Exhaust Management of Etch Processes

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Overview

- Scrubbing technologies
- Etch processes; reactants and effluent
- Effluent scrubber priorities
- Pumping and abatement - a Systems Approach

There is no one-size-fits-all abatement technology

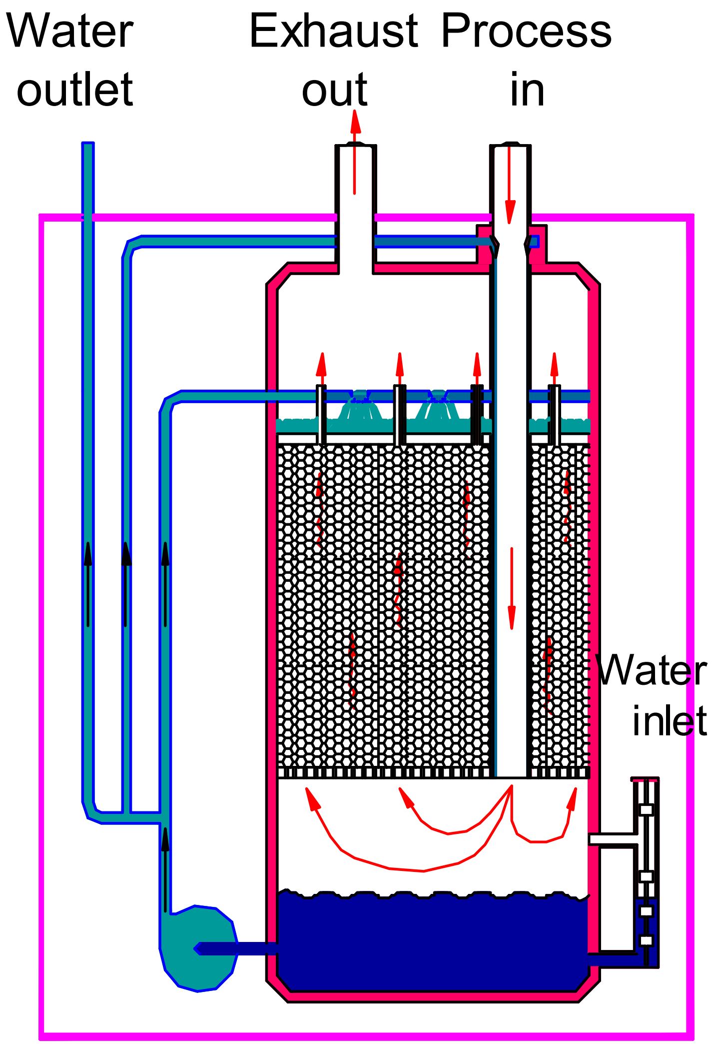
Exhaust Chemistry and Scrubber Technology

Families of Etch Gases

- **Acid gases - HF, HCl, HBr, BCl_3, $AlCl_3$, SiF_4, $COCl_2$, COF_2**
  - Very toxic, can corrode ductwork
  - Water reactive, water soluble
    - Water scrubbers, dry bed scrubbers
- **Corrosive gases (oxidizers) - Cl_2, F_2**
  - Very toxic, can corrode ductwork
  - Water soluble, somewhat water reactive
    - Water scrubbers, dry bed scrubbers, fuel-heated combustors
- **PFC Gases - CF_4, CHF_3, C_4F_8, SF_6**
  - Not generally toxic, not corrosive
  - Global warming gases; not water soluble
    - Dry bed scrubbers (reactive or catalytic), combustors, plasma

Water Scrubbers

- **Countercurrent air flow desired**
  - Air and water are mixed in a tower filled with packing material (air enters bottom and water enters the top)
- **Good N_2 inject design can prevent:**
  - Water backstreaming
    - Subsequent blockages
    - Corrosion
  - Heated inlet required for aluminum etch
- **Handles acid gases, corrosives, and particulates well**
  - PFCs not abated



