CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
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Lecture 33
Semiconductor Manufacturing:
Statistical Process Control (SPC)

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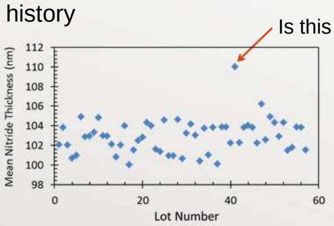
Process Control and Metrics

- Parametric yield is kept high in two ways
  - Designing a process that can tolerate and acceptable amount of process variation
  - Controlling the process to stay within that acceptable variation
- Two tools often used for process control
  - Statistical process control (SPC)
  - Process Capability metrics

SPC

- SPC is a tool to detect systematic process excursions: variations in a process parameter that are unexpected based on its known statistical history



Is this an problem?

SPC Method

- Establish historical mean and standard deviation for variable under consideration
  - The mean will follow a normal distribution even if the underlying variable does not (by Central Limit Theorem)
- Use “3σ” probability as an indicator of a problem
  - If an event occurs whose probability of occurring randomly is < 0.3%, chances are this is an error and not just normal variation
- Result: the Western Electric Rules

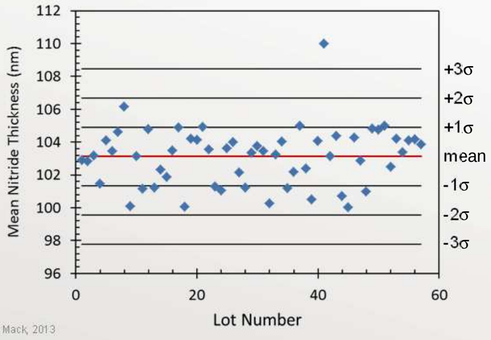
Main Western Electric Rules

- Any single point falls outside of the +/- 3σ limits
  - 0.3% probability
- Eight successive points are above the mean, or eight successive points are below the mean
  - 0.4% probability each
- Two out of three successive points are between 2σ and 3σ, or between -2σ and -3σ
  - 0.3% probability each
- Four out of five successive points are between 1σ and 3σ, or between -1σ and -3σ
  - 0.5% probability each

Using the Western Electric Rules

- Rules can detect both a mean shift and growth in variation
  - There are a few more rules besides these
- Alarm whenever a rule is violated
  - Look for a cause and fix it!
  - Sometimes, though, the alarm will be false
- Measure of control: average run length = average number of points between alarms

SPC Chart



Process Capability

- SPC charts show how the process is doing compared to its historical behavior
- The "Process Capability" metric seeks to compare this long-term behavior to the specifications
  - Spec: if we keep the parameter within these limits, we are pretty sure our yield and performance will not be affected (based on experience and/or modeling)

Process Capability Index (C_p)

$$C_p = \frac{USL - LSL}{6\sigma}$$

Historical fab performance

USL = upper spec limit
LSL = lower spec limit

- Higher C_p means a more capable process
- Problem: this metric will not detect a mean shift

New Metric: C_{pk}

$$C_{pk} = (1 - k)C_p$$

$$k = \frac{2|Target - mean|}{USL - LSL}$$

- $C_{pk} > 1$ is minimum requirement
- $C_{pk} > 1.5$ is good
- $C_{pk} > 2$ is great (called "six-sigma" quality)

Lecture 33: What have we learned?

- What is the guiding principle of SPC?
- What are the Western Electric rules?
- What do you do when there is an SPC alarm?
- What is the difference between C_p and C_{pk}?
- What constitutes mediocre, good, and great capability?