CMP Waste Treatment: Electrophoretic Cross-Flow Filtration

(Subtask A4-1)

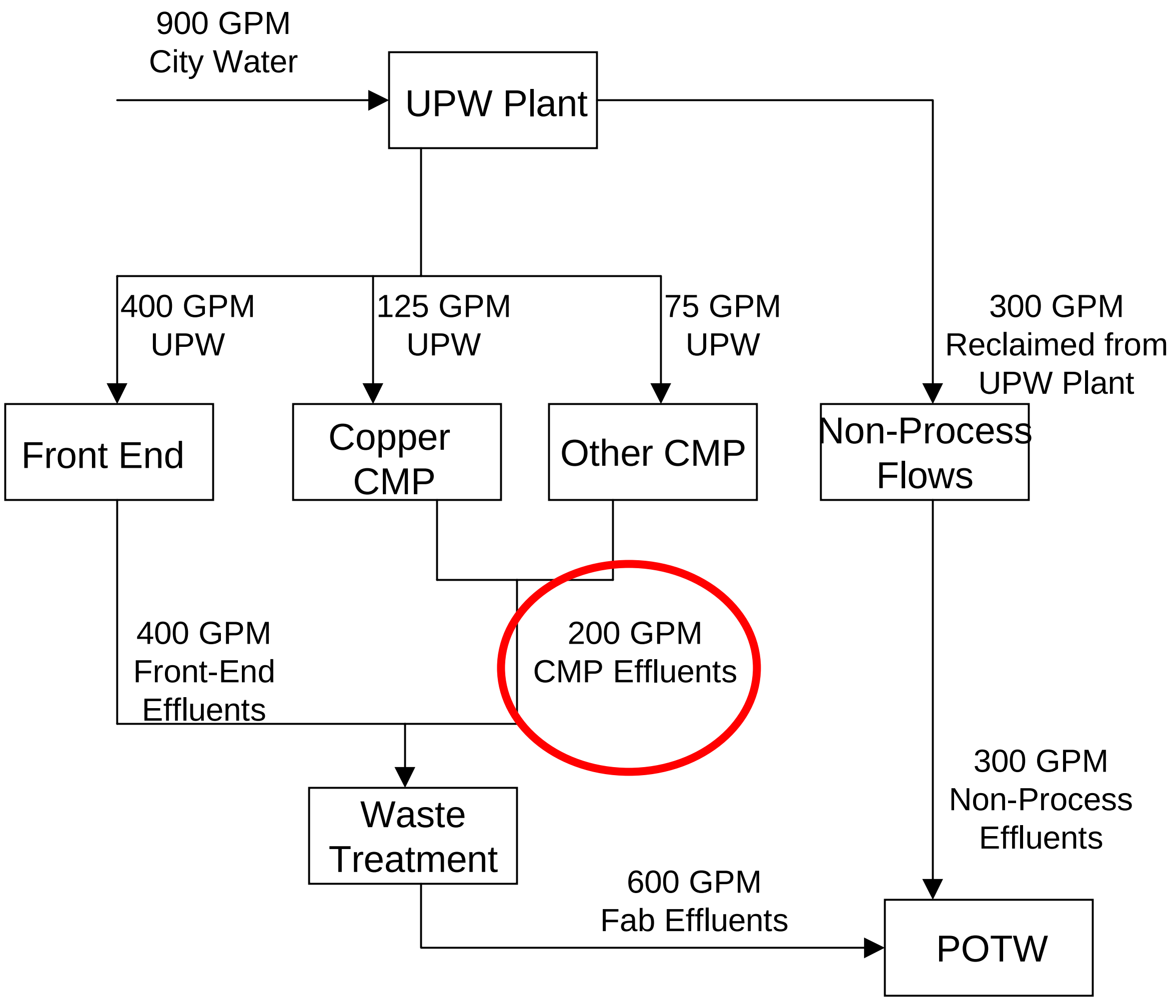
Jamie L. Ludke	Chemical and Environmental Engineering
Paul A. Safier	Chemical and Environmental Engineering
Milan Bier	Chemical and Environmental Engineering
James C. Baygents	Chemical and Environmental Engineering
Srini Raghavan	Materials Science and Engineering

The University of Arizona

Outline

- Significance of CMP waste problem
- Principles of electrophoretic cross-flow filtration
- Illustration of apparatus
- Electrophoretic filtration of silica suspensions
- Electrophoretic filtration of dissolved copper
- Power consumption of electrophoretic filtration
- Summary of results and future work

Significance of CMP Waste Problem



Single fabrication plant produces 200 GPM of CMP effluent†

† Maag, Benoit, "Copper CMP Effluent Flow in a Semiconductor Facility", ERC TeleSeminar, April 6, 2000

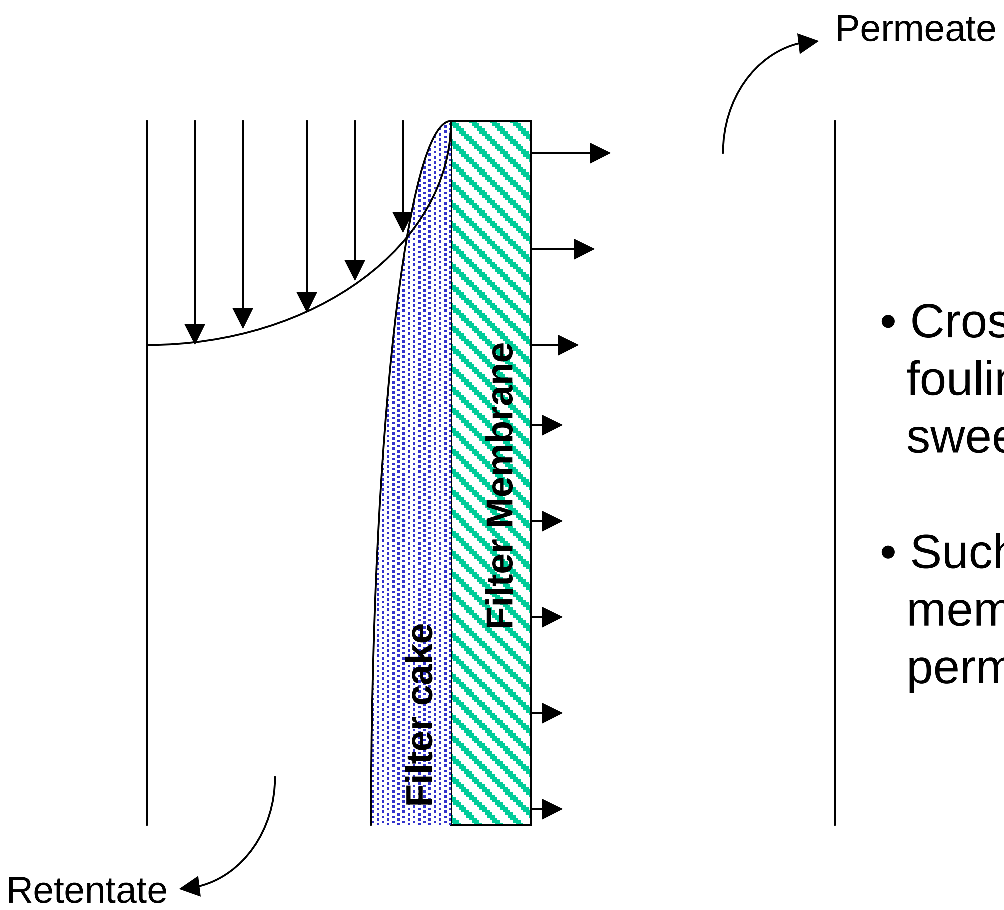
Waste Characteristics versus Environmental Regulations

- Effluent contains approximately 500-5000 ppm TSS and 5-50 ppm Cu‡
- Environmental regulations require that effluent be reduced to <5 ppm TSS and 0.1-2 ppm Cu before it may be discharged to waste treatment system‡

‡ Task A-4 Fourth Year Annual Report, Vol. 2, NSF/SRC Eng. Research Center, January 7, 2000.

