Water and Chemical Usage Practical Considerations

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Manufacturing

- **Semiconductor manufacturing is most successfully done in fabs that are fully loaded with profitable products moving as quickly as possible through the process line with a high yield**
- **High Throughput-minimum changeout and qualification**
- **Low Cost-minimize use of consumables**
- **Robust Processes-work every time, all the time**

Wet Chemical Processing

- **Purpose of wet chemical processing is to remove contaminants and, in some cases, films from wafer surfaces. This must be done in a uniform, consistent and reliable manner**

- **Chemical and DI water use in these processes should be minimized based on bath stability, and wafer surface effects**

Areas of Savings

- **Water**
  - **Water used in processing**
  - **Other water used in fab**
- **Chemicals**
  - **Production processes**
  - **Non-product processing-Test wafers, quartzware**
- **Other products and equipment**

Water Flow

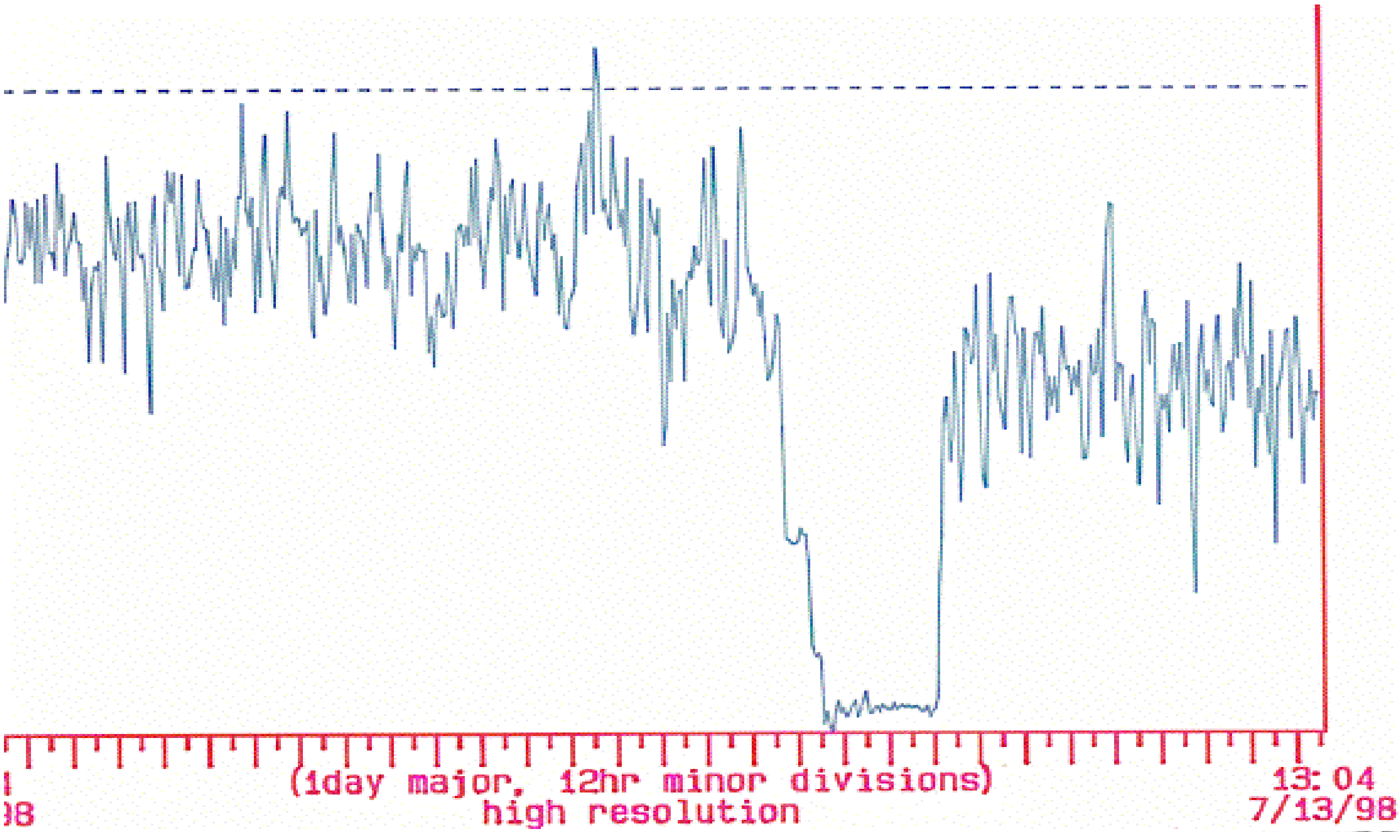
- **All DI systems contain bacteria**
- **In an effort to inhibit bacterial contamination, all water lines are kept flowing at all times**
- **Water flow through the lines going to rinse baths results in “low flow” down the drain**
- **This flow may not seem to be very significant until one considers the number of baths in a fab.**