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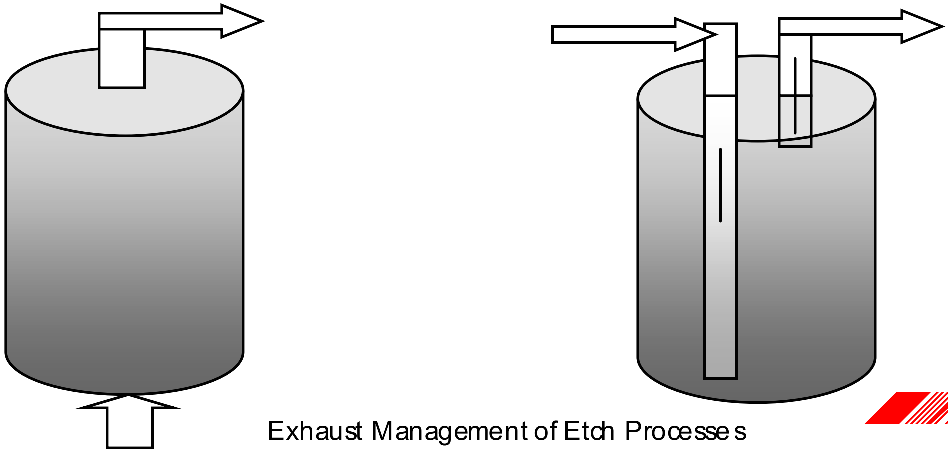
Dry Bed Reactors

- **Granular solid medium in container; gases reacted**
  - Room temperature or elevated
  - Can be consumed (chemisorption) or catalytic for PFCs
- **Different solids required based on process**
  - Optimized for metal etch vs. poly etch vs. oxide etch
- **Endpoint detection required**
  - Tells when medium is consumed
  - Succeptible to maximum gas flows (residence time)
- **Acid gases, corrosives, PFCs (depends on packing)**



Combustors

- **Combustors burn fuel to destroy exhaust gases**
  - Natural gas (methane, CH_4) or H_2
    - Fuel is source of H so halogens, halides can form HF, HCl
  - PFC gases require more effort to burn completely
    - Additional fuel, O_2 may be needed
- **Most combustors have incorporated wet scrubbers**
  - Removal of particulate
  - Removal of acid gases (HF, HCl)
  - Removal of heat
- **Combustors use air**
  - CDA or room air
- **Be wary of side reactions**
  - HBr may form Br_2 at high temperatures - combustors not recommended for poly etch

Plasma Device

- **This plasma device operates in foreline**
  - Uses “forming” gas to complete the reaction
    - H_2O, H_2/O_2, CH_4
  - Atmospheric plasma also available
- **High levels of destruction for PFCs**
  - 95 - 99% DREs for all PFCs
  - Conversion to HF, CO, COF_2, CO_2
  - Breakdown products cannot be eliminated
    - POU required