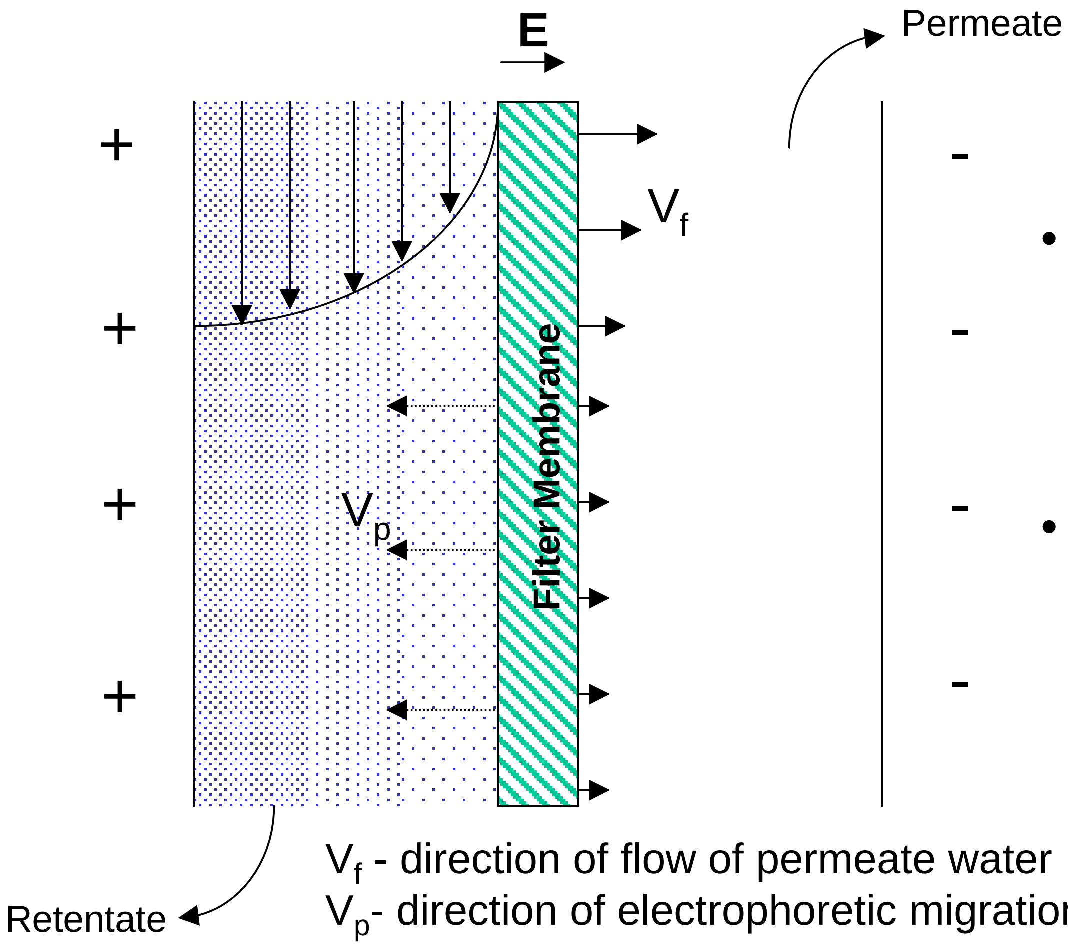
Principles of Electrophoretic Cross-Flow Filtration

Cross-Flow Filtration



- Cross-Flow Filtration reduces membrane fouling (filter cake build-up) by continuously sweeping the membrane surface.
- Such action extends the life of the membrane and helps sustain flow of permeate through the membrane.

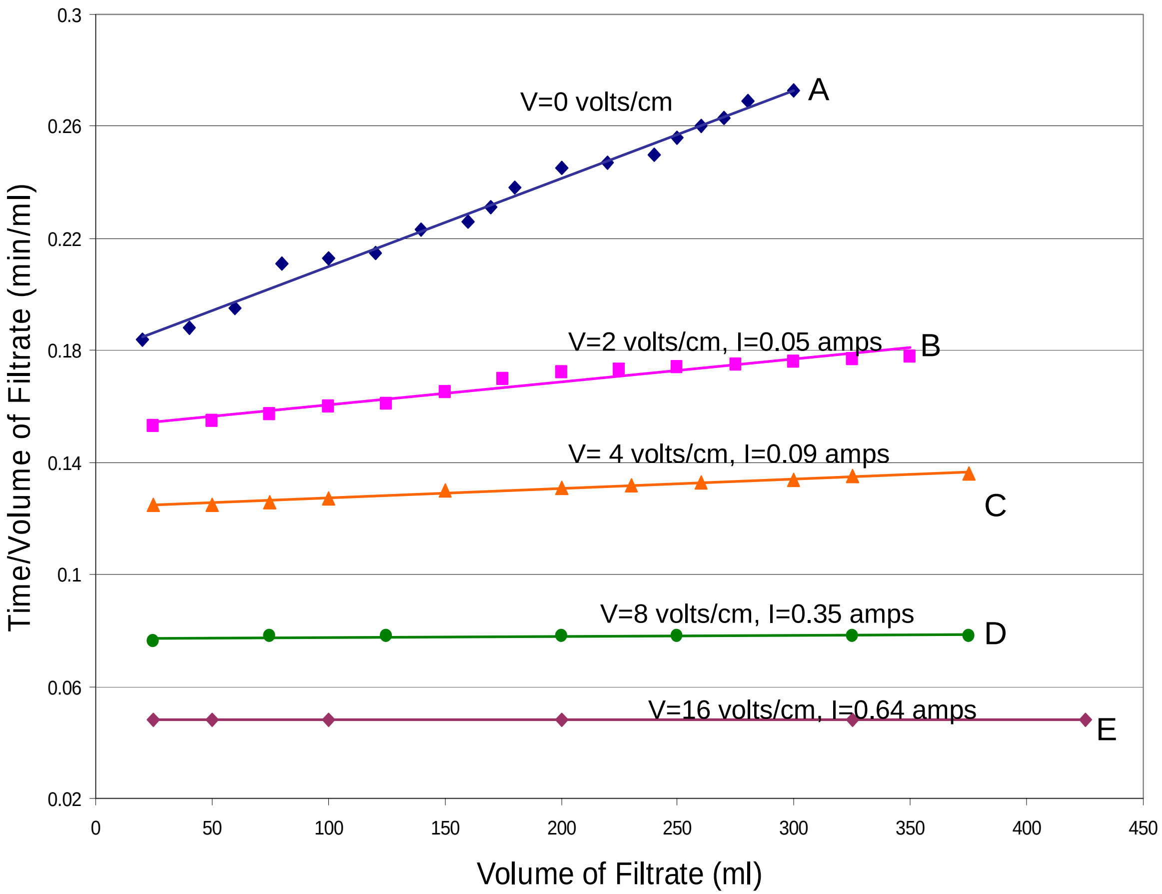
Cross-Flow Filtration with Electric Field



- An electric field enhances cross-flow filtration process by electrophoretically driving particles away from filter surface.
- Thus, filter cake is suppressed and filter effectiveness maintained.

V_f - direction of flow of permeate water
V_p- direction of electrophoretic migration of particles

Filter Cake Prevention



- The upward slope of several of these curves illustrates the decrease in filtration rates resulting from filter cake build-up.
- The slope of the lines decreases with applied voltage.
- This is evidence of decreased rate of filter cake deposition due to electrophoretic transport of particles away from the filter surface.