Water Valves

- Low flow is regulated by a needle valve built into the body of an AOV
- Low flow is a method only of keeping water flowing through the plumbing and thus does not need to be regulated
- Removing needle valve for low flow bypass and replacing with flow restrictor had significant impact.

FLOW RESTRICTORS

ADDITION OF RESTRICTORS RESULTED IN DECREASE IN FLOW OF 40GPM



DI Water Usage

- **Water is the most heavily used chemical in semiconductor processing**
- **Much of the usage goes into rinsing chemicals from wafer surfaces**
- **Work has been and continues to be done on rinse processes and rinse modeling but little information exists on the effect of inadequate rinsing**

How Much is Enough?

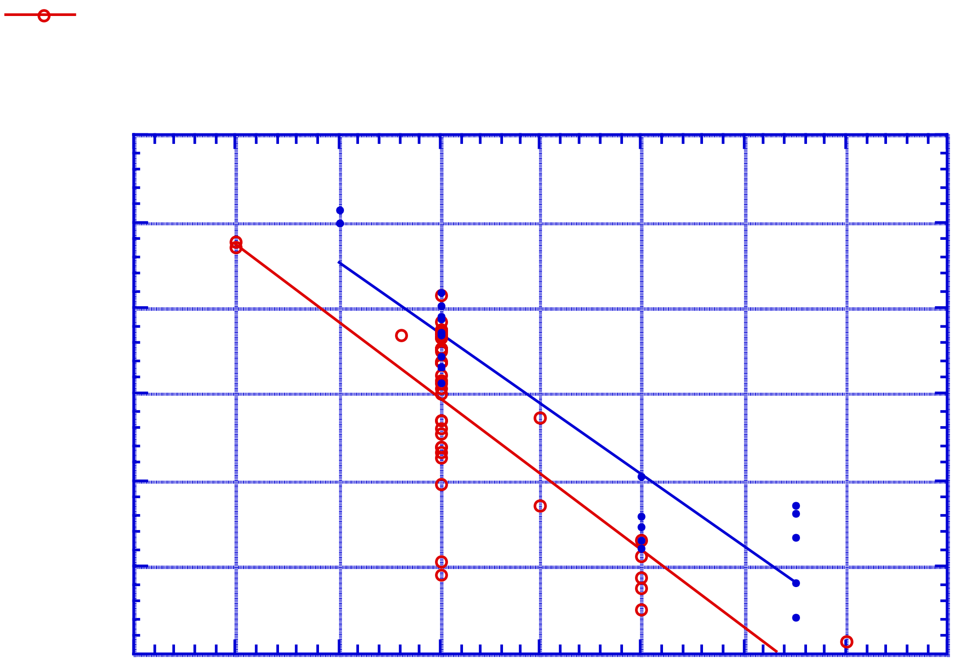
- **Most processes are followed by rinsing for a period of time or until a resistivity is reached**

- **Our rinse processes are described as rinsing to resistivity but are actually rinse for a time period**

  This is due to the way the automation works on out wet processing systems

- **The information we need is how much chemical is left on the wafer surface after any rinse process**

