Copper CMP Effluent Flow in a Semiconductor Facility

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Outline

- A simple facility model
  - Assumptions
  - Flows
- A simple model slurry
- Copper flows
  - Results
  - Copper Discharge Regulations

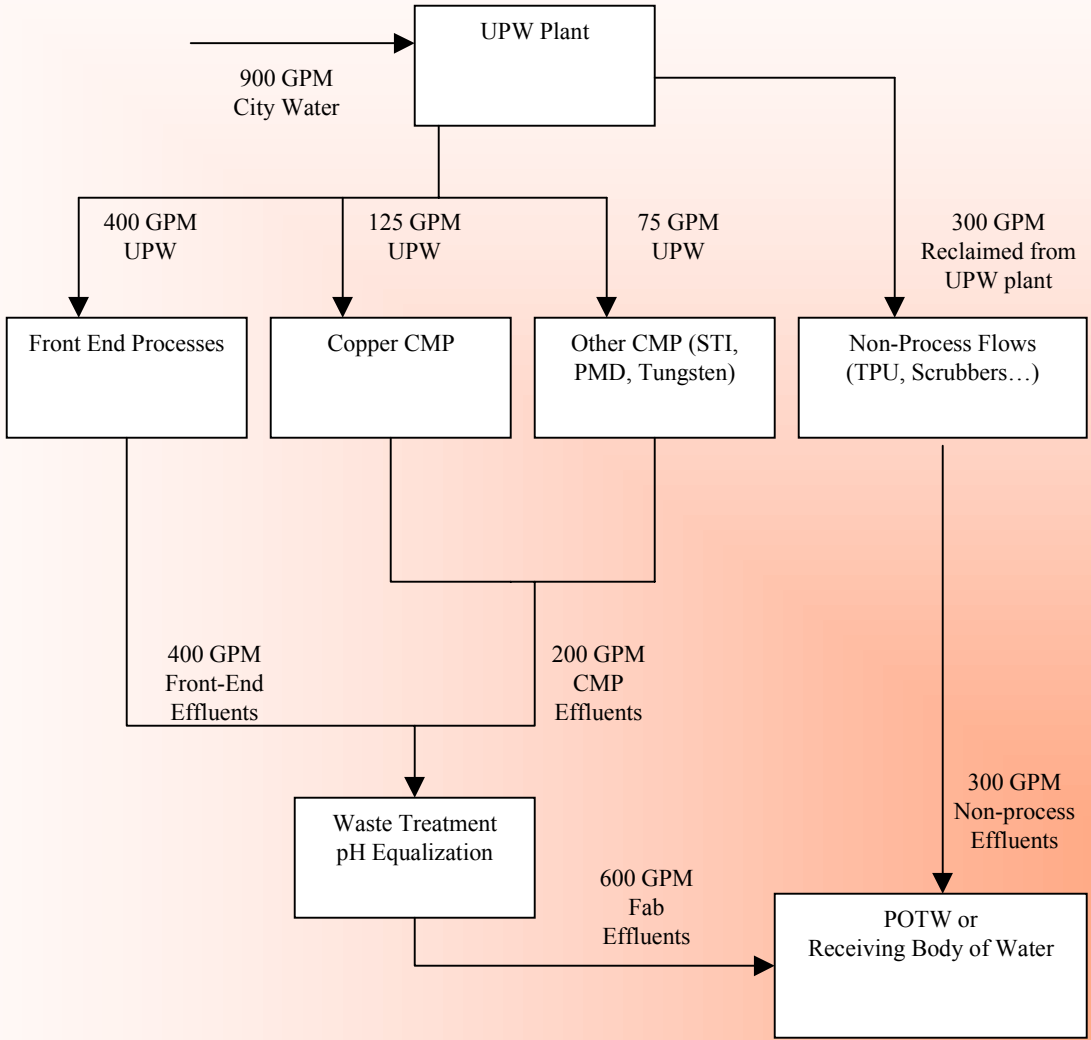
A simple facility model - Assumptions

- 6 300 8-inch wafers per week
- 900 GPM city water flow
  - 600 GPM UPW
    - 400 GPM Front-End
    - 200 CMP
  - 300 GPM non UPW (reclaim) for non-process
- Microprocessor
  - 5 copper CMP steps (1 micron removed per step)
  - 3 non-copper CMP steps (STI, PMD, Tungsten)