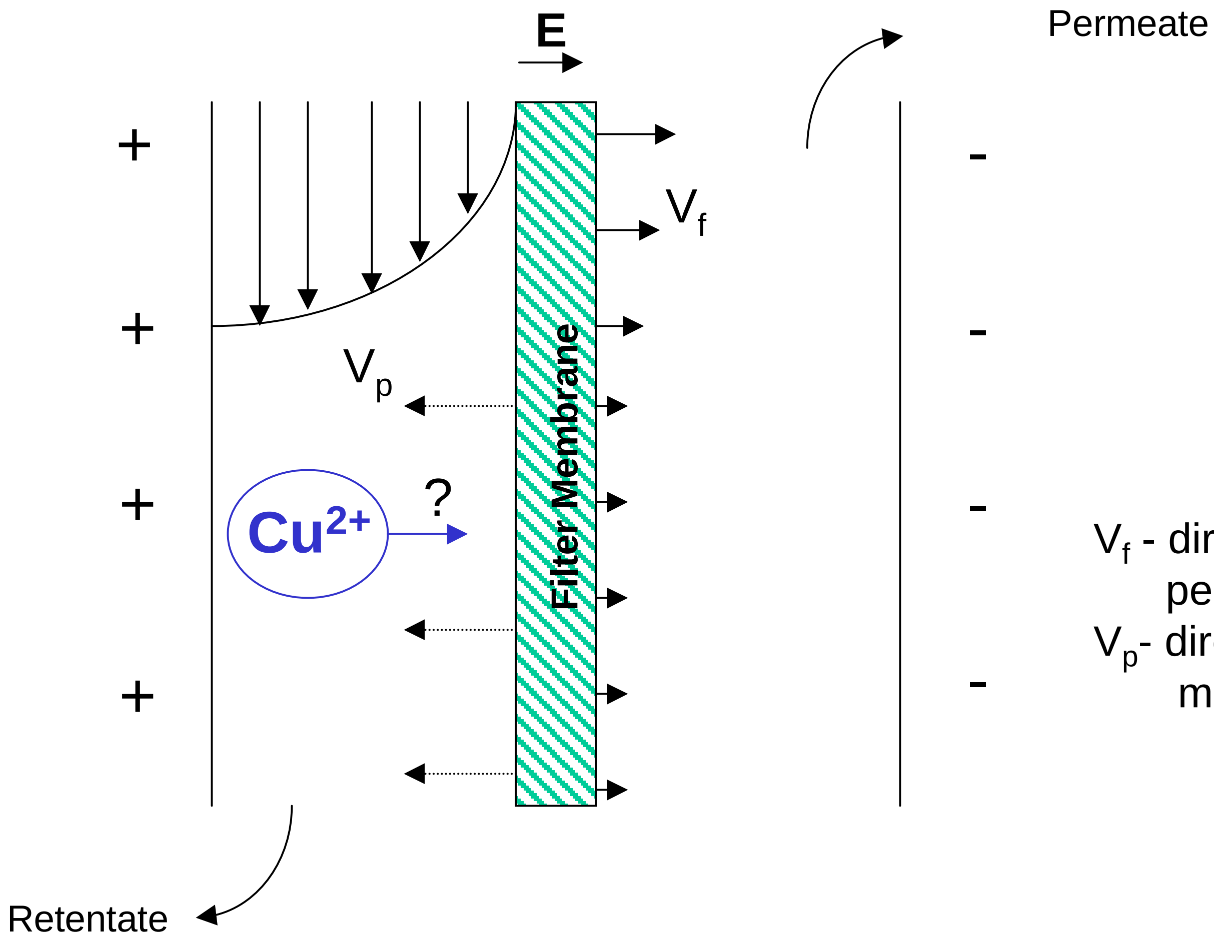
Plot T/V versus V for clay suspension of 450 mg. Clay (200 mesh) and 450 mg. NaCl per liter‡

‡M. Bier, S.P. Moulik, F.C. Cooper, *Journal of Colloid and Interface Science*, 24:4, 427-432, 1967.

Reasons for Investigating the Technology

- An electric field suppresses filter cake build-up and enhances cross-flow filtration.
- An electric field biases the transport of copper and other solutes.

Electric Field Biases Transport of Cu



V_f - direction of flow of permeate water

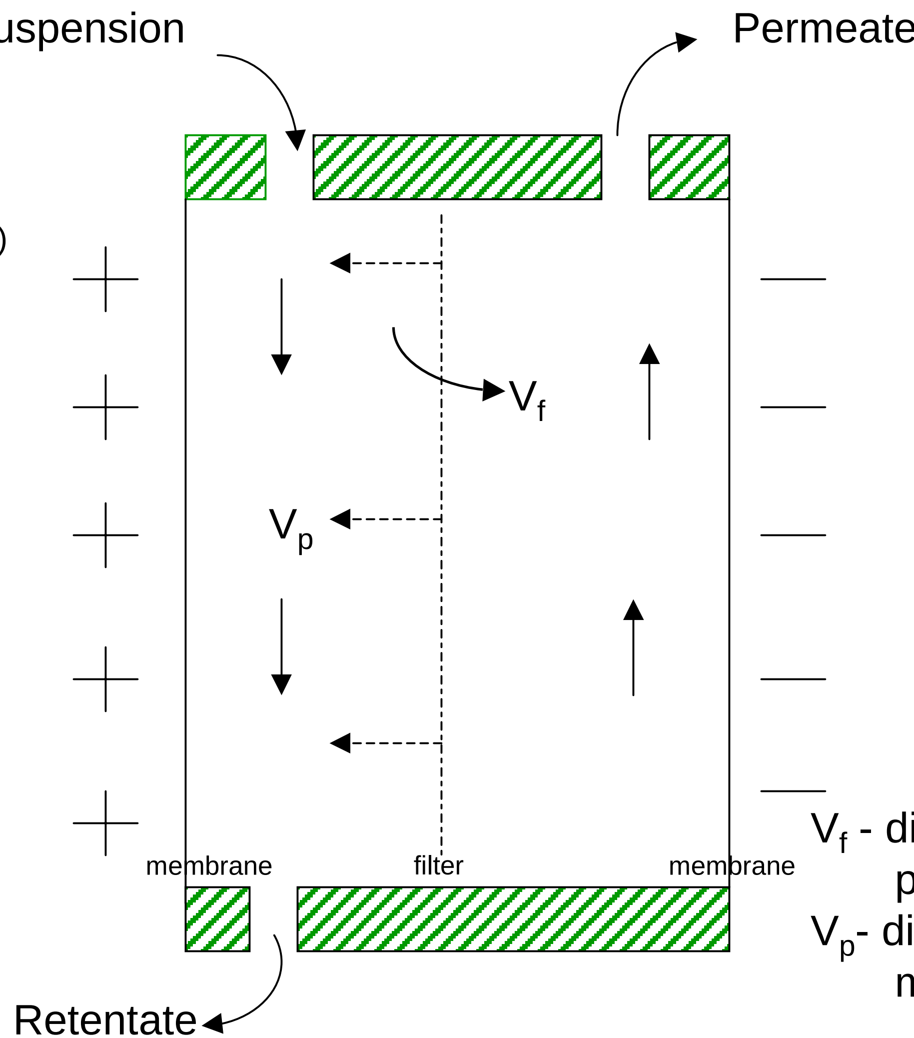
V_p- direction of electrophoretic migration of particles

