Gas Supply to Large-Scale HB-LED Factories

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Head of Market Development, Global Semiconductors and LED
Linde Electronics
Introduction to Linde

— World leading gases and engineering company

— 50,000 employees

— Presence in around 100 countries worldwide

— FY 2009 achieved sales of EUR 11.2 billion

The strategy of The Linde Group is geared towards earnings-based and sustainable growth and focuses on the expansion of its international business with forward-looking products and services.
About Linde LienHwa

Linde Greater China

LienHwa MiTac Group TaiWan)

Serving the Electronics Market in China

Semiconductor

TFT-LCD

Solar

LED
6 new LED customers

During 2010 Linde has been awarded gas supply contracts with six major LED manufacturers in China, including

Three Taiwan invested LED fabs in Jining(ShanDong), Suzhou(JiangSu) and Changzhi(ShanXi)

• Neo-Neon in Yangzhou
• Focus Lighting Technology in Suzhou
• Walsin United Technology in Xi’an.
Gases in LED Manufacturing
LED Process Flow

**Substrate**
- SiC
- Sapphire
- Silicon
- Bulk GaN
- Composite substrates

**Epitaxy Buffer layer**
- AlN
- Low T° GaN
- AlN/GaN sandwich

**Epitaxy Active layers**
- InGaN

**Back-End level 0**
- Back-grinding
- Dicing, Flip-chip
- Laser Lift-Off: LLO
- Die shaping

**LED dies**

**Back-End level 1**
- Binning, Pick-and-place
- Phosphor coating
- Packaging, Housing

**LED dies-on-wafer**

**Front-End**
- Litho, etching, metallization...

**Lateral LED structure**
- Vertical LED structure

**Packaged LED**

**LED lamp**

Source: Yole Research
MOCVD - Main materials used

Process gases:
- N₂ Source: High Purity NH₃
- Dopants: Boron and Phosphine
- Etch Gases: NF₃, SF₆, CF₄
- Diluant: Hydrogen
- Pump and Vent Gas: Nitrogen
- Others: SiH₄, N₂O, CH₄, He

Organometallics:
- Ga Source: Trimethyl Gallium
- Aluminum Source: Trimethyl Aluminum
- Indium Source: Trimethyl Indium

Solids
- Gold, nickel, ITO & other contact metals
Critical Gases

- **NH3**: 63%
- **H2**: 22%
- **N2**: 13%
- **Other ESG**: 2%

High Purity NH3 drives majority of gas cost

Hydrogen is a critical co-reactant/diluant gas to control the surface reaction

Nitrogen primarily used for Vacuum pump purging and chamber venting

Other ESG’s are the dopants and etch gases

**Gases represent 5% of LED Chip Manufacturing. Cost is important but performance is critical**
Critical Materials Supply
Larger scale fabs require more on-site solutions

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<th>Ammonia</th>
<th>MOCVD Tools</th>
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Nitrogen: Variable size on-site generators for all size LED fabs

Threshold for N²-Onsite depends on proximity of fab to an ASU

Liquid assist plants use delivered liquid N₂. Compressor plants can operate without Liquid N₂

Typical lead time of small plants is 12-18 months

Initial production ramp is managed by Liquid N₂ tanks

Back up is by Liquid N₂ tanks

Pipeline possible based on location

Packaged Liquid-assist plants 250-2500 Nm³/hr

Packaged Compressor plants 350-3500 Nm³/hr
Hydrogen – large consumption drives on-site generation

Up to 50 Tools
- < 250 Nm3/hr
- Tube trailer/Electrolyser
- 3-6 months Leadtime

50-250 Tools
- 250-1000 Nm3/hr
- Small SMR
- Tube trailer back-up
- ~12 months leadtime

> 250 Tools
- 1000-4,200 Nm3/hr
- Large SMR
- 18-24 months leadtime
LED performance depend upon stable purity and large fabs require high flows at stable pressure

- Moisture is a killer impurity. Supply NH3 needs to be below 100 ppb \text{H}_2\text{O}

- Purity Stability is important. Variations in purity affect yeild and purifier lifetime

- Large fabs require high flow rate, 2500 SLPM typical for 50+ tools
Ammonia Supply and Delivery Chain: Must maintain stable purity up to the MOCVD tool

Requirements

**MERCHAND PRODUCT**
- Moisture purity critical
- <150ppb H₂O

**BULK DELIVERY**
- Container size, Quality and availability

**DISPENSE & PURIFY**
- High flow rate
- ~2,500 slm
- For 50 tools

**MOCVD Needs**
- 10 t/yr, 50 slm
- Per tool
- 20 to 100 tools per fab

Linde has multiple supply modes to meet LED fab needs as capacity ramps
The first UHP Ammonia Purification Plant in China

- Fractional distillation to purify crude Ammonia via Linde’s patented Y-Column purification system, which removes both heavy and light contaminants.
- Capacity: 500 metric tonnes per year
- Purity: Grade 7 and above - >99.99999 % pure. < 50ppb Moisture
- Supply in Cylinders, Y-Tons, T-Drums and ISO tanks
Scalable NH3 delivery solutions

Linde UHP Plants

Drums

BSGS

ISOs

Purifier

MOCVD Reactor

Agri Grade SOURCE

On-site Purification

99.99999%
Conclusions

Gases are a very important component of large-scale LED manufacturing

Stable Purity, Low Moisture and Reliable High Flows are critical for good device yield

Linde Lien Hwa provides scalable full turnkey solutions in China which allows scale up from small (< 20 MOCVD) to large (> 100 MOCVD) HB-LED fabs