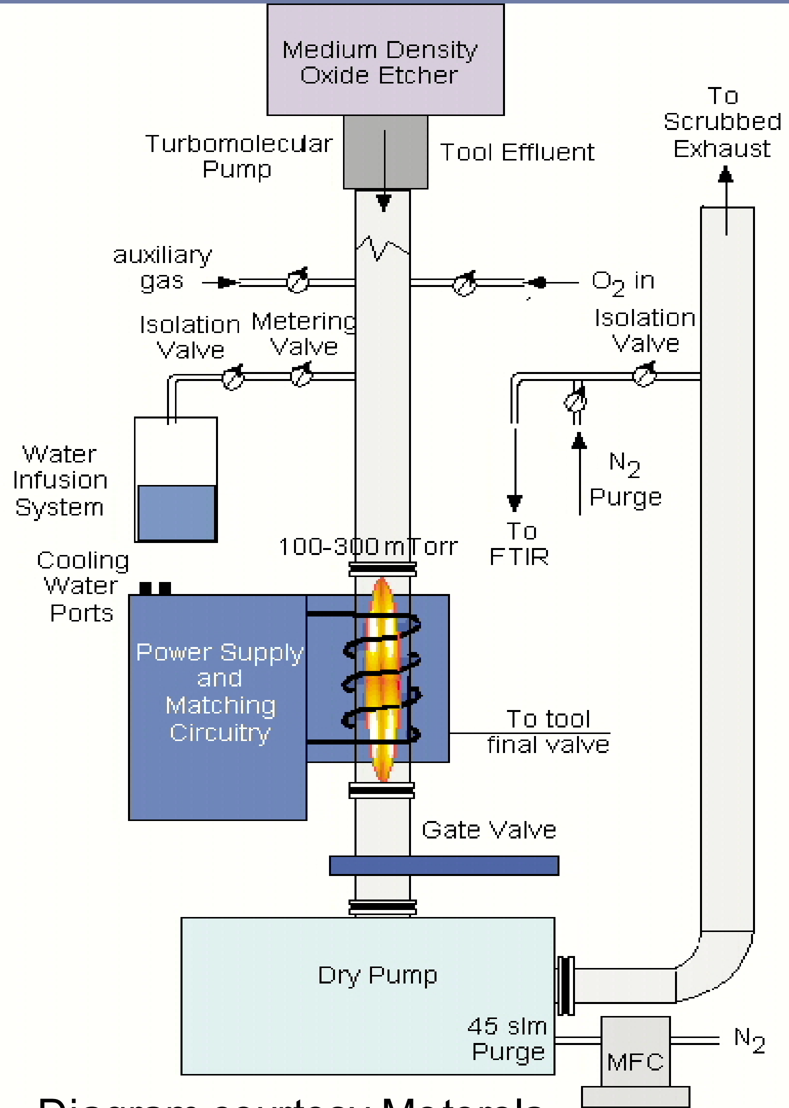


Diagram courtesy Motorola

See Sematech report 99123865A-ENG

Dielectric Etch

Input Gases:
CF_4, HBr, NF_3, Cl_2, C_4F_8, SF_6, CHF_3, & O_2

→ **Tool** →

Output Gases:
Input gases

+

Byproducts:
SiF_4, $SiBr_4$, $SiCl_4$, HF, HCl & HBr

- Safety: Cl_2 is toxic (TLV=1 ppm) and an irritant; byproducts are acidic with TLVs levels below 5 ppm. SiX_4 will block ducts, generate HX (X = F, Cl, Br)
- Environmental: byproducts are acid gases, CF_4 is global warmer
- Downtime: routine pm; relatively clean process (maintenance low)

Dielectric Etch

- **Water Scrubber**
  - Will remove acid gases and most Cl_2
  - Will not remove SF_6, CF_4, CHF_3 …
- **Combust / scrub**
  - All the gases and byproducts will be combusted into non toxic chemicals and scrubbed from exhaust
- **Cold Absorbers / Hot bed Reactor**
  - Ensure not only the input gases but the byproducts are also abated.
- **Plasma PFC abatement**
  - Ensure the abatement device does not generate other hazardous compounds

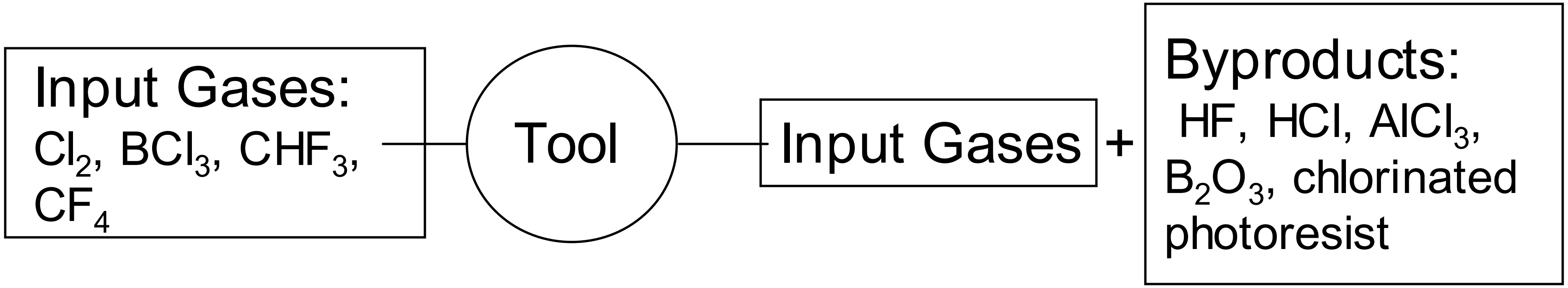
Dielectric Etch

- Input: CF_4, HBr, CHF_3, SF_6, Cl_2, HCl, NF_3, C_4F_8
- Output: Process gases, HX*, $SiX*_4$

	CF_4	HX*	CHF_3	Cl_2	SF_6	NF_3	C_4F_8	$SiX*_4$
Water	N	Y	N	Y	N	N	N	Y
Burn	?	N**	Y	?	Y	Y	Y	Y
Cold Bed	N	Y	N	Y	N	N	N	Y
Hot Bed	?	Y	Y	Y	Y	Y	Y	Y
Plasma	Y	N	Y	N	Y	Y	Y	N
Burn/ Scrub	?	Y**	Y	?	Y	Y	Y	Y

*The "X" in SiX_4 and HX refers to F (fluorine), Cl (chlorine), or Br (bromine).
**HBr dissociates to Br_2 in combustors - not removed by scrubbers.

Metal Etch



- **Safety: Cl_2 is toxic (TLV=1 ppm) and an irritant; chlorinated photoresist is teratogen, carcinogen**
- **Environmental: byproducts are acid gases, CF_4 is global warmer**
- **Downtime: $AlCl_3$ & BCl_3 will form solids in contact with moisture - may cause blockages. $AlCl_3$ sublimes below 100° C and is notorious for duct blockages after the pump. Heat trace required.**

Metal Etch

Pumping: Run pump hot to keep acid gases in gaseous form.