Illustration of Apparatus

Single Cell

CMP aqueous waste suspension

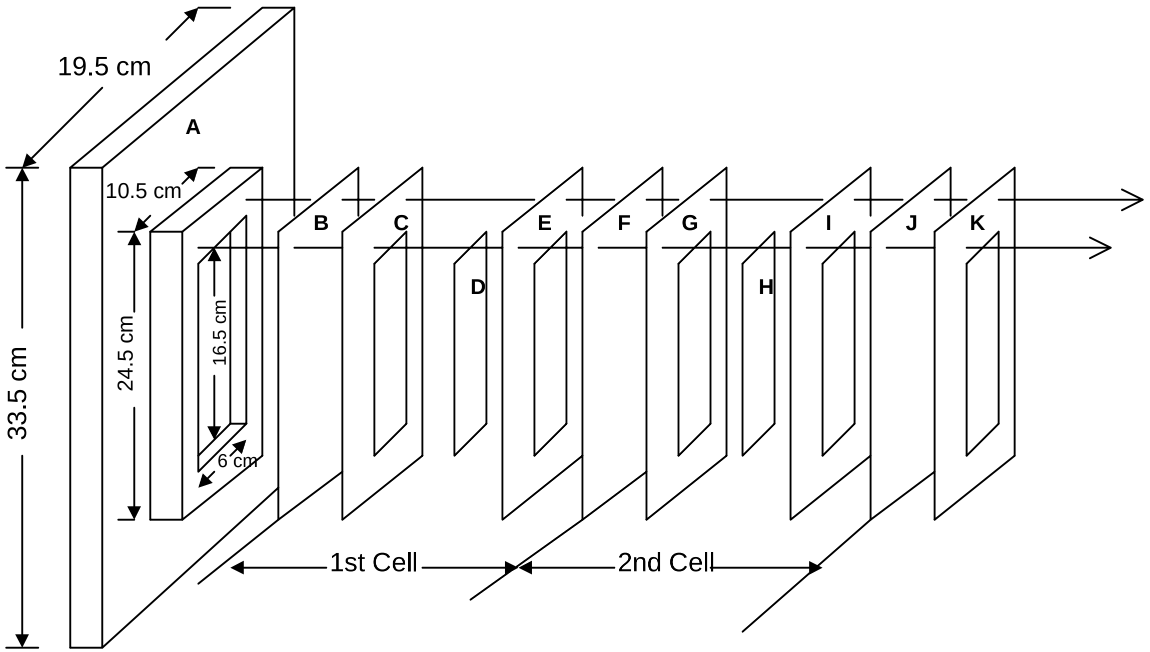
Constituents:
- Solids (0.05-0.5 w/v %)
  - e.g. Silica (80 nm)
- Copper
  - Copper ions (5-50 ppm)
  - Copper complexes
- Copper chelating agents
  - e.g. Citric Acid
- Corrosion inhibitors
  - e.g. BTA
- Conductivity
  - 300-1500 μS/cm



V_f - direction of flow of permeate water

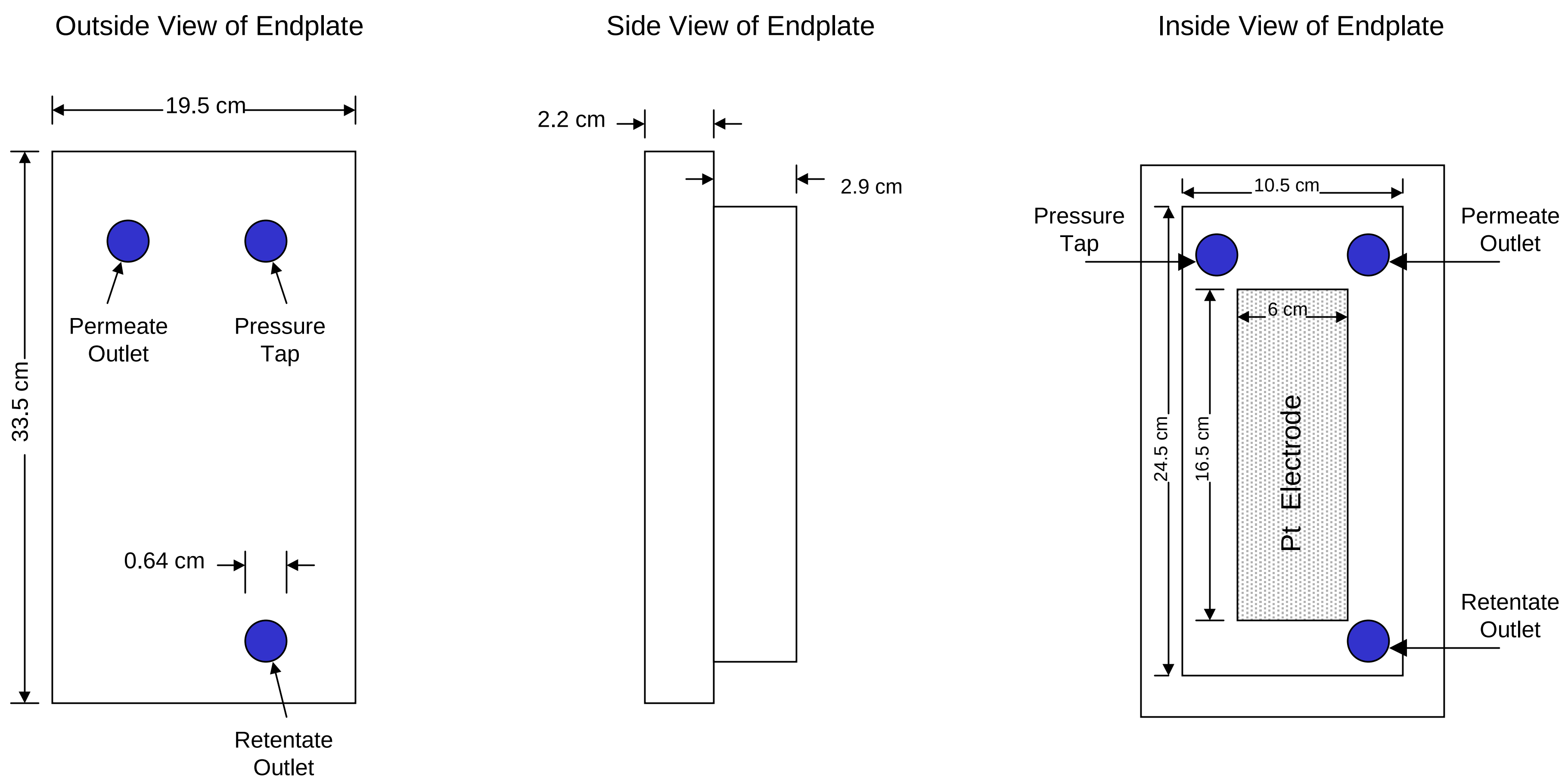
V_p - direction of electrophoretic migration of particles

