Investing in Taiwan: Benefits of Domestic Development and Production of Strategic Electronic Materials

Fox Fang, Vice President of Electronics Supply Chain, Linde LienHwa (LLH)
Taiwan: Semiconductor and electronics powerhouse

The New York Times
SEPT. 15, 2013

Taiwan, an island of 23 million people, is the world’s biggest chip maker. The industry generated about $63 billion in sales here last year — more than one-fifth of the global total, according to the Taiwan Semiconductor Industry Association. Made-in-Taiwan chips are major components of many of the world’s PCs, smartphones...

Why Amazon Picked Taiwan For Its Latest Innovation Center

Amazon periodically moves a city somewhere in the world by opening an innovation center that lets startups get launched in its cloud services. Amazon Web Services, or AWS for short, agreed in 2015 to open one center in Taiwan, South Korea, and it operates two regional ones in China. The Seattle-based commerce giant delighted a crowd of Taipei on August 29 with its latest one.

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Taiwan: Long history of semiconductor manufacturing

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Taiwan: Products enabled
Taiwan: Metrics

15% of total semiconductor sales

16% of fabless sales

5 of the top 15 foundries

65% of all foundry sales
Taiwan: Small in land size and population and big in electronics

- 300mm wafer starts
  - 1,450,000 per month
  - 500 wafer starts / km²

- Semiconductor sales
  - USD 51B
    - 15% of global

- Population
  - 24 million
    - 0.32% of global

- GDP
  - USD 520B
    - 0.84% of global
Taiwan: Semiconductor component supply chain underweight

- 20% of installed wafer capacity
- 1 of top 10 wafer manufacturers
- 20% of equipment sales
- 0 of top 10 equipment manufacturers
- 20% of electronic material sales
- 0 of top 10 material manufacturers
Taiwan: Commerce giant with convenient ports, infrastructure
Taiwan: Long distances for international supply chains

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Natural and man-made disasters can disrupt supply chains

- Fukushima earthquake and tsunami
- Tianjin port explosion
So can politics

Qatar land blockade and helium disruption

Trade disputes
Taiwan: Continuing to invest in semiconductor industry
The Linde Group worldwide

Operating in over 100 countries
Revenue of 20 Billion USD
60,000 employees

Reportable segments
- Americas
- EMEA
- Asia/Pacific

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Global EM supply network of Linde

N. America
- BCl₃
- B₂H₆
- CHF₃
- Cl₂
- DCS
- Halocarbons
- HBr
- Laser gas
- NH₃
- Si₂H₆
- WF₆
- BF₃
- ClF₃
- D₂
- GeH₄
- HCl
- HF
- He
- SiH₄
- TCS
- Xe

Europe
- Dopants
- HCl
- GeH₄
- HF
- He
- NH₃
- N₂O
- Xe
- TCS

Asia
- CO
- DCS
- F₂ Mix
- Halocarbons
- HBr
- HCl
- HCl
- HF
- NF₃
- NH₃
- SF₆
- Si₂H₆
- F₂
- GeH₄
- HCDS
- He
- N₂O
- POCl₃
- SiH₄
- TCS

>50+ sources globally
LLH: A local Taiwanese company continuing to invest in semiconductor industry

Linde LienHwa (LLH) is a 50:50 joint venture company within The Linde Group

Leading electronic materials supplier in mainland China and Taiwan since 1984

Over 1,600 employees, leading industrial gases manufacturer in Taiwan with production, warehousing, and trading capabilities

Local partner. Global expertise. Bringing the global reach and resources of the Linde Group to focus on local customers in Taiwan and the rest of Asia

Electronics Research and Development Center

LLH TW Headquarters

LLH CN Headquarters
Linde LienHwa Taiwan infrastructure

Hsinchu Science Park (North)
Taichung Science Park (Central)
Tainan Science Park (South)

- On-site / merchant plant
- PGP plant
- EM plant
- AUECC plant (wet chemicals)
- ESG warehouse
- Electronics R&D Center

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LLH improving EM supply chains for Taiwan