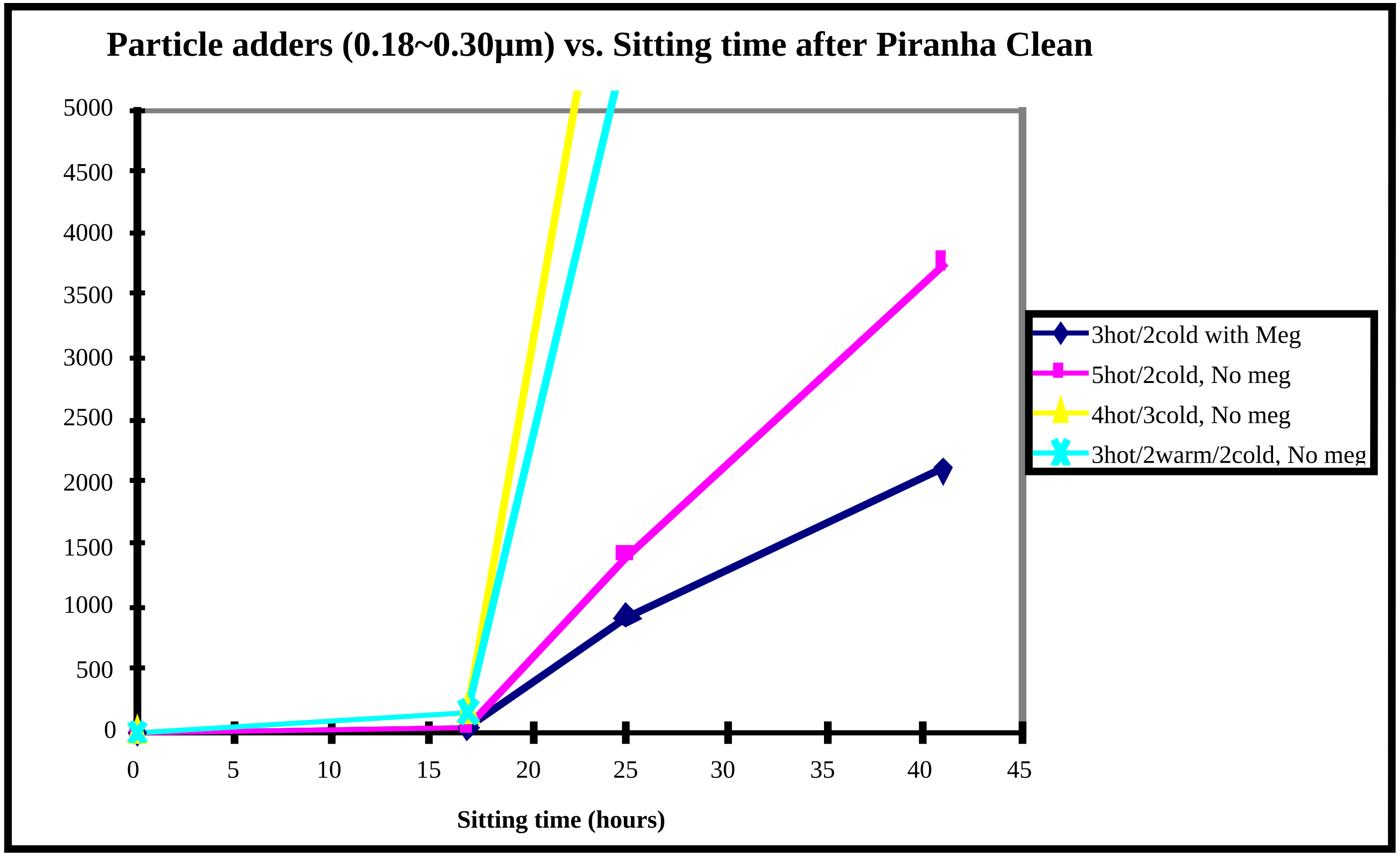
HF Remaining -Bare and Oxide Wafers



Chemical Carryover

- **Rinsing of sulfuric acid is probably the most difficult and water intensive process**
- **Recent work at HP has shown that spray rinsing can be more effective but not all equipment is capable of spray rinsing.**
- **However, this does not address the issue of chemical carryover. Sulfur is the most predominant "impurity" on wafer surfaces.**