The exhaust line <u>must be heated</u> to keep $AlCl_3$ from condensing.

- **Water Scrubber**
  - Removes acid gases and condensible byproducts
  - Will not remove SF_6, CF_4, & CHF_3
  - Chlorinated photoresist is not water-soluble.
- **Combustion**
  - Electrically heated tube not recommended for Cl_2; may form ClO_2
  - Combustion must be done with excess H (fuel) to form HCl.
  - Chlorinated photoresist may form chlorinated dioxins if not combusted thoroughly.
- **Hot bed dry reactor works well.**
  - CoO may be high
- **Trapping of $AlCl_3$ NOT recommended !!!**

Metal Etch

- Input: Cl_2, BCl_3, CHF_3, CF_4
- Output: Process gases, $AlCl_3$*, chlorinated photoresist CP), HF, HCl

	Cl_2	BCl_3	CHF_3	$AlCl_3$	CF_4	CP	HF	HCl
Hot Bed	Y	Y	Y	Y	?	Y	Y	Y
Water	Y	Y	N	Y	N	N	Y	Y
Burn	?	?	Y	N	?	?	N	N
Cold Bed	Y	Y	N	Y	N	N	Y	Y
Burn/ Scrub	?	Y	Y	Y	?	Y	Y	Y

*$AlCl_3$ condenses out as a solid after the pump and requires heat trace to prevent blockages. DO NOT COLLECT.

Prioritizing Effluents

It is the responsibility of the customer to select appropriate abatement:

- **Some considerations:**
  - Dilute or remove flammable gases to avoid fires
  - Remove solids to prevent blockages
  - Remove acid gases to prevent corrosion
  - Consideration to municipal regulations
  - Remove gases to below IDLH
    - IDLH (Immediately Dangerous to Life and Health level)
  - Remove gases to below TLV
    - TLV (Threshold Limit Value)
  - Remove all gases including non hazardous but environmentally damaging gases e.g. PFCs

CapEx protection

Safety-driven

- **Technology to use will be decided by performance level needed**

Prioritizing Effluents

Priority usually based on production demands:

❶ **Prevent duct blockages (mostly metal etch)**
- Heated pipework moves $AlCl_3$ to POU abatement
  - Water scrubber, dry scrubber

❷ **Prevent duct corrosion (acids, corrosives)**
- HCl, HF, BCl_3, COF_2, Cl_2
  - Water scrubber, dry scrubber

❸ **Abate PFCs, global warmers**
- CF_4, SF_6, CHF_3, C_4F_8
  - Plasma, combustion, dry bed (catalytic)

A Look into the Future

International Technology Roadmap for Semiconductors (ITRS)

- **ITRS guides semiconductor industry into future**
  - Many details - from photolithogrraphy, geometry, and low k, to facilities usage and installation of new equipment

- **Utility Reduction - power**
  - 50% reduction in 300mm production fab equipment energy consumption compared to 1999 200mm value by 2003
    - Per square inch of silicon

Year of Production	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
	130nm	*115nm*	*100nm*	*90nm*	*80nm*	*70nm*	*65nm*
Chemicals,Materials and Equipment Management Technology Requirements							
Energy Consumption							
Overall fab equipment (KWh/cm2)	0.5-0.7		0.4-0.5		0.4-0.3		
Fab facility (kWh/cm2)	0.5-0.7		0.4-0.5		0.4-0.3		
Tool energy usage per wafer pass (300mm vs 200mm); baseline 1999	1.5				1.0		