Expanded Cell Assembly

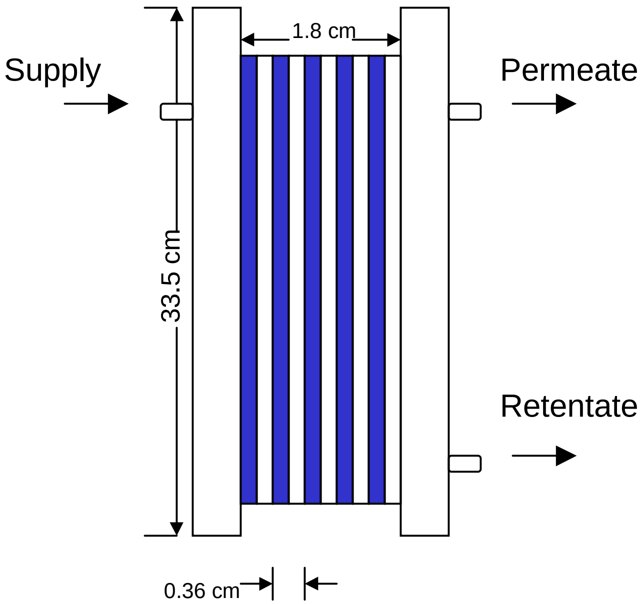


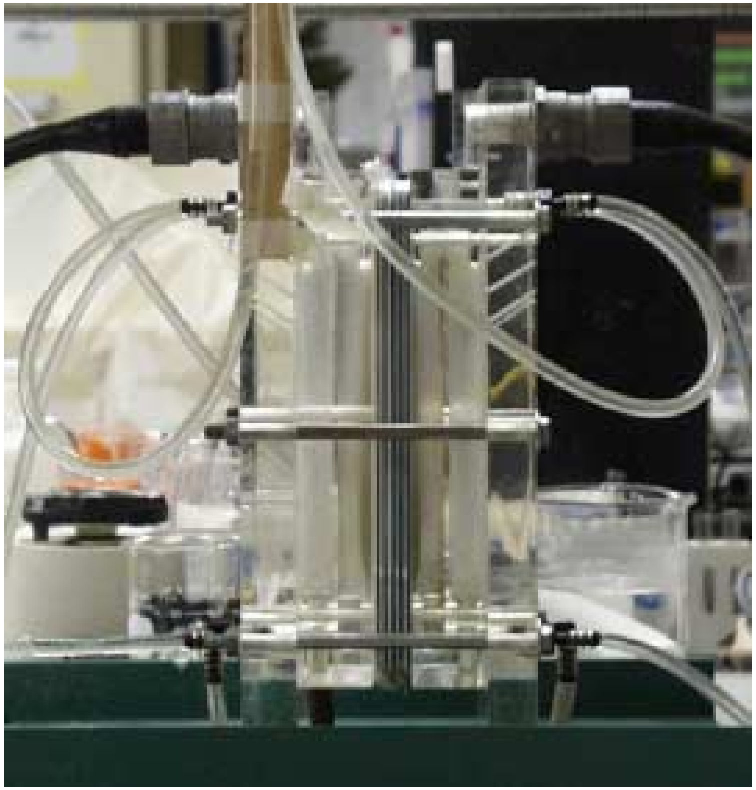
A End plate with Electrode
B Dialyzing Membrane
C Input Spacer for 1st Cell
D Micro Filter (0.8 µm)
E Output Spacer for 1st Cell
F Dialyzing Membrane
G Input Spacer for 2nd Cell
H Micro Filter (0.8 µm)
I Output Spacer for 2nd Cell
J Dialyzing Membrane
K Input Spacer for 3rd Cell

View of Endplate with Electrode



Front View





Entire Device

Components of Device

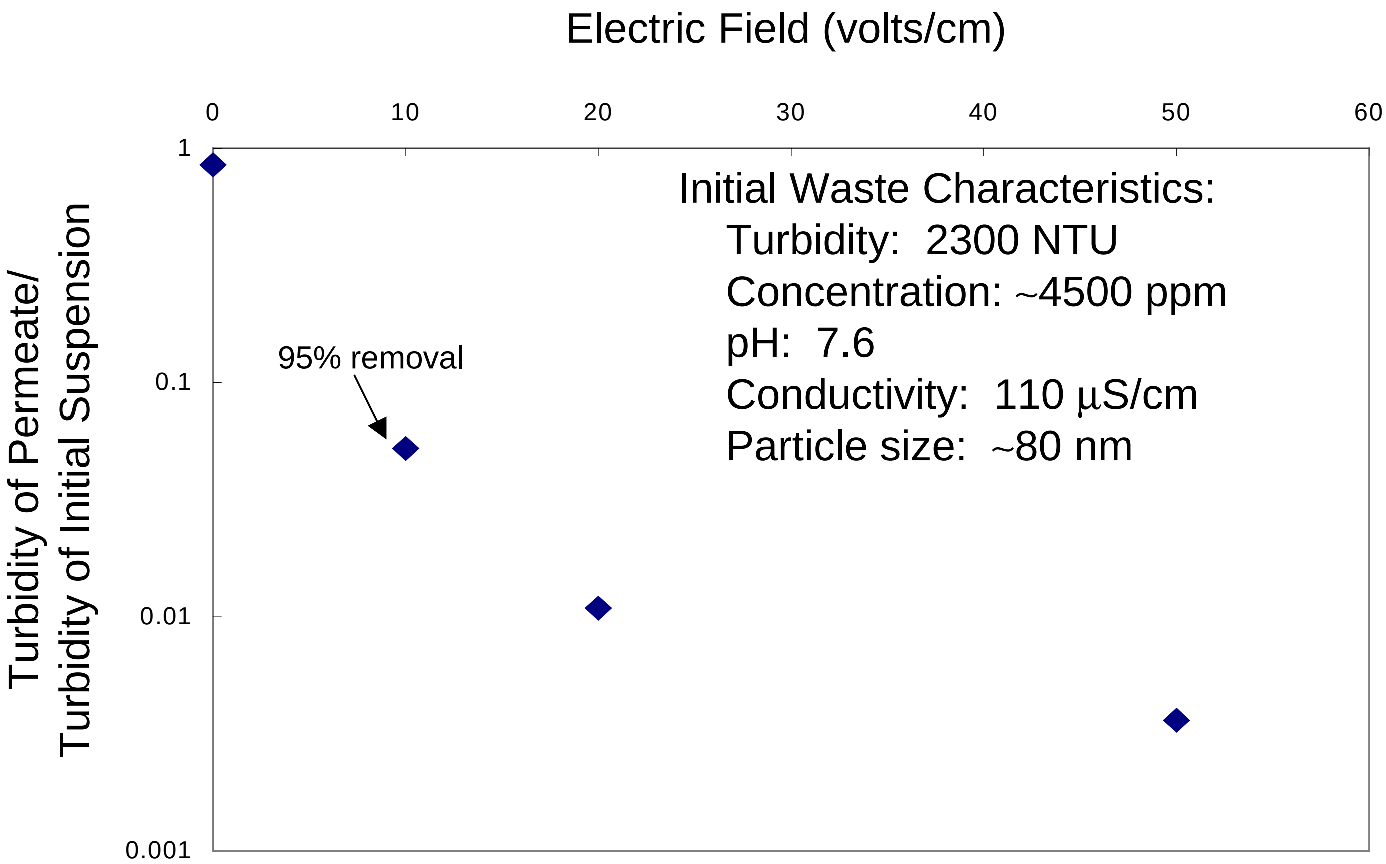
- Electrodes - platinum
- Membranes - dialyzing cellophane
- Filter membranes - ~ 0.8 μm porosity

Electrophoretic Filtration of Silica Suspensions

- Oxide CMP Waste
- Model Silica Suspensions
- Model Silica Suspensions doped with Copper

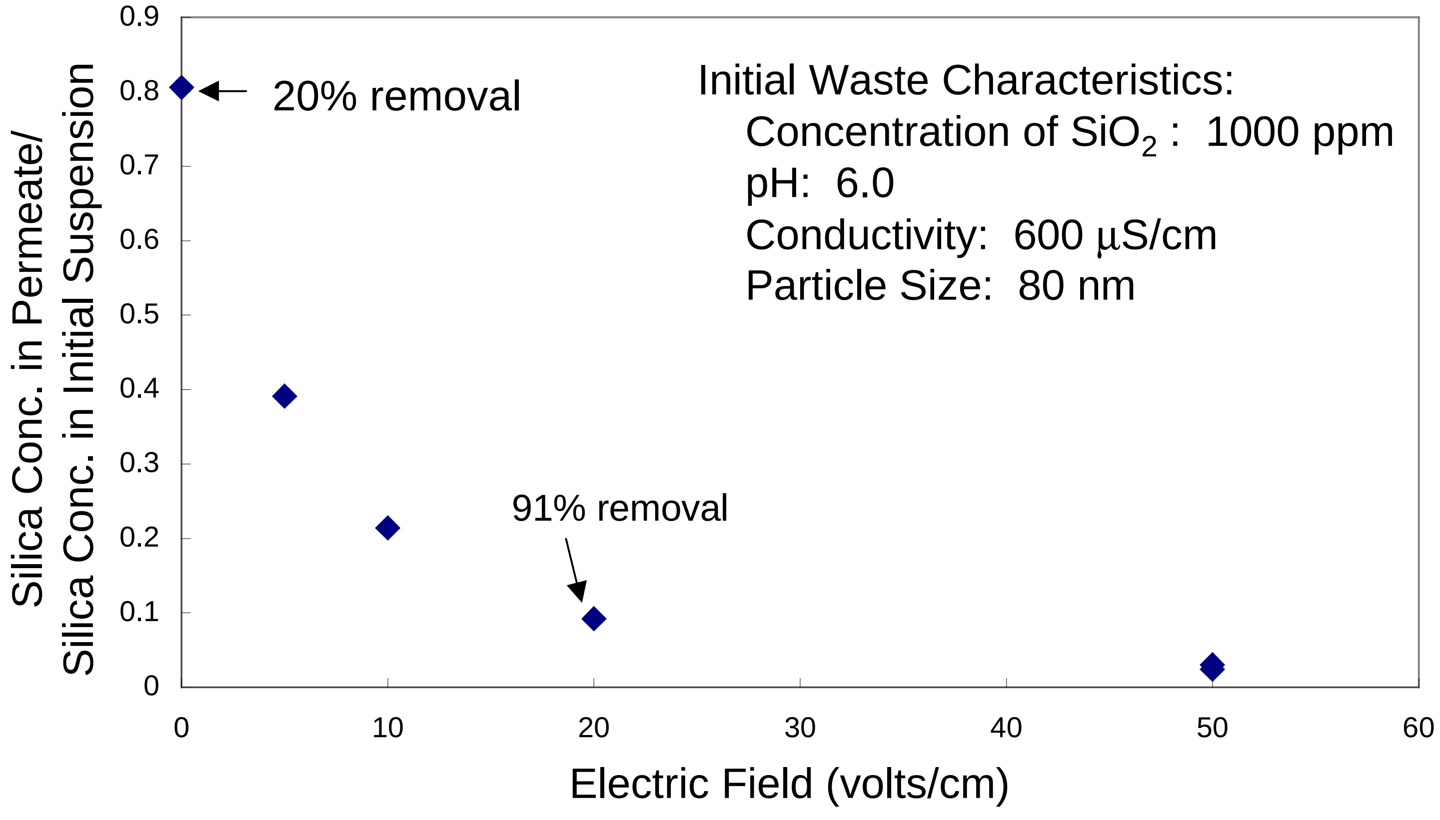
Electrophoretic Filtration of Oxide CMP Waste