Piranha Rinse



Particles will grow on the wafer surface after a Sulfuric-peroxide Clean

Chemical Carryover

- Chemical carryover, for example from a sulfuric acid bath can affect the etch rate of an HF etch

$$HF = H^+ + F^-$$

$$HF + F^- = HF_2^-$$

$$\frac{[H^+]\,[HF_2^-]}{[HF]^2} = 2.7 \times 10^{-3}$$

TOFSIMS RESULTS

50 Wafers were put through an HF process and then rinsed using overflow with either 45 or 90 gallons of water.

	Fluoride	Total Counts
Wafer-Vol		(X 10-6)
Bare Si-90	0.039	1.3
Bare Si-45	0.071	0.76
SiO2-90	0.0059	4.2
SiO2-45	0.0071	4.2
Bare Si-90	0.065	0.56
Bare Si-45	0.059	0.61

Analysis of wafer surfaces after rinse appear to show little dependence on total rinse volume in these experiments

Chemical Utilization

- Chemical processes are typically “inherited”
  A successful start up depends on quickly getting product out the door and that product (and process) is transferred from another fab. This can result in the perpetuation of poor chemical utilization.

- Once product is qualified, process changes become difficult.
  Depending on the perceived level of change, the customer may be notified and the new process may require “burn-in” of product

Process Changes

- **Process changes are typically done to improve product, improve throughput or improve economics of the process (in that general order)**

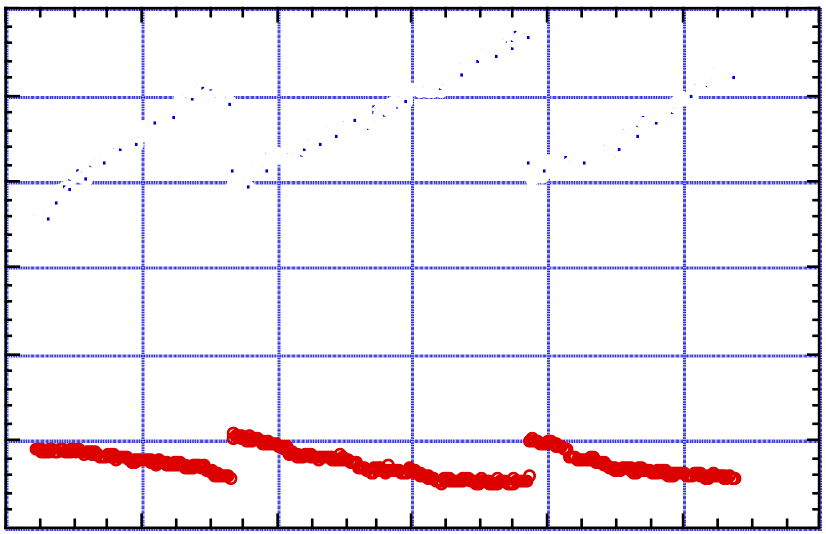
- **Current processes are often based on lower purity chemicals**
  - **Spiking (adding chemicals to the bath on a timed or per lot basis) is done due to previous problems that may have been due to lower purity chemicals**

Bathlife Extension

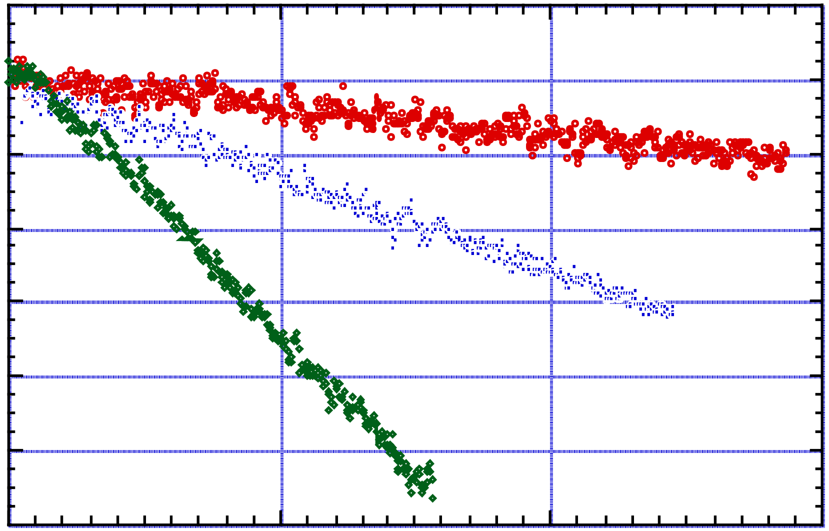
- To increase bathlife, we need to prove that the increased time will not affect product.
- For example, etch rates will not be affected, metal buildup in the bath will not occur or will not end up on the wafer, particle performance will not be affected, etc.
- In addition to improving chemical utilization, bathlife extension will improve throughput.

