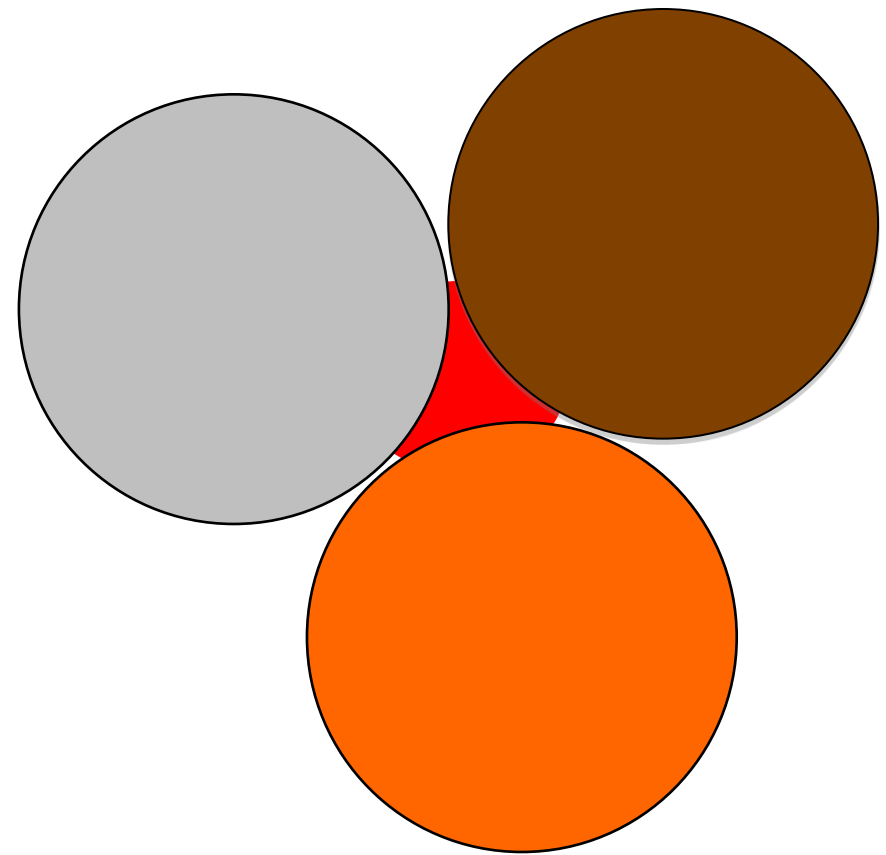


# Capacitive Deionization of Sea and Brackish Waters

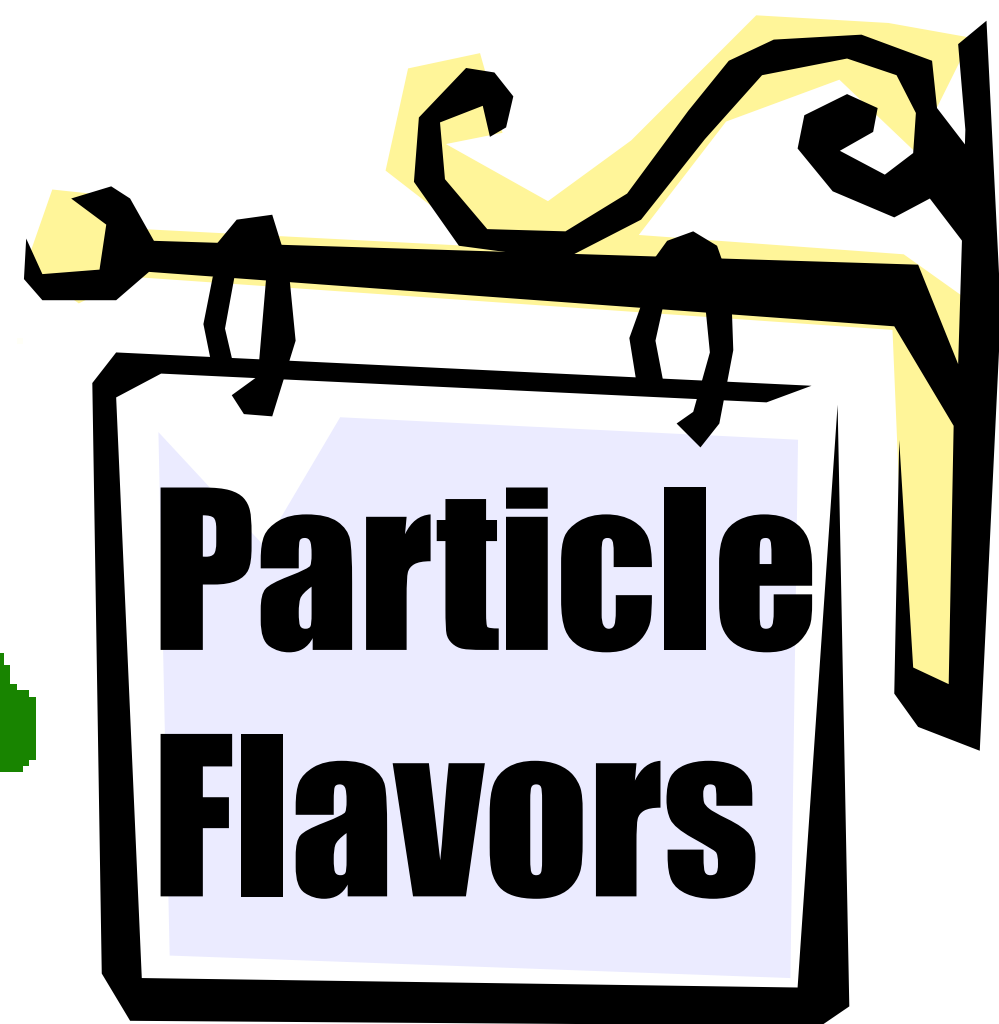