(Oxide CMP waste provided by: Microelectronics Lab, U of A)

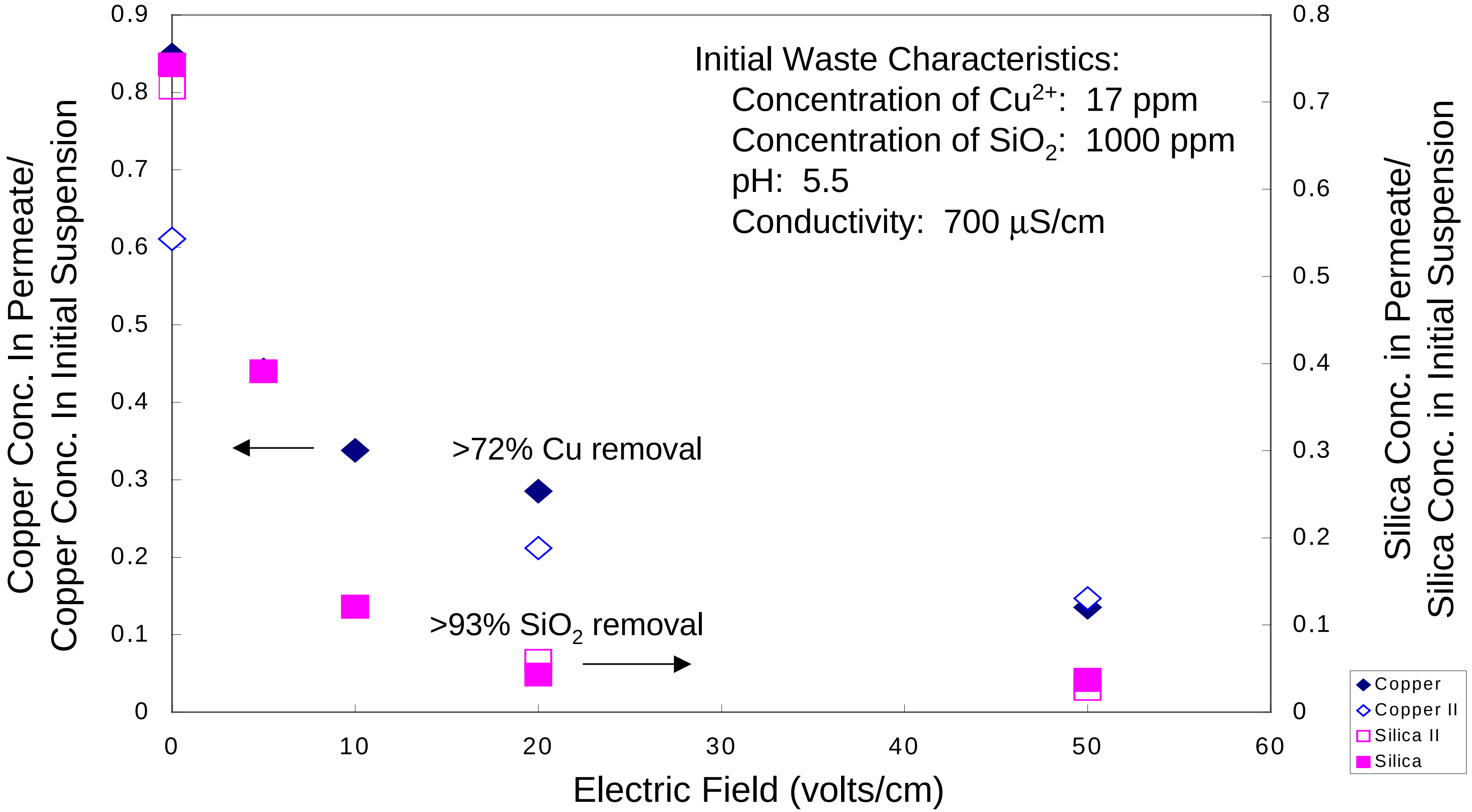


Electrophoretic Filtration of Silica Suspension

(Klebosol Colloidal Silica)