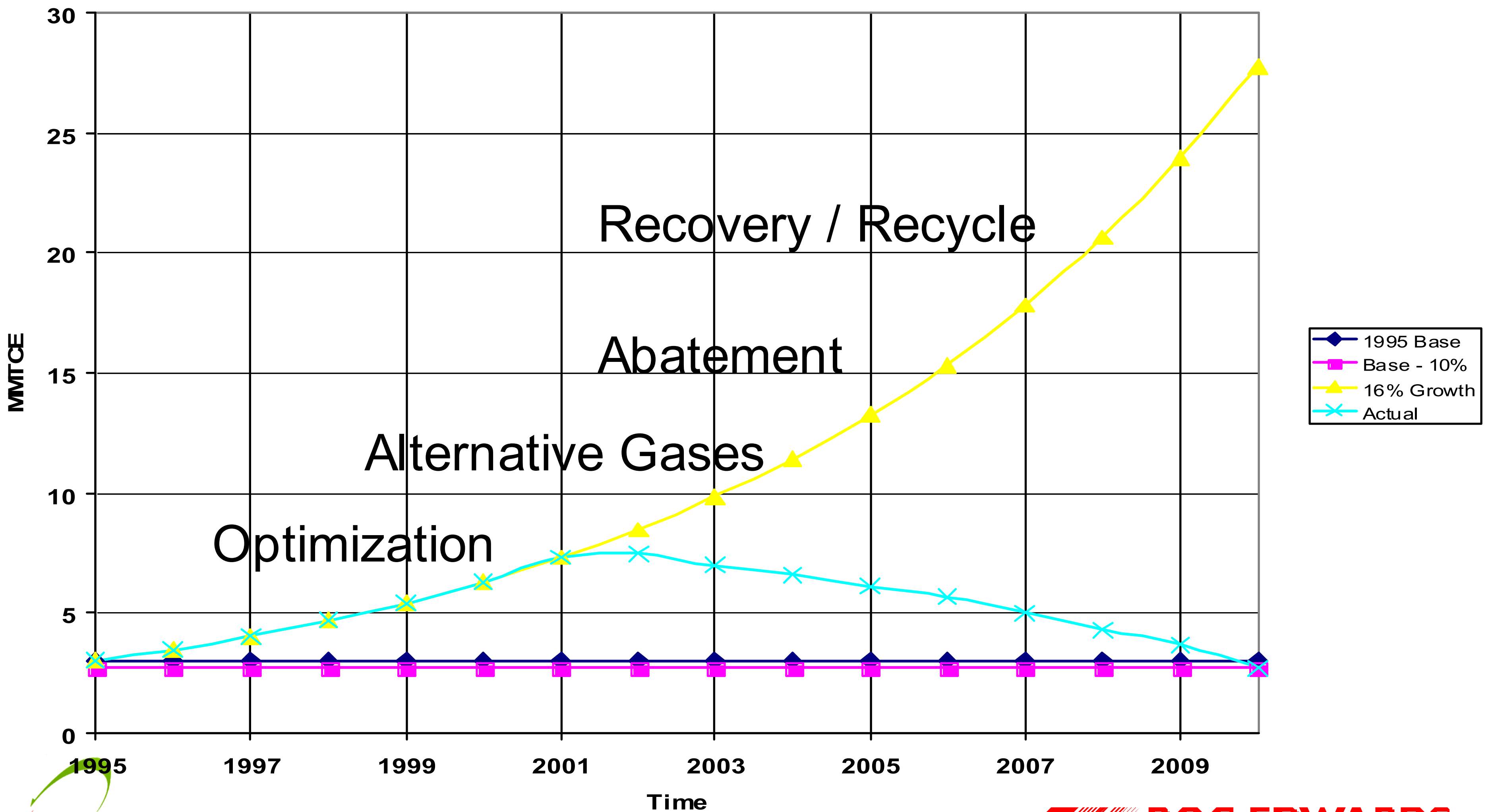
ITRS Driving Forces

- **Utility reduction – water**
  - Aim for 5% water usage reduction per year

Year of First Product Shipment Technology Generation	*1997 250 nm*	*1999 180 nm*	*2003 130 nm*	*2006 100 nm*	*2009 70 nm*	*2012 50 nm*
Decrease net feed water use, gal / in ^{2} silicon	30	10	6	5	2	2
Decrease UPW* use (gal / in^2 silicon)	22	10	7	6	5	5
Lower water purification cost	X	90% X	80% X	70% X	60% X	50% X