SC1 Concentration

- **Process using peroxide and ammonium hydroxide spike in equal volumes with 4 hour bathlife**



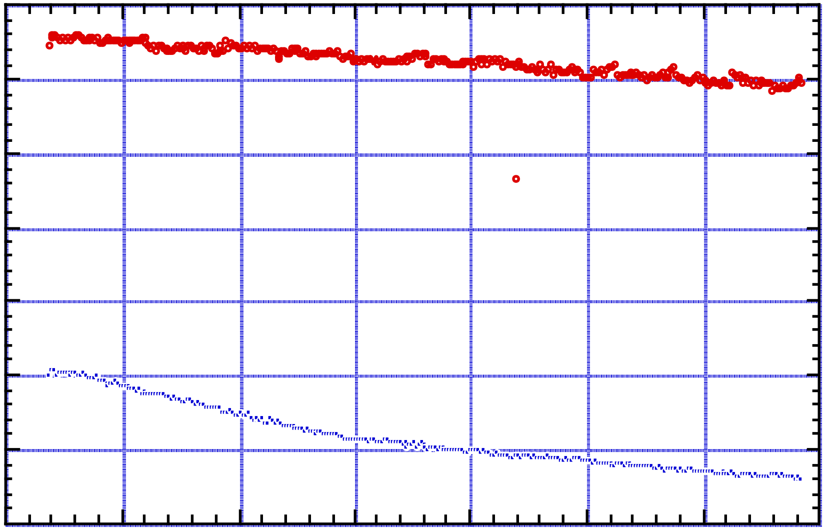
Hydrogen Peroxide Decomposition



- **PPB grade hydrogen peroxide decomposes slowly in solution**

Effect of Wafer Cycling Through Bath

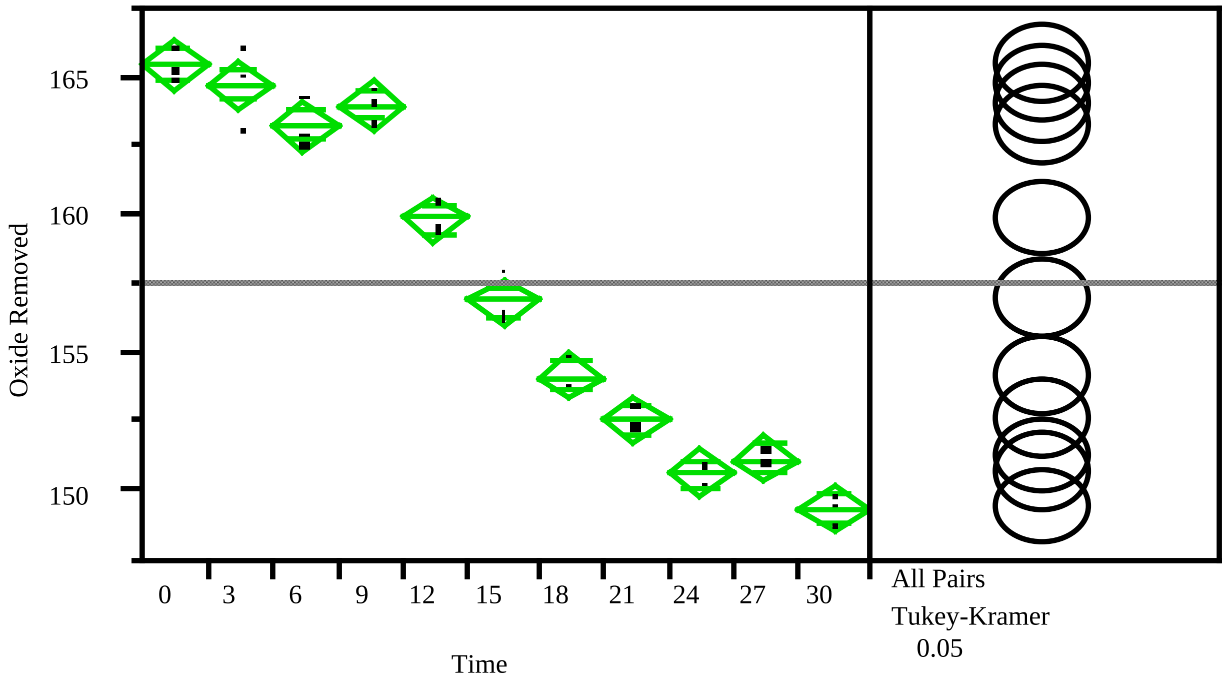
- **Wafer cycling affects only the ammonium hydroxide concentration.**