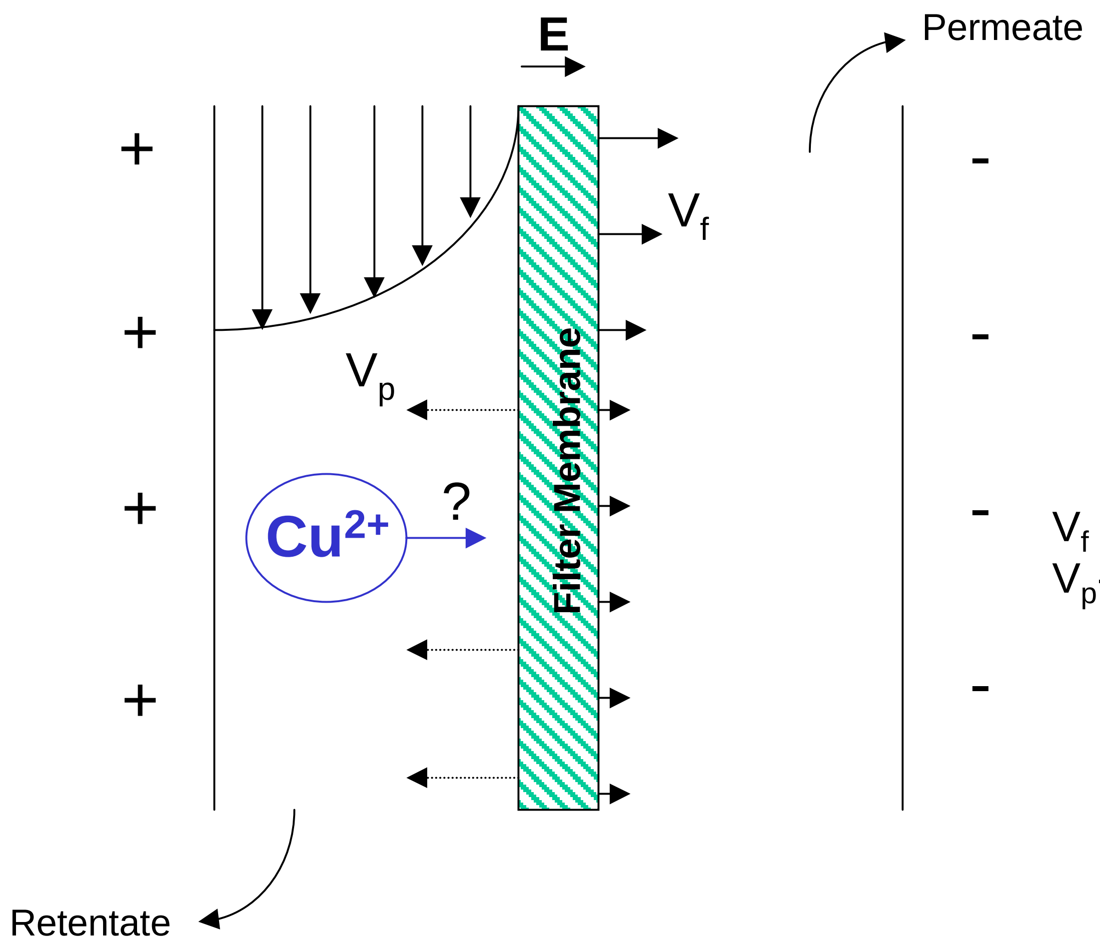


Electrophoretic Filtration of Silica Suspension Doped with Copper



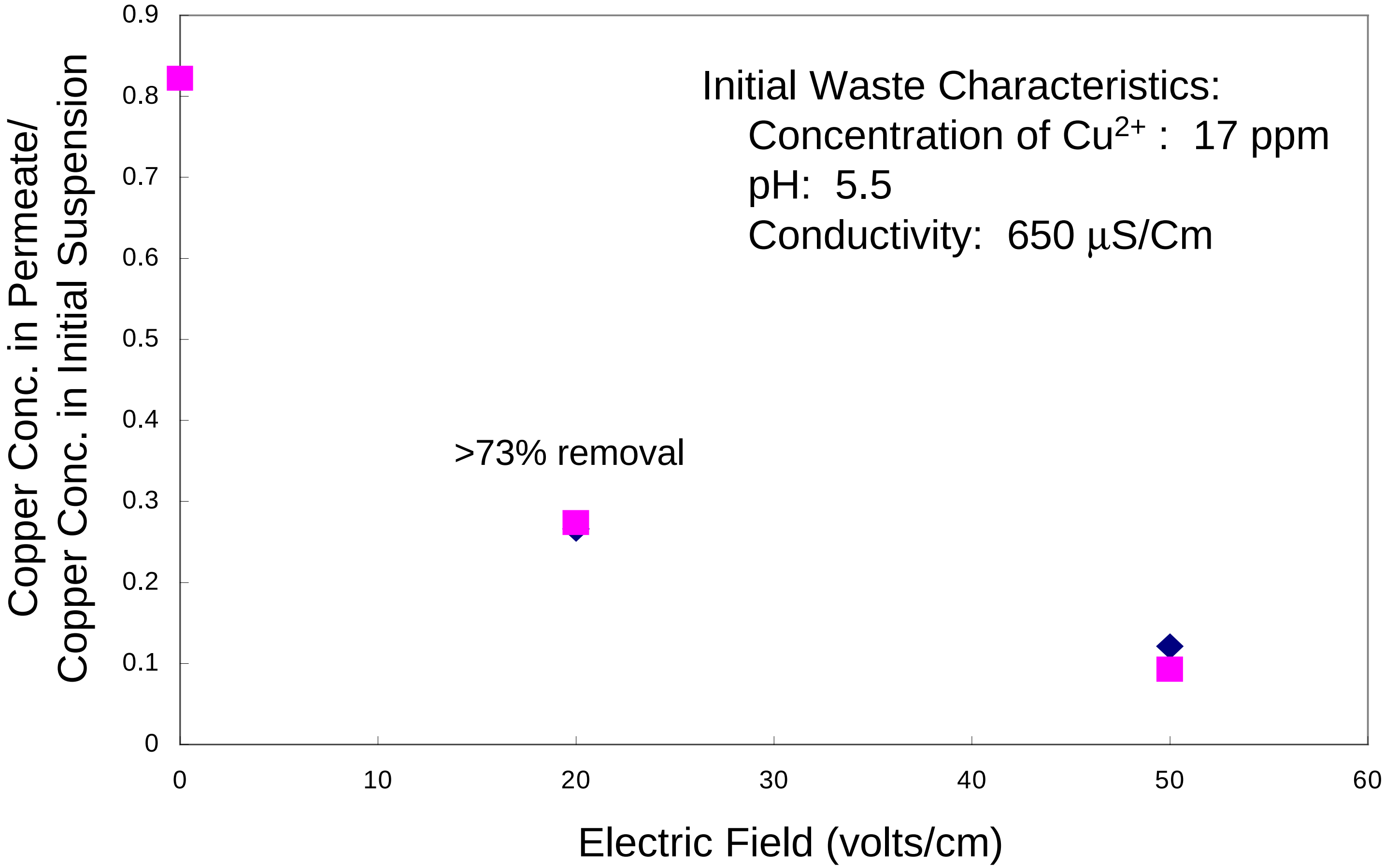
Electrophoretic Filtration (Electrodialysis) of Dissolved Copper

Electric Field Biases Transport of Cu



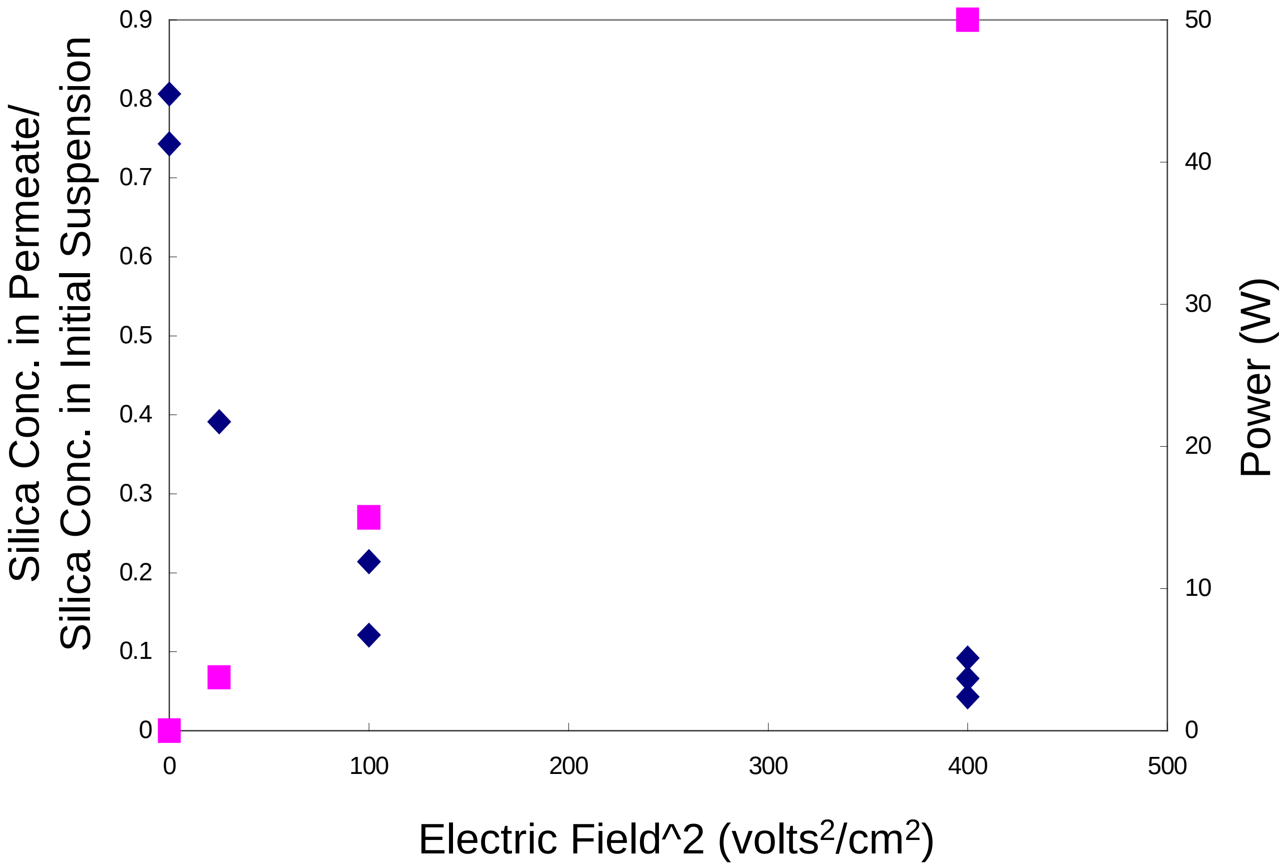
V_f - direction of flow of water
V_p- direction of electrophoretic migration of particles