ITRS Driving Forces

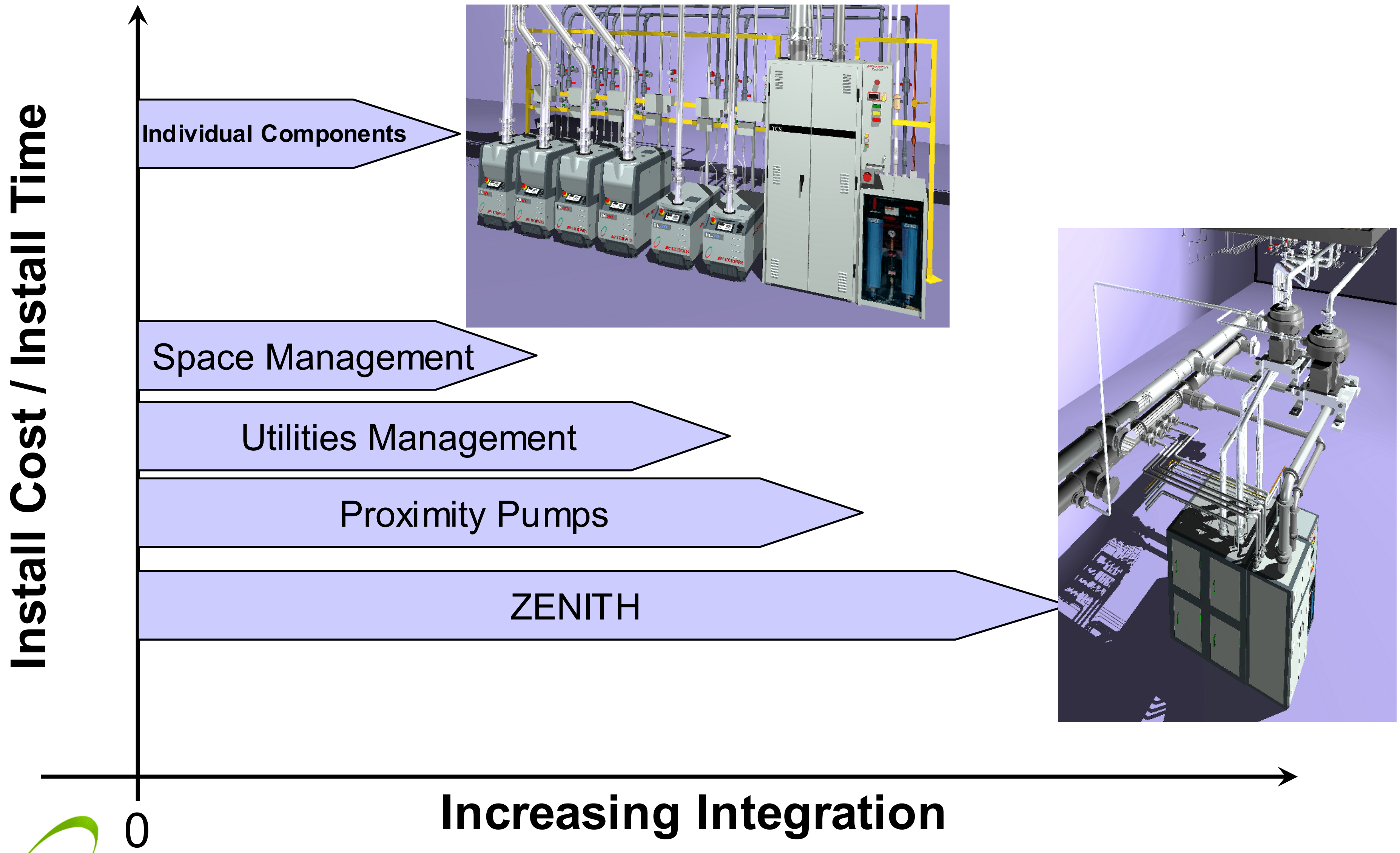
- **PFC reduction to <90% 1995 value by 2010**



ITRS: Integration of Pumps and Abatement

- **Combine vacuum pumps and with scrubbers in single system**
  - Engineered to work together “out of the box”
- **Operational Benefits**
  - Wafer Security
  - Reduced COO
  - Fewer Components, less servicing
- **Safety**
  - Risk Minimisation/ Transfer
  - SEMI Certification
- **Installation Cost Savings**
  - Space Saving
  - Time/ Cost/ Ease of install
  - Single Vendor
- **Integration concept known as ZENITH**

Integration Detail



Minimized Footprint

- **Equipment footprint reduced by 44%**
  - vs. Individual components
- **Required service footprint reduced by 68%**

	Individual compon-ents	**Zenith & Proximity Pumps**
Footprint Reduction	4.45m²	2.47m³ 44%
Service Footprint Reduction	7.26m²	2.34m³ 68%

Reduced Utility Hook-ups

- **Save 60% on utilities connections**

	Individual compon-ents	Zenith & Proximity Pumps
PCW Supply	7	1
PCW Return	7	1
Nitrogen	5	1
Power	7	1
Fuel	1	1
Make up water	1	1
Acid Drain	1	1
Oxygen	1	1
Vac-EMS Hookup	4	0
Bypass Hookup	4	4
Sub Wafer Forelines	6	4
F15 Extraction	0	1
Acid Extract	1	1
Total	45	18
Reduction		60%