HF Bathlife Extension

- Dilute HF sloution is used as part of many cleans to remove oxide and the impurities that may be present on the surface of the oxide
- As a dilute solution, the bathlife extension may not be economically important but the throughput improvement can be significant
- $6HF + SiO_2 \rightarrow H_2SiF_6 + 2\ H_2O$

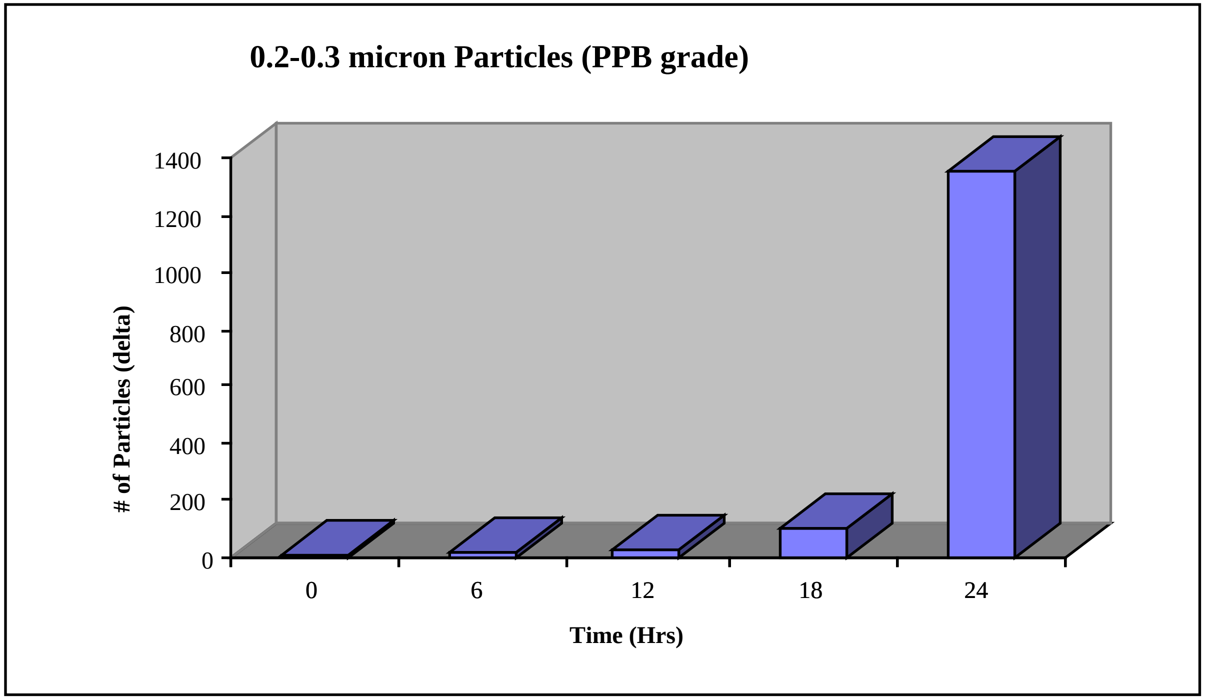
HF Bathlife Extension



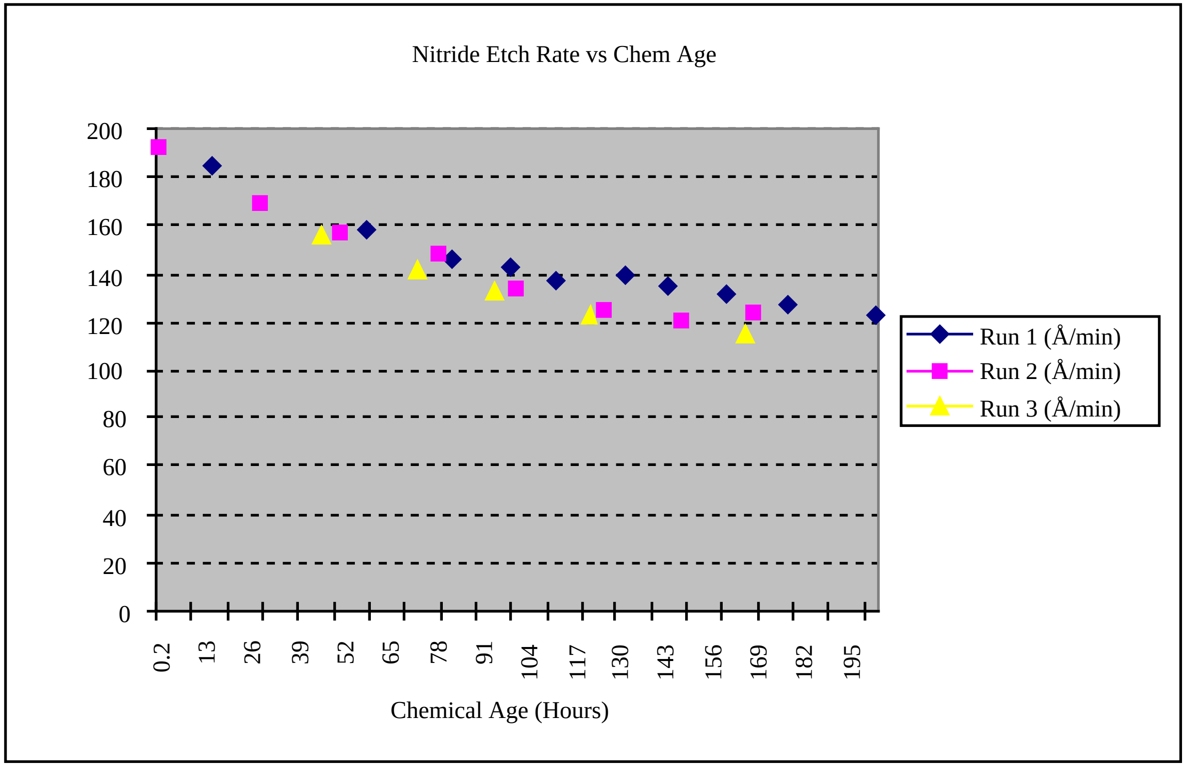
- **Processing wafers through a dilute HF bath causes change in etch rate over time**

Bathlife Extension

- **Phosphoric Acid experiments**



Concentrated HF Bathlife



- **HF is used for removal of Nitride from dummy and test wafers in the fab. Assuming we etch the wafers for a long enough period, no problem should result from using the bath for 1 week**

Bath Filter Life

- Bath filters are a small but significant part of the costs associated with wet processes.
- Use of a high temperature filter according to our original plan was costing us ~$90K per year.
- No information existed about how to decide when a filter should be replaced.
- We are currently analyzing particle data to compare recent data with particle data early in the life of the filter to see if we can see degradation in particle performance.

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