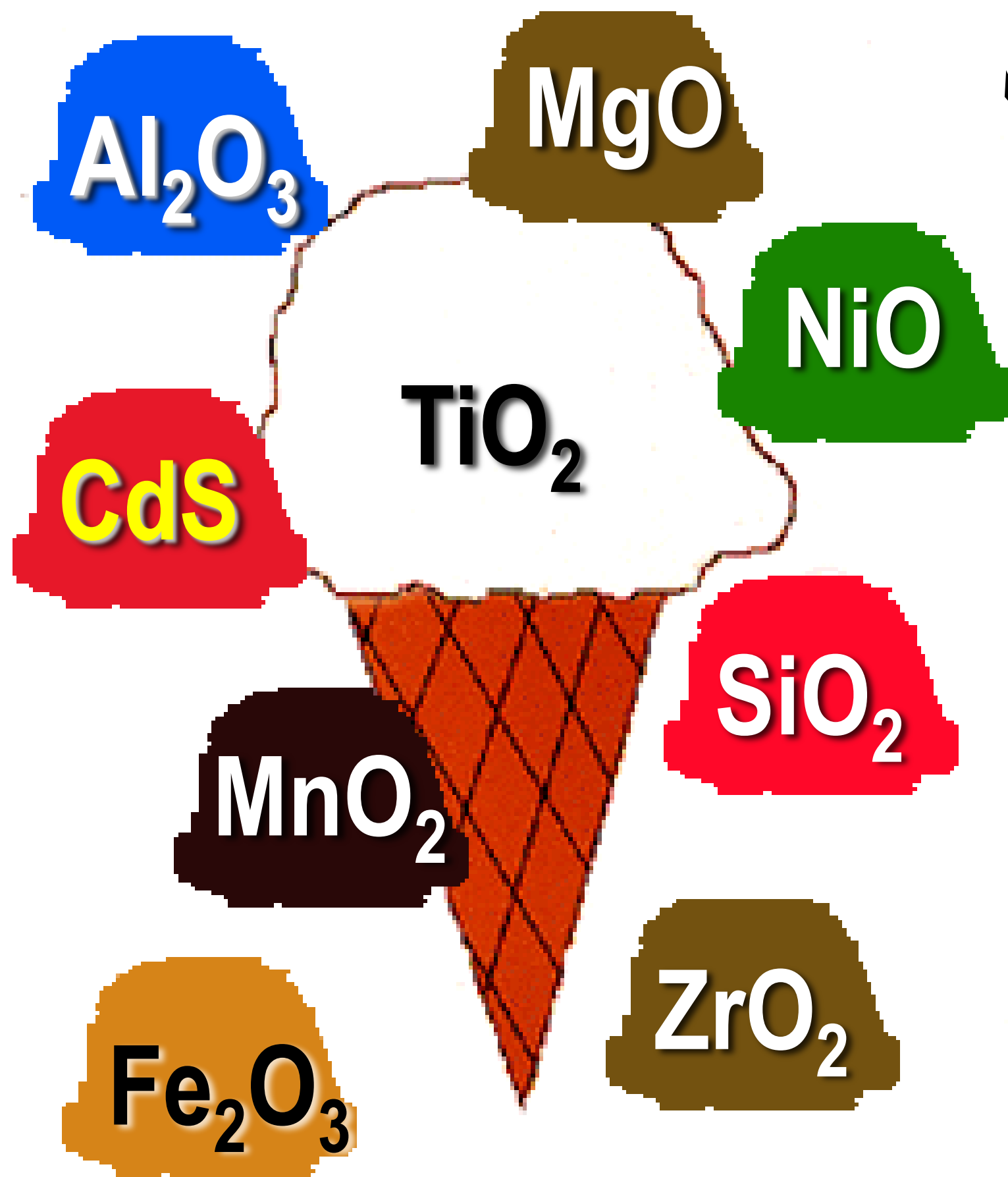
*Clean Drinking Water and Storing Energy!*  
*OECD Paris 2009*