A simple facility model - Assumptions

- Equipment
  - 20 dry-in / dry-out machines
  - 10 GPM constant flow per machine (copper and non-copper)
  - 40% idle time
  - Throughput 25 wafers / hr
  - 2 GPM process flow, 8 GPM non-process + post-CMP clean
  - Slurry flow 200 ml /min
  - Process time 2.5 min / layer

A simple facility model - Flows



A simple model slurry (1)

- Copper polish step

Chemical	Dosage	Function
Acid for pH-control Citric acid	**$2.2.10^{-4}$ M** pH around 3.5	Keep pH at the desired level throughout the CMP operation
Oxidizer Hydrogen peroxide Iodate Hydroxylamine	**5 % vol H_2O_2** An optimal value exists. Several % is a typical value	Oxidize copper since copper oxide is more readily polished away by the abrasive particles than copper itself
Abrasive particles Alumina, 200 nm	**5 % wt** 3 – 7 % wt	Abrasion of the copper oxide layer
Surfactants	Depending on micelle size	To keep the abrasive particles suspended
Complexing agent EDTA, EDA, Citrate	**9.10^{-3} M** Appropriate amount to complex copper at removal location	To allow for larger quantities of dissolved copper carried away by the spent slurry flow
Corrosion inhibitor Benzotriazole (BTA)		To avoid unwanted corrosion of copper

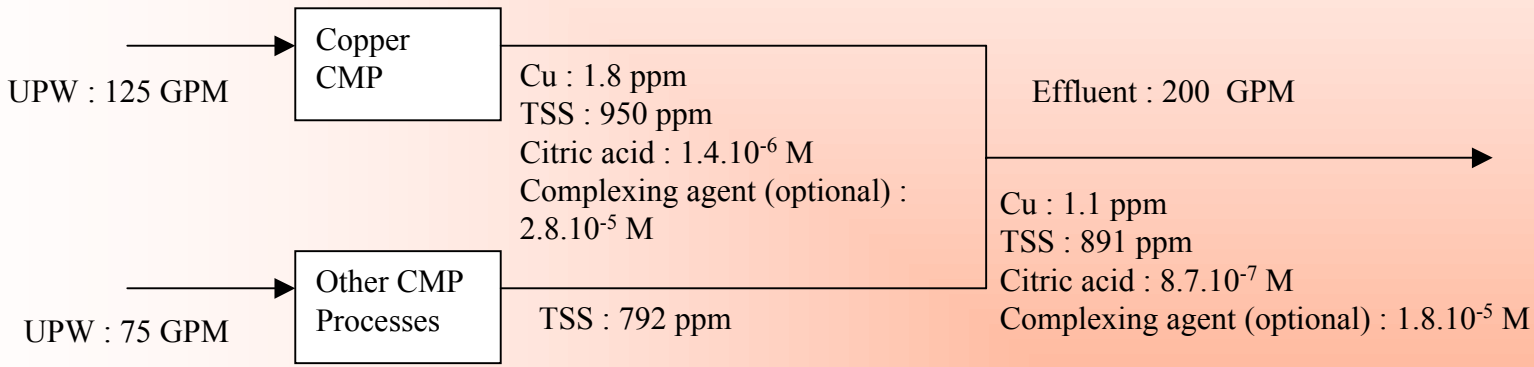
- (1) Based on Pr Raghavan's work. See for example the proceedings 'Fundamentals of CMP', NSF/SRC ERC for Environmentally Benign Semiconductor Manufacturing / Sematech, Nov 15-16 1999

A simple model slurry

- Other steps
  - Ta/TaN
    - Colloidal silica slurry (50 nm)
    - pH = 3.5 maintained by citric acid
  - Oxide, STI
    - Colloidal silica slurry (50 nm)
    - pH 11.5
  - Tungsten
    - Colloidal silica slurry (50 nm)
    - pH = 3.5