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<tr>
<th></th>
<th>$\text{C}_4\text{F}_8$</th>
<th>CO</th>
<th>$\text{F}_2/\text{N}_2$</th>
<th>$\text{GeH}_4$ blends</th>
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<tbody>
<tr>
<td><strong>Before</strong></td>
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<tr>
<td>Supply</td>
<td>Japan and US</td>
<td>Japan and US</td>
<td>Primarily Japan</td>
<td>US</td>
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<tr>
<td>Risk</td>
<td>Length of supply chain</td>
<td>Length of supply chain and carbonyl generation</td>
<td>Export licensing, and blend degradation and package corrosion</td>
<td>Length of supply chain and blend degradation</td>
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<td><strong>After</strong></td>
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<tr>
<td>Production</td>
<td>LLH ChungGang</td>
<td>LLH Taoyuan</td>
<td>LLH GuanYin</td>
<td>LLH ChungGang</td>
</tr>
<tr>
<td>Capability</td>
<td>Purification</td>
<td>Purification with proprietary carbonyl removal</td>
<td>Linde electronics grade fluorine generation and precision blending</td>
<td>Precision blending</td>
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<tr>
<td>Sourcing</td>
<td>Flexible</td>
<td>Proprietary low nitrogen</td>
<td>Own generation</td>
<td>Multiple pure sources</td>
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<tr>
<td>Local supply chain</td>
<td>Climate controlled</td>
<td>Climate controlled</td>
<td>Climate controlled</td>
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<td>Analytical</td>
<td>Local analysis, fingerprinting, and technical support</td>
<td>Local analysis, fingerprinting, and technical support</td>
<td>Local analysis and technical support</td>
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Electronics R&D Center (ERDC) in Taichung

- World-leading analytical capabilities for electronic materials
- Fingerprinting: “broad spectrum characterization” of raw materials and finished products
- Forensic analysis capability: product and customer troubleshooting
- Improved technical interaction with key customers driving product and application development
- Back-up for Linde production analytical laboratories
ERDC: Best in class analytical hardware and capabilities

- **GC-PDID/FID**: Forensic / broad-spectrum / method development suite
- **High-resolution ICP-MS**: Sampling selected ESGs for metallic impurities prior to testing via ICP-MS
- **FTIRs (high resolution)**: Dedicated for moisture analysis in inert and corrosive gases
- **Binary gas analyzers**: For lithography laser gas mixes
- **GC-TCD**: Portable in-plant or field diagnosis via mass spectrometry
- **GC-MS/ECD/FID**: General-purpose ‘workhorse’ GC with connectivity to ICP-MS
- **Gas/Liquid Sampling Systems**: Metallic/elemental analysis in ESGs; connectivity to GC-PDID/FID
- **Moisture Analyzers**: Broad spectrum analysis
- **Laser particle counter**: For inert gas streams (e.g. empty cylinder characterization)
- **RGA**: Dedicated analyzers for specific impurities (e.g. O₂, N₂, etc.)

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The Linde SPECTRA brand

Linde SPECTRA® brand: a long history with two high-value, high-recognition electronic market products:

- SPECTRA-N nitrogen generators
- SPECTRA lithography

Expanding our portfolio of SPECTRA products and launching the SPECTRA EM brand with three tiers of electronic materials:

**SPECTRA EM**
Industry-leading purity, packaging, and analysis

**SPECTRA EM Gold**
The next level of excellence with customized specification and local analysis

**SPECTRA EM Platinum**
Guaranteeing your processes with ship-to-control quality

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Introducing SPECTRA EM brand and products

Our initial products included in the SPECTRA® EM suite are:

<table>
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<tr>
<th>Product</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>Carbon monoxide</td>
<td>CO</td>
</tr>
<tr>
<td>Fluorine / Nitrogen mixtures</td>
<td>F₂/N₂ mixtures</td>
</tr>
<tr>
<td>Hexachlorodisilane</td>
<td>HCDS</td>
</tr>
<tr>
<td>Hydrogen bromide</td>
<td>HBr</td>
</tr>
<tr>
<td>Nitrogen trifluoride</td>
<td>NF₃</td>
</tr>
<tr>
<td>Octafluorocyclobutane</td>
<td>C₄F₈</td>
</tr>
<tr>
<td>Octafluoropropane</td>
<td>C₃F₈</td>
</tr>
<tr>
<td>Sulfur hexafluoride</td>
<td>SF₆</td>
</tr>
<tr>
<td>Tetrafluoromethane</td>
<td>CF₄</td>
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These products are the first of the SPECTRA EM portfolio, which will expand to all LLH products and the global Linde EM offering.

These products offer the flexibility of custom specifications for certain impurities, or for package size and configurations, all while maintaining quality, reliability, and an eye on cost.

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LLH electronic materials making an impact

Linde ERDC shines a light on new material development

Linde ERDC shines a light on new material development

Linde LienHwa making new gas production investments in Taiwan

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