In the Land of the Lilliputians...

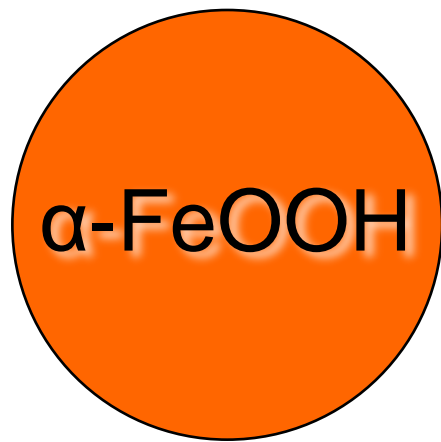


But Not POORLY !



# APPLICATIONS





# Adsorption 1974-

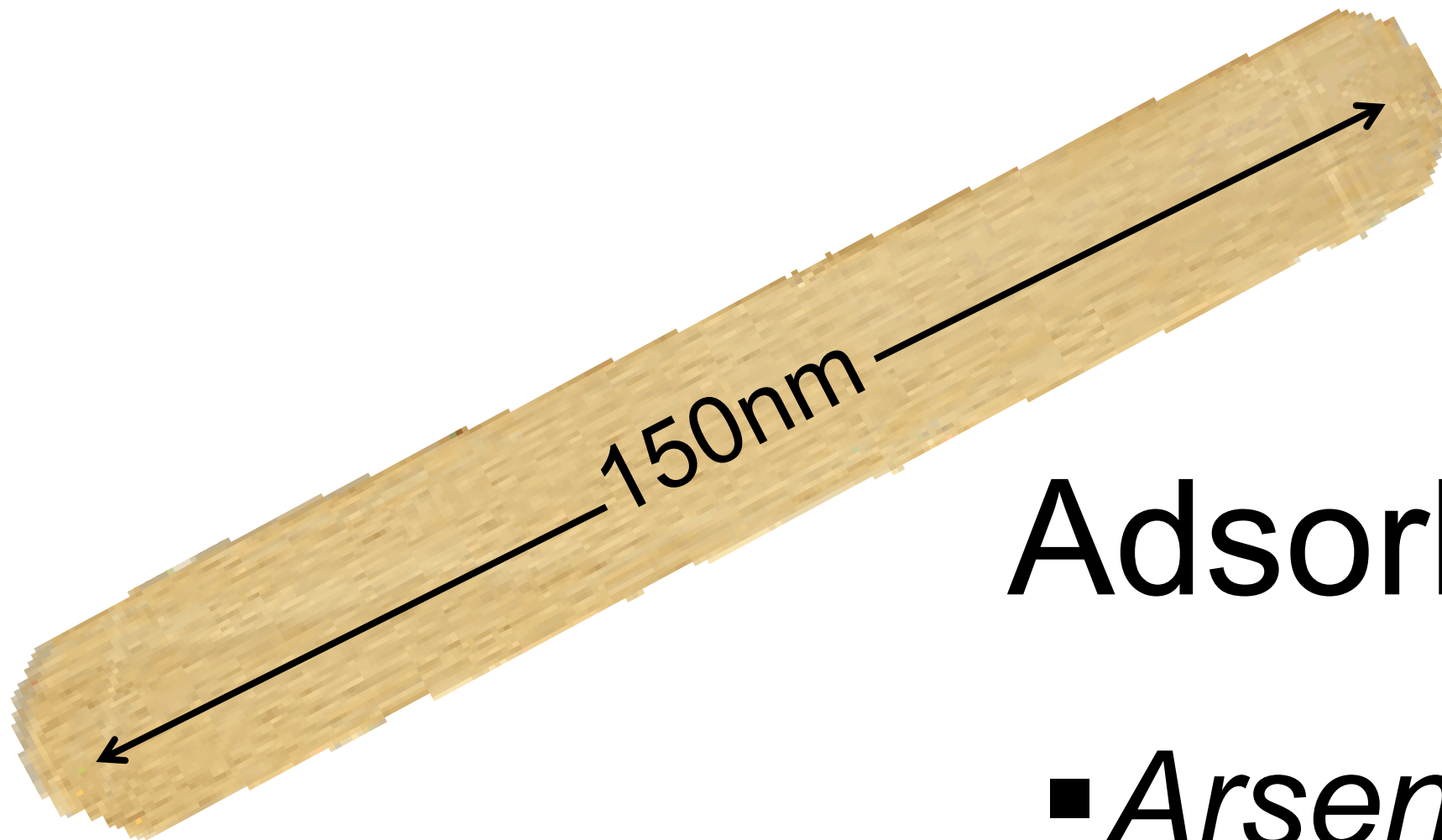
