Plessey GaN-on-Silicon LED

The Impact of GaN-on-Silicon on SSL

2nd December 2014
Plessey: An innovative technology design and manufacturing company

- Plessey founded as a mechanical engineering company
- Plessey re-launched from the Swindon and Plymouth facilities
- Acquisition of CamGaN provides access to ground-breaking LED technology
  - Plessey doubles efficacy within the year, from 32 to 64lm/W
  - Plessey produces world’s first commercial LEDs manufactured on 6" (150mm) diameter silicon substrates
- Market-leading sensor technology developed alongside legacy product sales
- Transfer of experimental recipe onto production tool completed
  - Mainstream GaN-on-Si production
  - 10 reactors installed at Plymouth facility
  - Expanded product range
  - Efficacy at 100lm/W, and higher

1917 | 1957 | 2010 | 2011 | 2012 | 2013 | 2014 AND ONWARDS

- Plessey Electronics and Equipment Group set up and Plessey Semiconductors founded; first Integrated Circuit model produced
- Market-leading sensor technology developed alongside legacy product sales
- Transfer of experimental recipe onto production tool completed
- Mainstream GaN-on-Si production
- 10 reactors installed at Plymouth facility
- Expanded product range
- Efficacy at 100lm/W, and higher

www.plesseysemiconductors.com | COMPANY CONFIDENTIAL
Plessey’s LED Fab In Plymouth

- Plessey-owned land and buildings: ~53,000m² operational plus an additional ~60,000 m² of property for expansion
- Manufacturing standards ISO9001, TS16949 (automotive), ISO14001, OHSAS 18001

Two wafer manufacturing lines
- 8-inch (200mm) wafer manufacturing facility: 1,550sqm, Class 1000, with better than Class 1 SMIF mini environment
- 6-inch (150mm) wafer manufacturing line: 1,200sqm, Class 10: GaN-on-Si for LED and power devices
LED Technology
MaGIC™ — Manufactured on GaN-on-Si I/C
Substrates for Gallium Nitride growth

Other substrates:
- LiAlO$_2$
- MgAlO$_2$
- ZnO
- Glass

Sapphire

SiC

(Freestanding) GaN

Lower Cost

Higher Efficacy

Courtesy:
- led-professional.com
- compoundsemiconductor.net
- lux123.ezweb1-2.35.com
What makes GaN-on-Si growth difficult?

1) 17% Lattice mismatch between GaN and Si → High defect density
2) 54% Thermal mismatch (CTE) → Material cracks upon cooling
3) Meltback etching → 3D defects causing poor yield

![Diagram showing lattice mismatch and thermal mismatch between GaN and Si](image)
What makes GaN-on-Si growth difficult?
How Does Plessey tackle the issues?

- **Thermal mismatch**
  Strain engineering layers enables $(0\pm10)\text{um}$ bow upon cool down

- **Lattice mismatch**
  Recovery layers, defect reduction layers as well as strain engineering layers enable good material quality

- **Melt-back**
  Special treatment of the substrate surface as well as buffer layers eliminate the melt-back effect
Plessey’s GaN-On-Si Technology Benefits

42x2” sapphire V.S. 7x6” silicon

**Features**
- Si
- 6”
- Thin-GaN
- Automated processing

**Benefits**
- Lower unit substrate costs
- Lower epitaxy costs
- Lower processing costs
- Higher throughput
- Higher yield

Other benefits include good wavelength uniformity and high binning yield; Increasing popularity with wafer scale packaging bodes well with GaN on Silicon
The Technical Advantages of our Technology (GaN on silicon)

**Technical Features**

- **Material:** Silicon
- **Chip Architecture:** Surface emitting
- **Process:** Growth Process Control

**Technical USP’s**

- Better thermal performance
- A very focused light emitting area
- Less efficiency loss in big die
- Better on-wafer uniformity
Better thermal performance

Si 149 W/m·K
Sapphire 27 W/m·K

Three dimensions to leverage the better thermal performance

Lower LED operating temperature
Higher reliability

Higher driving current
More lm per die area

Simpler heat sink
Lower system cost
Focused light emitting surface - smaller Etendue

- Surface emitter V.S. volume emitter: How “spread out” the light is
- Simpler and lower cost optical system
Less efficiency loss in big die

- Better lm/W maintenance when scaling up die size

Scaling up the chip size from 500um to 1500um
The Manufacturing Advantages

- Automated depreciated facility
- ISO Qualified factory and JEDEC qualified Product
- Product development integrated in the factory
- World class manufacturing systems
- Low cost product
- Reliable and high yield product
- Short cycle times for product devt
- Flexible and responsive to changing requirements
World-class Manufacturing Control System

World class IT Infrastructure enables maximum yield and minimal costs for LED manufacturing.

System integrates
- Real time MOCVD growth in situ measurements of temperature, wafer reflectance and curvature
- Post growth measurements of x-ray diffraction, photoluminescence and wafer bow
- In line defectivity data
- Wafer probe data

This allows manufacturing engineers to continuously optimise the process for optimum results.
Wafer-to-Package Assembly Line Flow

Assembly Wafer Preparation

- Wafer Probe
- Wafer Tape Machine
- Laser Scriber
- Wafer Expander
- Die Sorter

Die Assembly

- Die Attach & Bonder
- Curing Oven
- Wire Bonder
- Wire Bond Pull
- Encapsulation
- Singulation

- Die Tester
- Package sorter
- Tape & Reel Packager

- Production process for probe, saw, sort and supply of die on membrane
- Facilitates Plessey to rapidly prototype and evaluate new chip designs
- Capability to produce engineering samples in 3535, 3020, 5630 package
- Capability to produce development samples of COB modules
Product Portfolio & Roadmap

MaGIC™ — Manufactured on GaN-On-Si I/C
Technology Roadmap

To be added in the slide set but not published
Summary

MaGIC™ – Manufactured on GaN-On-Silicon
Summary

- World’s leading proprietary GaN-on-Si LED technology
- State-of-the-art in-house manufacturing capability from a European LED supplier
- Disruptive product portfolio addressing the massive and fast-growing SSL market
- Strong heritage and international brand recognition
- Blue-chip international partners
- R&D “engine room” for new technology