Machine Learning Applications for High Volume Materials Manufacturing
-Polysilicon

MARK LOBODA
HEMLOCK SEMICONDUCTOR
Polysilicon – A Foundation for Solid State Microelectronics

Parts per trillion impurity control

300-450mm ~400kg 30ft
Polysilicon – A Foundation for Solid State Energy Generation
What is Chemical Vapor Deposition?

"CVD is a process where gaseous precursors react to form a solid coating on a heated substrate”

Typical CVD processes are operated in very idealistic conditions and used in the production of integrated circuits – constant gas flow, uniform pressure, temperature…
Siemens CVD Reactor for Polysilicon

July 3, 1962

H. GUTSCHE
METHOD FOR PRODUCING HIGHEST-PURITY SILICON
FOR ELECTRIC SEMICONDUCTOR DEVICES
Filed May 23, 1960

3,042,494

1962
~1 m

2012
~3 m, 7 ton

HSC
HEMLOCK SEMICONDUCTOR
Powering Tomorrow with Proven Performance
Extremely Complex CVD Processes – Siemens Polysilicon Growth

- Optimization of SiemensCVD simultaneously for quality, efficiency and cost is very difficult due to large interaction effects of the process variables (gas flow, pressure, power (heat), time).

- Turbulent gas flow,
- Resistive rod heating,
- Thermal radiation,
- Gas-phase chemistry,
- Silicon deposition,
- Popcorn formation,
- Particle (dust) formation

- Temperature Sensors
- Pressure Sensors
- Flow Meters
- Heat Exchangers
- Electricity/Power Sensors
Scale Of Polysilicon Manufacturing

<table>
<thead>
<tr>
<th>Size</th>
<th>Mass Output per Year</th>
<th>Business</th>
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<tbody>
<tr>
<td>Small</td>
<td>&lt;20,000 t</td>
<td>Semi or solar</td>
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<tr>
<td>Medium</td>
<td>&lt;40,000 t</td>
<td>Semi and solar</td>
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<tr>
<td>Large</td>
<td>70,000 t +</td>
<td>Solar</td>
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- Equivalent of dozens of chemical tank trucks per day of silicon chemicals to support manufacturing.
- Many – many Siemens CVD systems required to achieve target plant capacity.
- Extreme electricity use:
  - Example: Hemlock is the largest consumer of electrical energy in Michigan!
Scale Of Polysilicon Manufacturing
Manufacturing Challenge

• Control several production plants on one manufacturing site
• Scheduling production
• Minimizing cost
• Maximizing yield and efficiency of CVD and gas management
• Significant testing required to guarantee performance of product
• Identify cause effect relationships buried in mountains of data…How?
Next: Machine Learning?

In 2015 GE launched its Brilliant Manufacturing Suite for customers, which it had been field testing in its own factories. The system takes a holistic approach of tracking and processing everything in the manufacturing process to find possible issues before they emerge and to detect inefficiencies.

Siemens has been using neural networks to monitor its steel plants and improve efficiencies for decades.

Forbes: Machine learning algorithms, applications, and platforms are helping manufacturers find new business models, fine-tune product quality, and optimize manufacturing operations to the shop floor level. Improving semiconductor manufacturing yields up to 30%, reducing scrap rates, and optimizing fab operations are is achievable with machine learning.
At Hemlock Semiconductor we now finding our business is in the midst of a conversion from a specialty materials business to a high volume commodity business.

New focus placed to establish improved automation, data analytics, cost reduction in play – We look to tap the best capabilities in the world to achieve our goals...

Next: Machine Learning?


Our manufacturing has nearly 1000 sensor data sources, plus data on materials tests, chemical tests, energy use, logistics/scheduling, process and product metrics.

It is a textbook opportunity to exploit machine learning and deep learning.
Next Steps:

Find experts, staff the organization, establish partnerships...learn. Repeat.