## Suspensions

Platelets  
!



*Natures Nanoparticulate “Tongue Depressors”*

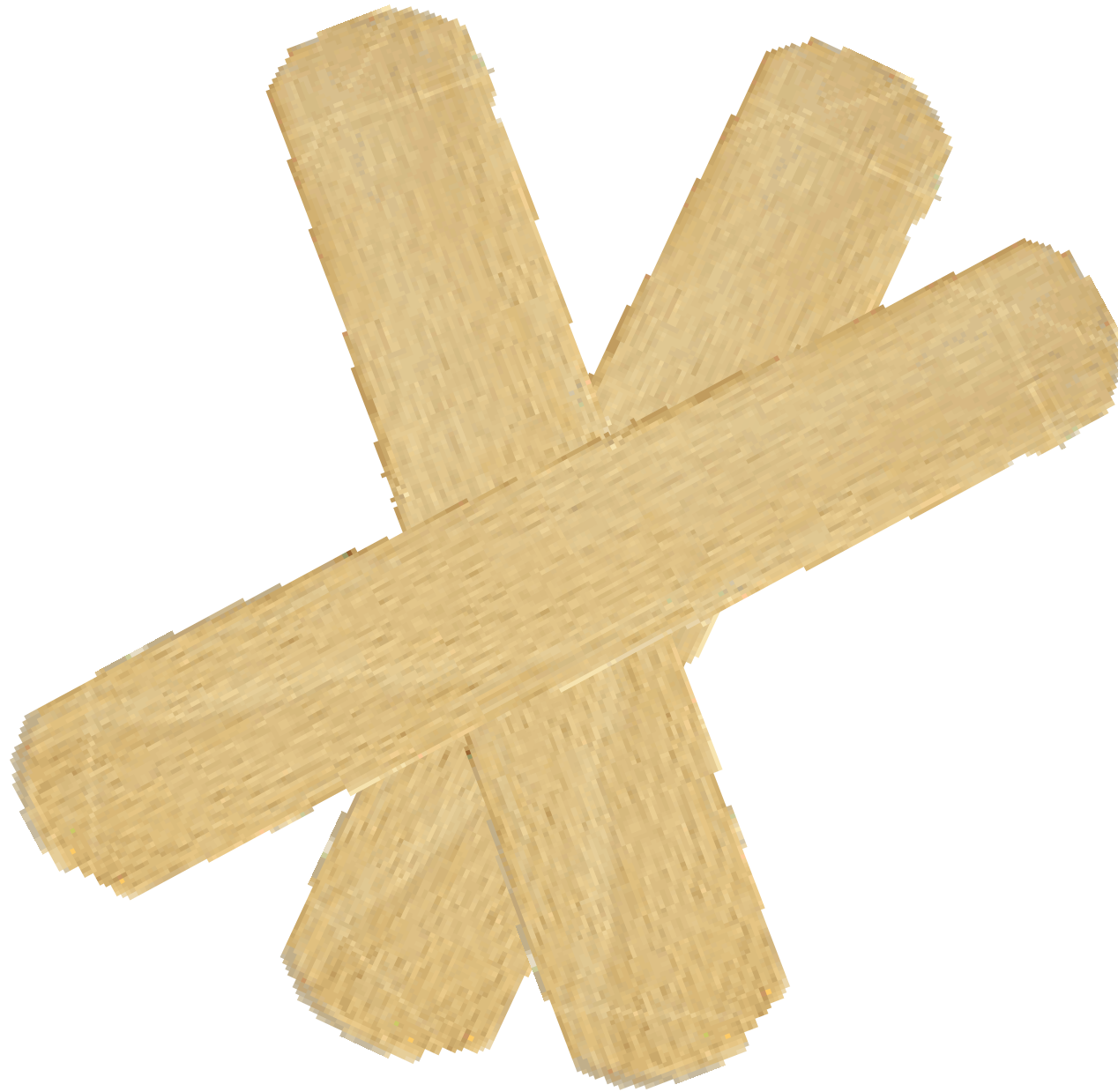
# $\alpha$ -FeOOH “Goethite”