Copper flows

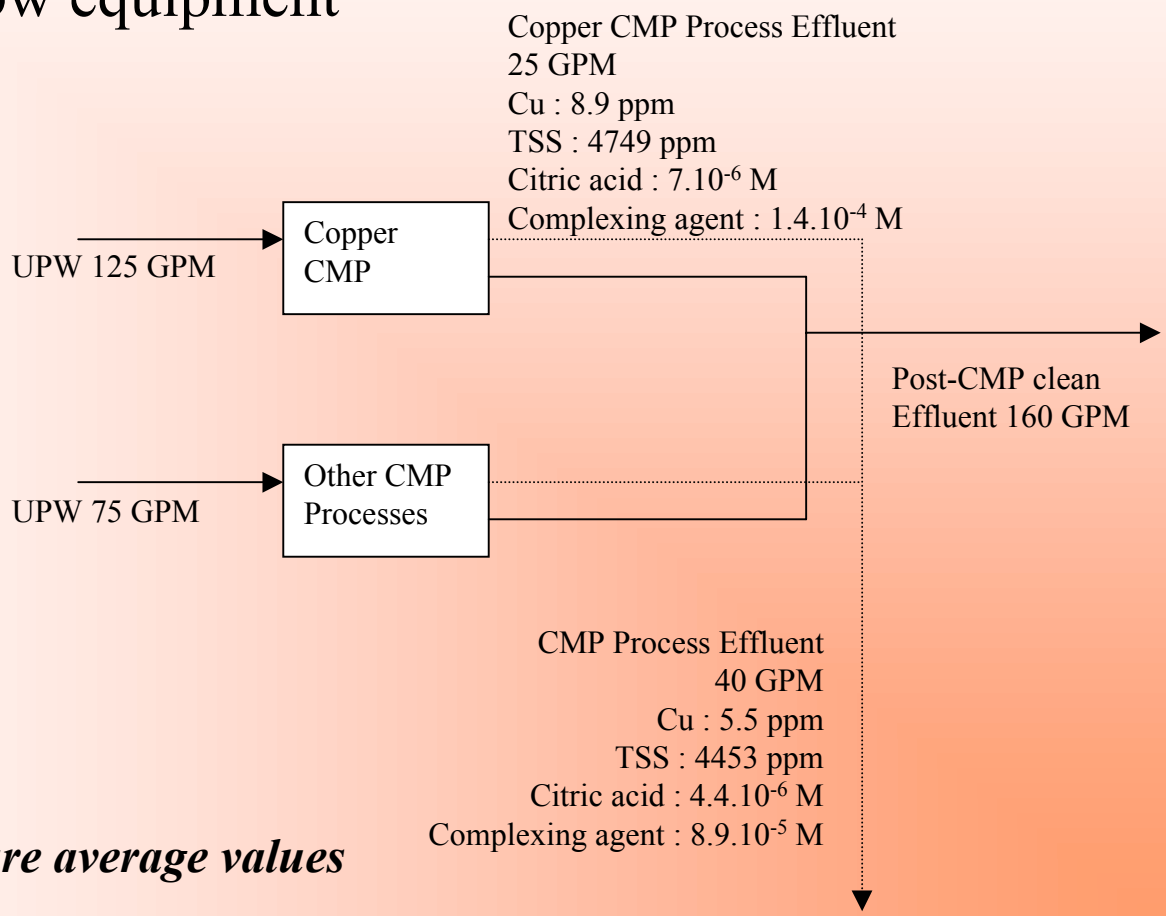
- Mixed flow equipment



- ***Note : All values are average values***

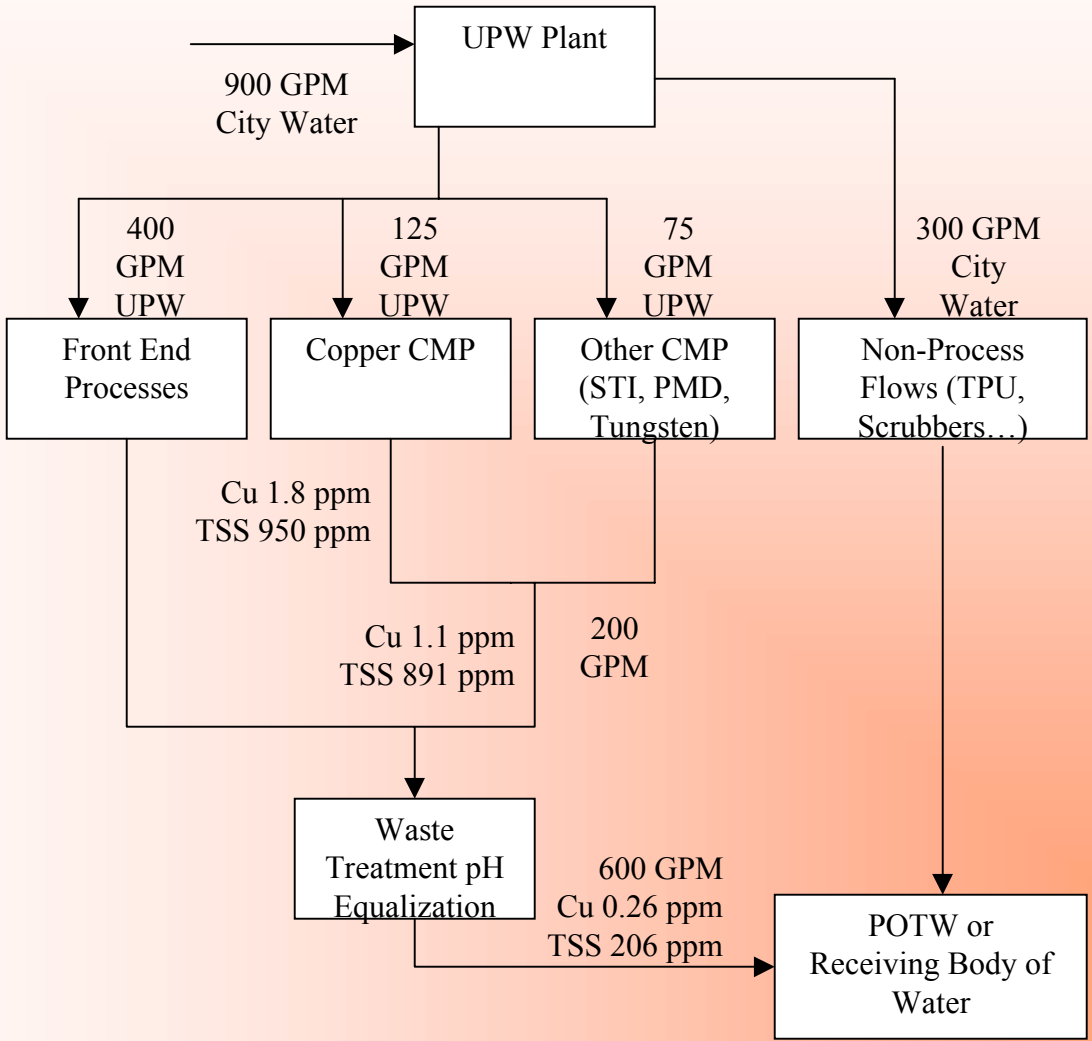
Copper flows

- Segregated flow equipment



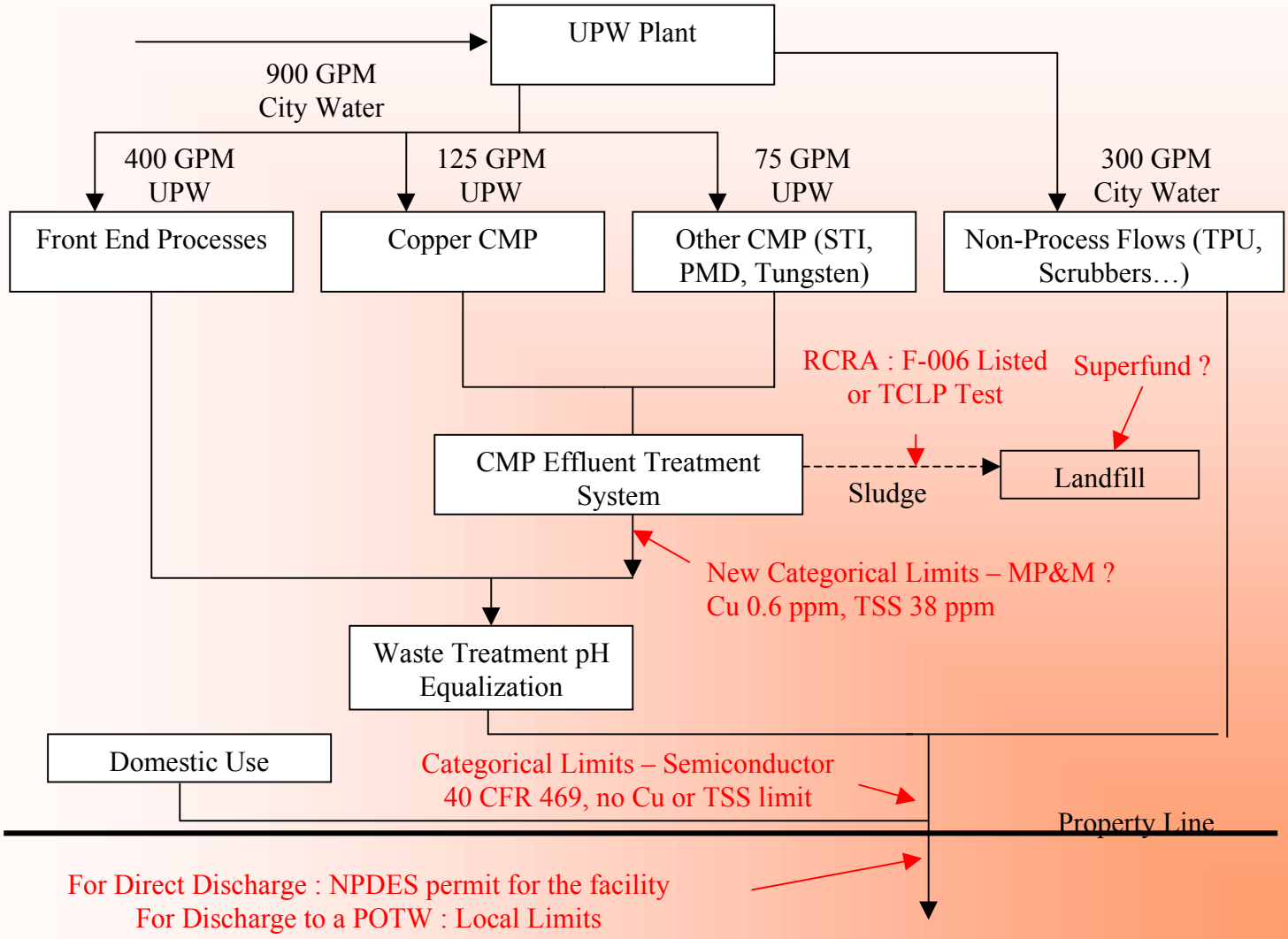
- ***Note : All values are average values***

Copper Flows



Per Day :
1.26 Kg of Copper
1 ton of sludge (dry-weight basis)

Copper Discharge Regulations



Copper Discharge Regulations

	Capacity / Average Flow MGD (1)	Water Quality Criteria for copper (µg/l or ppb)	POTW dilution credit	POTW discharge limit	POTW annual discharge limit	Industrial discharge local limit for copper
Deer Island, MA	1080 / 370	4.8 µg/l (acute) 3.1µg/l (chronic)	70:1	none	none	1.5 mg/l (2)