Electrophoretic Filtration (Electrodialysis) of Copper



Power Consumption of Electrophoretic Filtration

Power Consumption of Electrophoretic Filtration of Silica



Initial Waste Characteristics:
- Concentration of SiO_2 : 1000 ppm
- pH: 5.4
- Conductivity: 700 μS/cm
- Particle Size: 80 nm

Power Consumption: Mechanical Filtration versus Electrophoretic Filtration

	Power Equation	Power Consumption	Power Consumption/ Permeate Flow Rate
Mechanical Filtration (Ultrafiltration)	Q x DP	17 Watts (with 45% pump efficiency)	8 MJ/m^3
Electrophoretic Filtration of Simulated Copper CMP Waste (conductivity = 700 μS/cm)	V x I	50 Watts (Electric Field of 20 volts/cm)	32 MJ/m^3
Electrophoretic Filtration of Oxide CMP Waste (conductivity = 100 μS/cm)	V x I	2.5 Watts (Electric Field of 10 volts/cm)	4 MJ/m^3

Summary of Results

In the suspension studied thus far:

- Electrophoretic filtration readily removes more than 90% of silica particles from CMP suspension

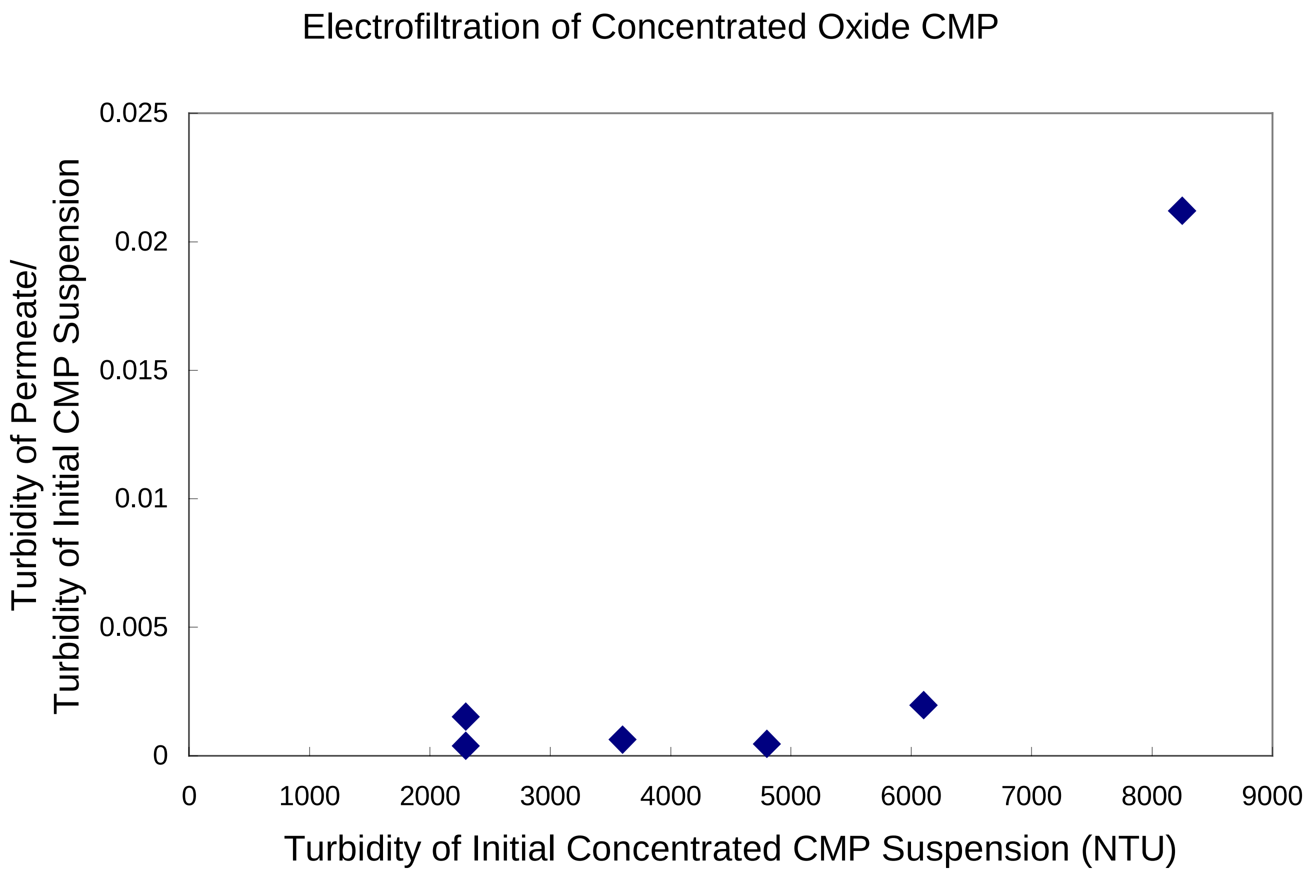
- Electrophoretic filtration removes approximately 75% of copper from the permeate stream

Potential Applications

1. Use immediately before standard ultra-filtration and ion-exchange processes to pre-filter CMP waste.

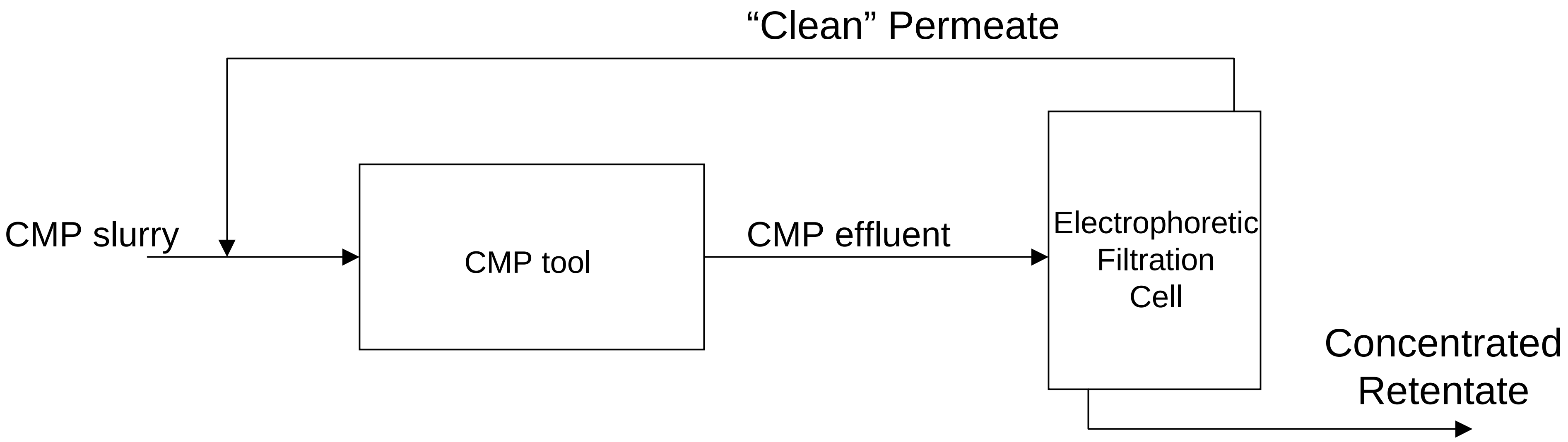
2. Use immediately after mechanical filtration process to further filter concentrated effluent.

Electrophoretic Filtration of Concentrated CMP Suspension



Potential Applications (cont.)

3. Small footprint enables each CMP tool to have its own individual filtration process.



Future Work

- Add chelating agent to the model copper suspension
- Concentrated silica suspensions (e.g. CMP sludge)
- Experiment with actual copper CMP waste (need samples !!!)
- Experiment with other types of filters