The New Silk Road: Challenges and Opportunities in China for Electronic Material Suppliers

Candice Fan, Global Strategic Supply Manager, Linde Electronics
China and Taiwan: close, common language, common culture

180 km distance
China and Taiwan: but also very different

<table>
<thead>
<tr>
<th>Parameter</th>
<th>China</th>
<th>Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td>300mm wafer starts</td>
<td>775,000 per month, 1 wafer start / km²</td>
<td>1,450,000 per month, 500 wafer starts / km²</td>
</tr>
<tr>
<td>Semiconductor sales</td>
<td>USD 16B, 5% of global</td>
<td>USD 51B, 15% of global</td>
</tr>
</tbody>
</table>
China and Taiwan: but also very different

<table>
<thead>
<tr>
<th></th>
<th>China</th>
<th>Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>1,400 million</td>
<td>23 million</td>
</tr>
<tr>
<td></td>
<td>19% of global</td>
<td>0.32% of global</td>
</tr>
<tr>
<td>GDP</td>
<td>USD 11,200B</td>
<td>USD 520B</td>
</tr>
<tr>
<td></td>
<td>18% of global</td>
<td>0.84% of global</td>
</tr>
</tbody>
</table>
Logistics Management
Importing electronic materials into China

- S. Korea: 3-5 days
- Taiwan: 2-3 days
- North China base: 1-3 days, 1200 km, 3-5 days
- West China base: 1400-1900 km, 5-8 days
- East China base: 200-500 km, 1-3 days
- South China base: 1500 km, 5-7 days
- Shanghai port: 2-3 days
- Japan: 3-5 days
- S. Korea: 3-5 days
- America: 30 days
- Europe: 35 days
- South China base: 1200 km, 3-5 days
China raw material processor locations
Quality Gatekeeper
Examples of key China raw material supplies for electronic supply chain

Liaoning Fluorspar: HF, NF₃, SF₆, CF₄, etc.
Examples of key China raw material supplies for electronic supply chain

Inner Mongolia Rare Earths: Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, etc.
Examples of key China raw material supplies for electronic supply chain

Hubei Phosphoric Acid: \( \text{PH}_3 \)
Examples of key China raw material supplies for electronic supply chain

Guangxi Tungsten: WF$_6$, WCl$_5$
Examples of key China raw material supplies for electronic supply chain

Yunnan Germanium: $\text{GeH}_4$, $\text{Ge}_2\text{H}_6$
Examples of key China raw material supplies for electronic supply chain

Yunnan Arsenic: $\text{AsH}_3$
Between the variability of the raw material source
And the precision of manufacturing
Material suppliers like Linde LienHwa are the quality gatekeepers.
Quality: Holistic, collaborative approach

We achieve electronics industry quality standards with close collaboration throughout the supply chain

- **Raw materials**
  - Manage supplier performance
  - Manage deviations from specification
  - Manage process changes
  - Qualify suppliers
  - Qualify products

- **Linde LienHwa**
  - Manage deviations from specification
  - Ensure business continuity
  - Perform incoming material QC
  - Align with EICC
  - Establish and certify QMS
  - Manage process changes
  - Control production quality

- **Customer**
  - Check and develop required capability
  - Understand customer requirements
  - Manage deviations from specification
  - Manage process changes

Quality: Holistic, collaborative approach

We achieve electronics industry quality standards with close collaboration throughout the supply chain
Quality: reduce variability, tighten control limits

IC technology step changes drive electronic materials purity and analytical requirements

<table>
<thead>
<tr>
<th>High-purity EMs</th>
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<th>High-purity EMs</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 to 20 years ago</td>
<td>Within the last 10 years</td>
<td>Recent / Present</td>
<td>Near future</td>
</tr>
<tr>
<td>Tight consistency</td>
<td>Tighter consistency</td>
<td>Use of overall process control system</td>
<td>Use of overall process control system</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fingerprinting</td>
</tr>
</tbody>
</table>
Quality: Customers are driving tighter requirements

Customers
Expect Linde to meet purity specifications and control limits
Are even more concerned about unknown and uncontrolled impurities

Example
Specification: 50 ppm
Control limit: 20 ppm
Mean: 8 ppm

Mean +3σ
Spec

ppm impurities

Number of measurements
Quality: local and consistent

The highest quality demands production, stocking, and analysis local to the customer.
Quality: local and consistent

The highest quality demands production, stocking, and analysis local to the customer.
Quality: local and consistent

Copy-exact procedures to produce consistent results
Transformation of raw materials to electronic-grade products requires quality throughout the supply chain.