Clinton, MA	3 / 2.4	3.9 µg/l (acute) 2.7µg/l (chronic)	1:1	6.0µg/l (max) (3) 4.6µg/l (average) (3)	none	1.5 mg/l (4)
Austin, TX Walnut Creek	60 / 42			10 µg/l		1.9 mg/l
Sunnyvale, CA	29.5 / 15		none	8.6 µg/l (5)	715 lbs	0.7 mg/l (6) 0.5 mg/l (7)

Table 2.9 : Local Limits at several POTWs

(1) MGD = Million Gallons per Day

(2) Under revision, will probably be 1.0 mg/l

(3) Expected, currently under discussion

(4) Under revision, will probably be 1.0 mg/l or lower

(5) 1-Day Average

(6) Maximum Concentration, 'Grab' Sample

(7) Maximum Concentration, Composite Sample

Copper Discharge Regulation
Main Issues

- Is sludge from copper CMP classified F-006 Hazardous ?
- Effluent concentrations are OK for *indirect* discharge but
  - local limits may decrease when copper goes mainstream because of mass load limitation at the POTW
    - Reduced bio-treatment efficiency
    - Increased copper in POTW sludge
    - Increased copper in POTW effluents (limit usually low (< 10 µg/l) for river discharge)
- Effluent concentration should be too high for *direct* discharge and treatment is necessary

The Next Step

- Model speciation of copper (dissolved, adsorbed, complexed) at the various stages of the process
- Compare models with tests on real effluents
- Test copper speciation after mixing with freshwater or wastewater
- Assess potential hazards to POTWs and the Environment