Material Supply Innovations
Safe, sustainable and cost efficient solutions.

Andreas Weisheit
2011
Agenda

The Linde Group

Innovative gas supply solutions

Innovative PECVD chamber clean

Our References
The World’s Leading Gas and Engineering Company
11.2bn Euro sales. Present in more than 100 countries.

GROWTH

Emerging markets

Leveraging Gases & Engineering business synergies

Clean energy

Healthcare
Linde Offering to the Solar Industry

Turnkey scope

On-site Gas Generation (N\(_2\), H\(_2\), F\(_2\), O\(_2\))
Bulk Gas Supply Systems (N\(_2\), H\(_2\), O\(_2\), Ar, He)
Bulk Specialty Gas Systems (NH\(_3\), SiH\(_4\), NF\(_3\))
Specialty Gas Cabinets (NH\(_3\), PH\(_3\), CH\(_4\), TMB, B\(_2\)H\(_6\))
Valve Distribution Boxes, Valve Manifold Boxes
Piping to the tools
Gas Leak Detection, Gas Monitoring
Compressed Dry Air

Value Added Services

Application know-how & Engineering
Process Optimisation
Own Research & Development
Engineering & Hook-up Planning
Permitting
Total Gas & Chemical Management
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Our References
Global Linde Silane Footprint

HOW do we deliver Silane?

- Linde’s supply chains provide maximum security of supply & flexibility for our customers.
- Dedicated trailer fleet and buffer stocks in place across the continents.

WHERE are LINDE Sources?

- USA (> 1000MT Source)
  - Supplies to
    - China, Taiwan
    - Europe
    - USA

- EUROPE (>300 MT Source)
  - Supplies to
    - Europe
    - China
    - Taiwan

- KOREA (>1500 MT Source)
  - Supplies to
    - China
    - Taiwan
    - Europe

WHY use Global Silane?

- Linde have access to silane sources in 3 continents with >2000 MT contracts in place.
- Independent locations provide mitigation of currency and political risk.
Lowest Cost of Ownership by on-site dopant blending

**Dopant gases are typically delivered as 0.5…5% mixture in H₂.**

Dopant gases are hydrides from group III (e.g. TMB) or group V (e.g. PH₃) elements that can alter the electrical properties of a semiconductor layer and make it p(+) or n(-) conductive.

Dynamic Dopant Blending Systems use pure hydrides and H₂ available from the tankfarm to make the mix.

- **Safety**
  - Less cylinder handling steps

- **Cost Reduction**
  - Reduced cost of ownership

- **CO₂ Footprint**
  - Eliminates cylinder shipping
Multiple on-site generation technologies: Electrolysis, Steam Methane Reforming, Methanol cracking.
- High reliability and lowest cost of ownership.
- Quick installation and ease of maintenance.
- Conventional and reliable catalyst systems, proven reactor & PSA technology.

WHICH Technology for Hydrogen?

HOW do we deliver it?
Capacities from <50 to >1000 NM³/hr

WHY use LINDE?
Linde Hydrochem – manufacturers of over 200 Steam Methane Reformers.
Linde Installed record of Electrolysers

The LeadIng on-site Hydrogen supply
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Our References
Fluorine is the active ingredient in all silicon chamber cleaning.

Fluorine gas ($F_2$) is a faster and environmentally friendly replacement for Greenhouse Gases like $NF_3$ used to clean waste silicon from CVD process chambers.

**Productivity**
Faster chamber cleaning improves PECVD tool throughput, typically between 4 and 12%

**Cost Reduction**
Direct material cost saving of >15%

**Sustainability**
$F_2$ has **Zero Global Warming Potential**, eliminates risk of Green House Gas emissions and lowers overall $CO_2$ footprint.
Linde Delivers: F₂ Cleaning in European Photovoltaics

Experience in Electronics Applications

Successful Development Program in PV

Implementation in manufacturing

300mm Semiconductor

LTPS Displays

Large area TFT-LCD

Clean rate performance

Clean rate depends only on atomic fluorine flow, regardless of whether NF3 or F₂ is used.

Lower dissociation energy of F₂ means much higher flow of cleaning gas possible for same RPS power.

Wider process window for F₂ allows choice of energy-efficient cleaning or high-rate cleaning.

A lower temperature increase at the RPS outlet for F₂ vs. NF3 is beneficial for tool parts lifetime.

Successful Development Program in PV

High volume manufacture

Full scale demonstration
Linde Delivers: continuous application improvement

**In-situ activated clean**

- High dissociation by RF plasma.
- Chamber clean shorter than with RPS activation.
  - **Higher uptime**
  - **Lower cleaning costs**
  - **Lower CAPEX & maintenance**

**Direct molecular clean**

- F2 is reactive with silicon at temperature <200°C.
- No plasma activation required (no RPS).
- 80% clean time reduction achieved.
- No ion bombardment, ‘gentle’ clean.
  - **Lowest Cost of Ownership**

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Safe supply by on-site generation

- Never experienced an F₂ leak or fire, in > 10 years.
  Fluorine reactivity is well understood and managed safely at low pressures, low velocities and with proprietary system designs.
  Complete surface passivation ensures system durability.
  Linde F₂ Systems operate at < 1.5 bar.
- On-site systems operated in > 12 electronics customer facilities since 2001 with no F₂ incidents.
- Linde’s Intellectual Property – Patents, trade secrets and know-how ensure long term safe, reliable, high purity operation
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Our References
In Electronics, in all major sectors, Linde’s strategy is closely linked to the most dynamic growth leaders.

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<tr>
<th><strong>Semiconductor</strong></th>
<th><strong>Photovoltaic</strong></th>
<th><strong>LED</strong></th>
<th><strong>TFT-LCD</strong></th>
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| First choice for the top semiconductor manufacturers. | First choice for thin film customers the world over:  
- Oerlikon (7/11)  
- AMAT (8/11)  
- ULVAC (2/4)  
- Apollo (4/4)  
First choice for the global #1 module maker in c-Si (China)  
First choice as a technical partner:  
- Thin film JDPs  
- c-Si JDPs  
First choice for emerging regions  
- India (>75%) | First choice in Asia  
Taiwan – customers are #1 and #2 HB LED makers.  
China – currently executing gas supply projects for 6 major new fabs  
China – Just executed the first Grade 7.0 domestic Ammonia plant.  
Europe & USA – long-term contracts with #1 in each region. | First choice in China  
Currently executing the first 2 Gen 8 TFT fabs in China with a combined investment value of >Eur45m  
First choice for F2 |
Thank you for your attention

Linde Electronics.
The power behind tomorrow’s technologies