: donor level
- $A$: acceptor level

Energy gap / band gap

Conduction band

Valence band

Photon
EL Test Structure on 6 inch Sapphire

With p-GaN cap added and In contacts
III-N Based LED Processing

LED on sapphire substrate

LED on SiC substrate

Epi-Wafer

n-layer

p-layer

P 1

MESA Litho

P 2

RIE MESA etch
III-N Based LED Processing

LED on sapphire substrate

3. n-Contact Litho

4. n-Contact Evaporation + lift-off

5. p-Contact Litho

LED on SiC substrate

1

2
III-N Based LED Processing

LED on sapphire substrate

- p-Contact evaporation + lift-off
- Scribing + dicing

LED on SiC substrate

- p-Contact evaporation + lift-off
- Scribing + dicing

Anode transparent contact active zone
Inside the LED…

…the chip
Design of white LED

Fig. 11.5. (a) Structure of white LED consisting of a GaInN blue LED chip and a phosphor-containing epoxy encapsulating the semiconductor die. (b) Wavelength-converting phosphorescence and blue luminescence (after Nakamura and Fasol, 1997).

Fig. 11.6. Emission spectrum of a commercial phosphor-based white LED manufactured by the Nichia Chemical Industries Corporation (Anan, Tokushima, Japan).
Conclusion

- Basic MOCVD Technology explained
- Advantages of Showerhead MOCVD Reactor
- Advantages of Planetary Reactor
- Simple LED Processing
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