Material providers like Linde LienHwa are the quality gatekeepers.
Business Continuity
Supply interruptions can be caused by natural disasters

Fukushima Earthquake and Tsunami: 2011
Supply interruptions can be caused by human events

Beijing Olympics: 2008
Supply interruptions can be caused by human events

G20 Summit: 2016
Supply interruptions can be caused by human events

Tianjin Port Explosion: 2015
And they can happen close to home

921 Earthquake: 1999
And they can happen close to home

Kaohsiung Gas Explosions: 2014
### Global EM supply network

#### Linde global supply network

<table>
<thead>
<tr>
<th>N. America</th>
<th>Europe</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCL$_3$</td>
<td>BF$_3$</td>
<td>Cl$_2$</td>
</tr>
<tr>
<td>B$_2$H$_6$</td>
<td>ClF$_3$</td>
<td>DCS</td>
</tr>
<tr>
<td>Cl$_2$</td>
<td>D$_2$</td>
<td>F$_2$ Mix</td>
</tr>
<tr>
<td>DCS</td>
<td>GeH$_4$</td>
<td>Halocarbons</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>HCl</td>
<td>NF$_3$</td>
</tr>
<tr>
<td>HBr</td>
<td>HF</td>
<td>NH$_3$</td>
</tr>
<tr>
<td>Laser gas</td>
<td>He</td>
<td>SF$_6$</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>SiH$_4$</td>
<td>Si$_2$H$_6$</td>
</tr>
<tr>
<td>Si$_2$H$_6$</td>
<td>TCS</td>
<td>TCS</td>
</tr>
<tr>
<td>WF$_6$</td>
<td>Xe</td>
<td>Xe</td>
</tr>
</tbody>
</table>

> 50+ sources globally

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**SEMICON TAIWAN**

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Material supply by trading

Multiple sources – same product
Example: HCl

Sourcing
• Access to 4/7 Global suppliers representing 67% of HCl capacity
• Distribute prime source to the respective region, as well as introduce new source for BCP

Assets
• Variety of fleet
  − ISO tube trailers
  − Drum, Y Tonner, Cylinder
• Capability in ISO tube service
• Periodic testing, maintenance, and upgrading of assets in line with global standards

Quality
• Proven track record of bulk HCl supply to semiconductors customers across the world for several decades
• Multiple sources – same final product

Global Capacity 2017 (>17.5 Ktons)
Material supply by manufacture

**Multiple local plants – same process**

Example: N₂O

**Manufacture**
- High volume product – must be made close to customer for cost
- Manufacture in 4 countries to be close to customer
- Same process in each location

**Assets**
- Variety of fleet
  - ISO tube
  - Drum, Y Tonner, Cylinder
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![Chart showing market share with Linde leading at 31%]
Local Capabilities
Linde LienHwa Taiwan electronic material infrastructure

On-site / merchant plant
PGP plant
ESG plant
AUECC plant (wet chemicals)
ESG warehouse
Electronics R&D Center
Linde LienHwa China electronic material infrastructure

- Linde ASU site
- ESG plant
- ESG warehouse

Regions:
- Jilin
- Beijing
- Shanxi
- Sichuan
- Fujian
- Guangdong
- Hebei
- Tianjin
- Shandong
- Henan
- Anhui
- Hubei
- Jiangxi
- Shanghai
- Jiangsu
- Zhejiang
- Changshu
- Liaoning

Bulk gas plant on customer site
Linde LienHwa is the bridge to new markets and new materials

**Logistics management**
- Integrating global supply chains
- Networks covering all business zones

**Quality gatekeeper**
- Critical link between raw materials and fab
- New sources – same quality

**Business continuity**
- Dual trade lanes
- Multiple sources

**Local capabilities**
- Experience
- Capacity
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