Adsorbs...

- *Arsenate*
- *Phosphate*
- *Protons!!*

Without  $\text{PO}_4^{3-}$



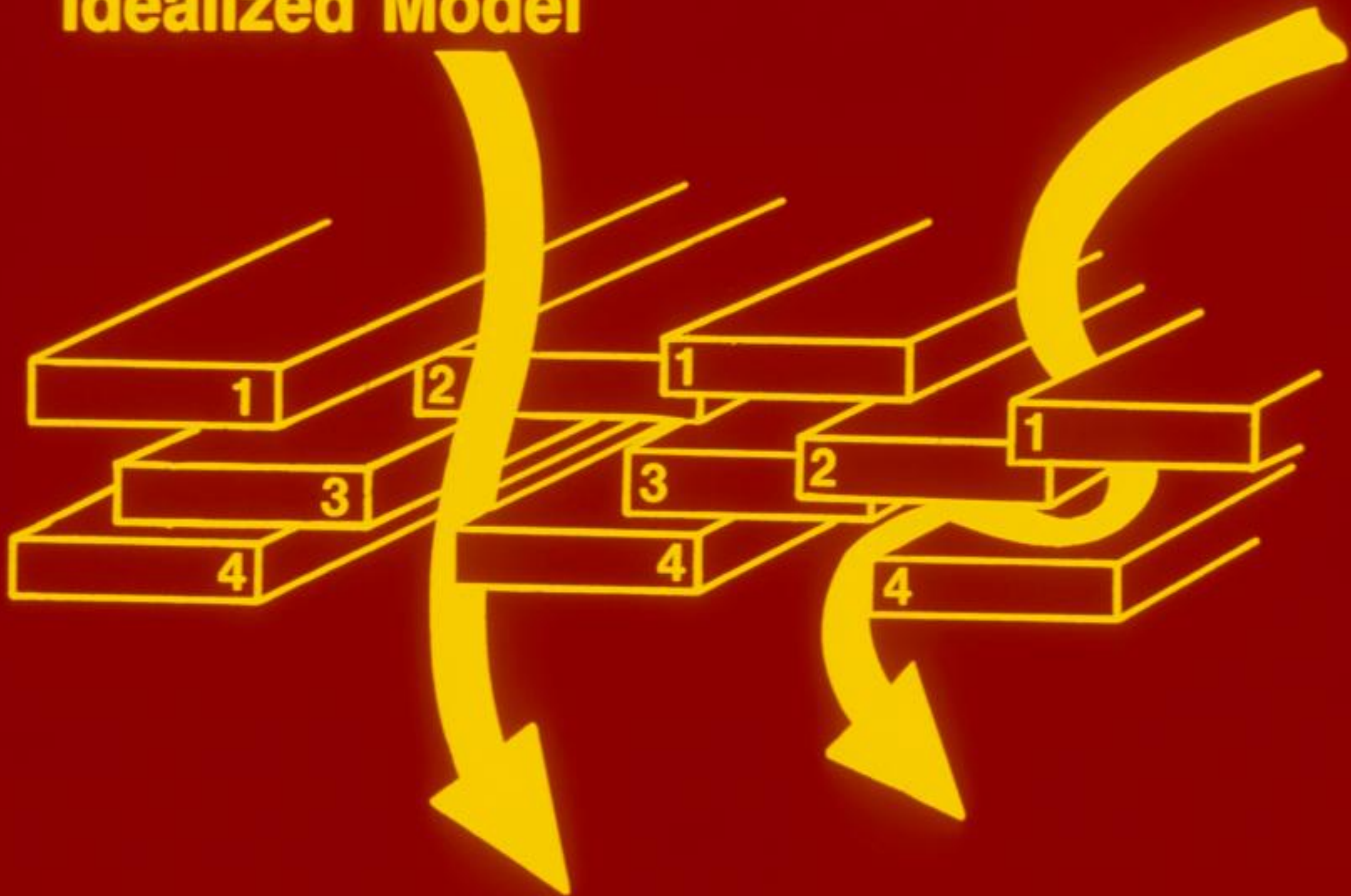




With  $\text{PO}_4^{-3}$



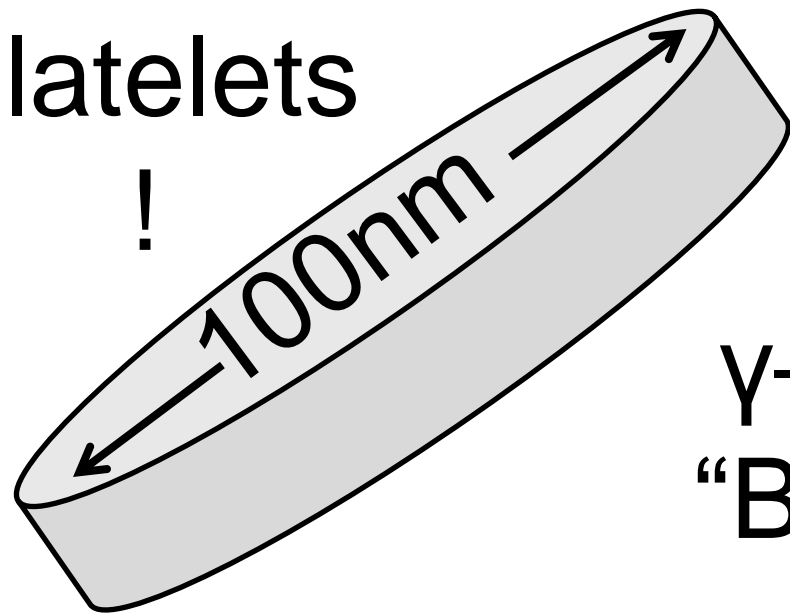