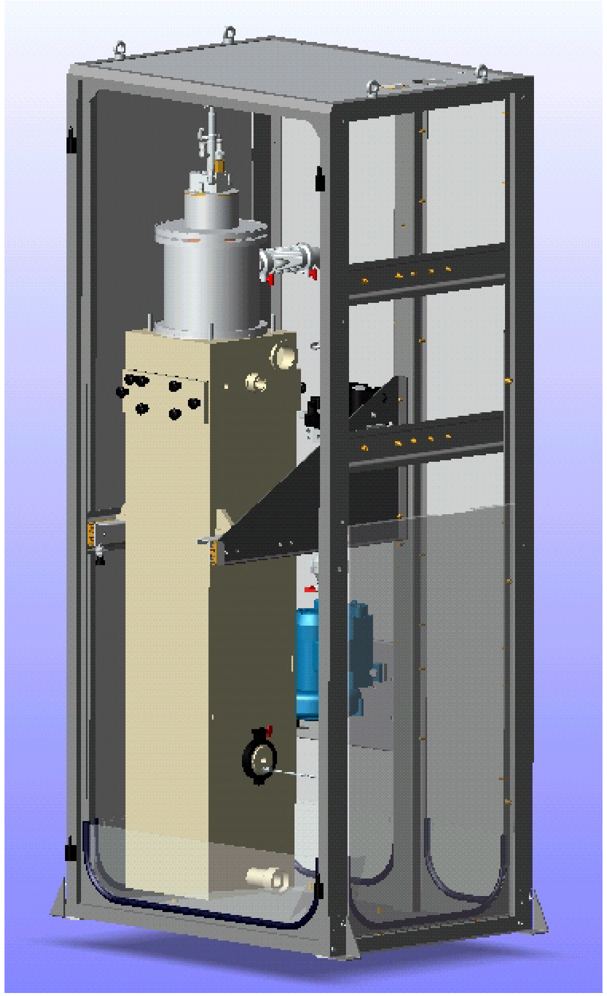
Safety and Reduced Risk

- **Zenith is tested and built to the following standards:**

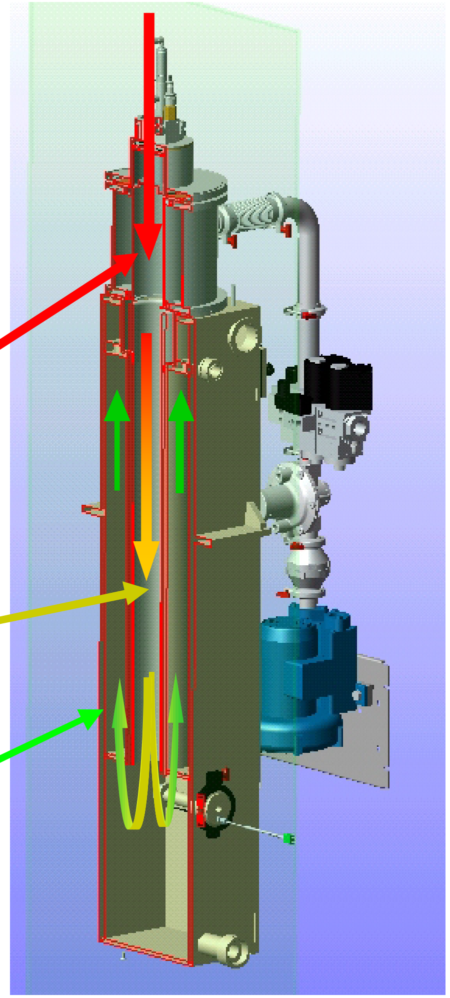
  - **SEMI Standards**
    SEMI S2-0302 (EHS)
    SEMI S8-0701 (Ergonomics)
    SEMI S14-0200 (Fire risk mitigation)
    SEMI F15-93 (Leak testing)

  - **CE Legislation and Standards**
    Machine directive 98/37/EC
    Low voltage directive 73/23/EEC
    EMC directive 89/336/EEC
    Potential explosive atmosphere directive 94/9/EC - ATEX
    Electrical safety laboratory measurement EN61010-1
    EMC Emissions/immunity EN61326

Mini – TPU For Etch Processes

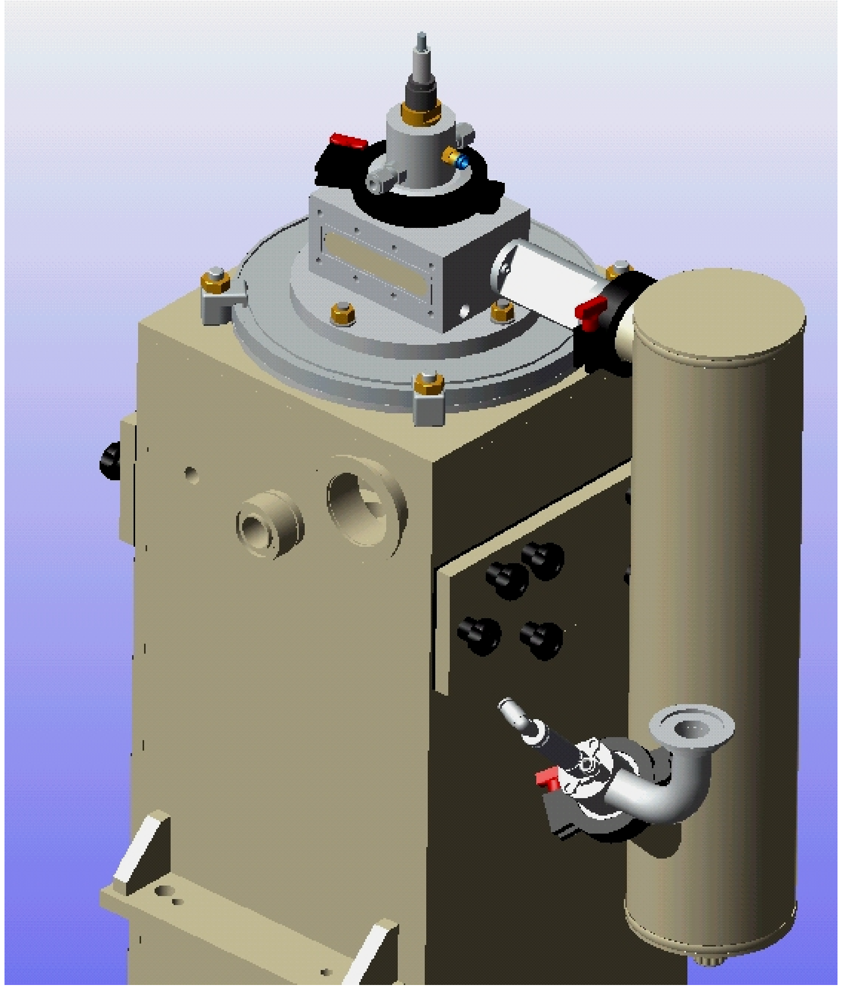


- **Smaller, more economical unit for etch processes**
  - Proven Inward fired combustion
  - New compact wet scrubber
- Reduced fuel consumption
- Quench zone for cooling
- Scrubber to remove HAPs



Atmospheric Plasma - Ionis

- **2.45 GHz Microwave**
  - Compressed high density electric field
- **Inducement of a stable plasma**
- **Suitable chemical environment for the destruction of PFC gases**

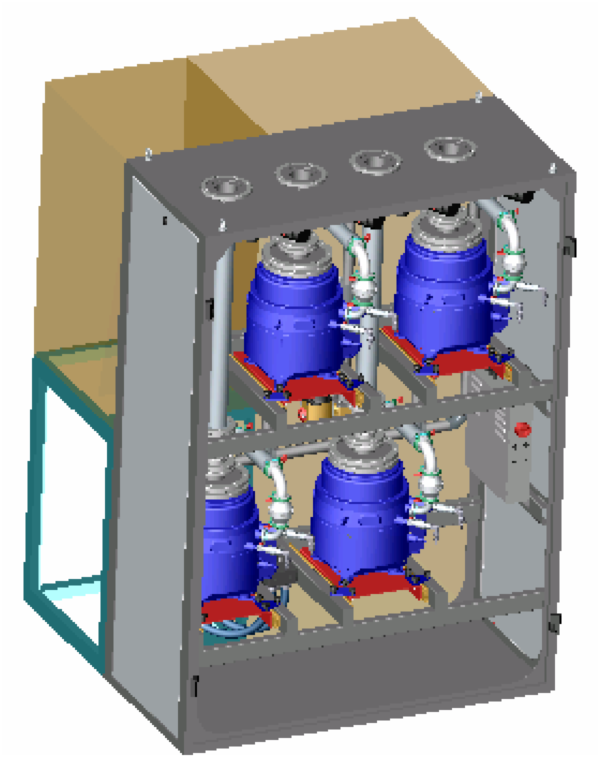


EPX – Dry Pumps

- **EPX500P**
  - Peak Speed – 500 m3h-1
  - Atmospheric – 10^{-6} mbar
- **Purge gas flow**
- **Only 1.4 kW power at Ultimate**
- **600W idle mode**

Zenith Etch Development Roadmap

- Incorporation of miniature TPU (CF_4 DRE > 90%) or Ionis atmospheric plasma (CF_4 DRE > 90%) into cabinet with EPX pumps
- Footprint ~ 1m X 2m for scrubber and 4 pumps
- Single electrical, N_2, water, PCW, and exhaust drops



Summary

- **Etch exhaust byproducts contain corrosives and PFCs**
- **Some abatement technologies don't remove all the exhaust gases**
  - This is for the customer to decide
- **ITRS is driving towards integration of pumps and abatement**
  - Smaller footprint, better CoO, lower utilites demand
- **Etch-specific technologies are available to address ITRS guidelines**