# Idealized Model



# From Suspensions to Thin-Films



Platelets  
!

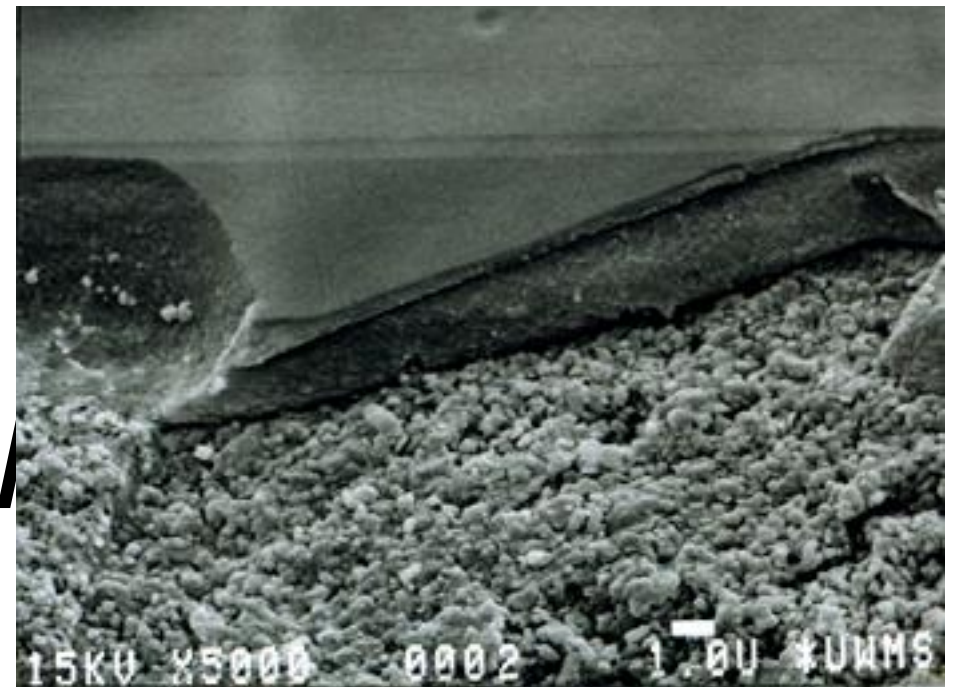


$\gamma$ -AlOOH  
"Boehmite"

**Ceramic  
Membranes  
1983-**



*Now – Smaller Particles  
Nanofiltration*



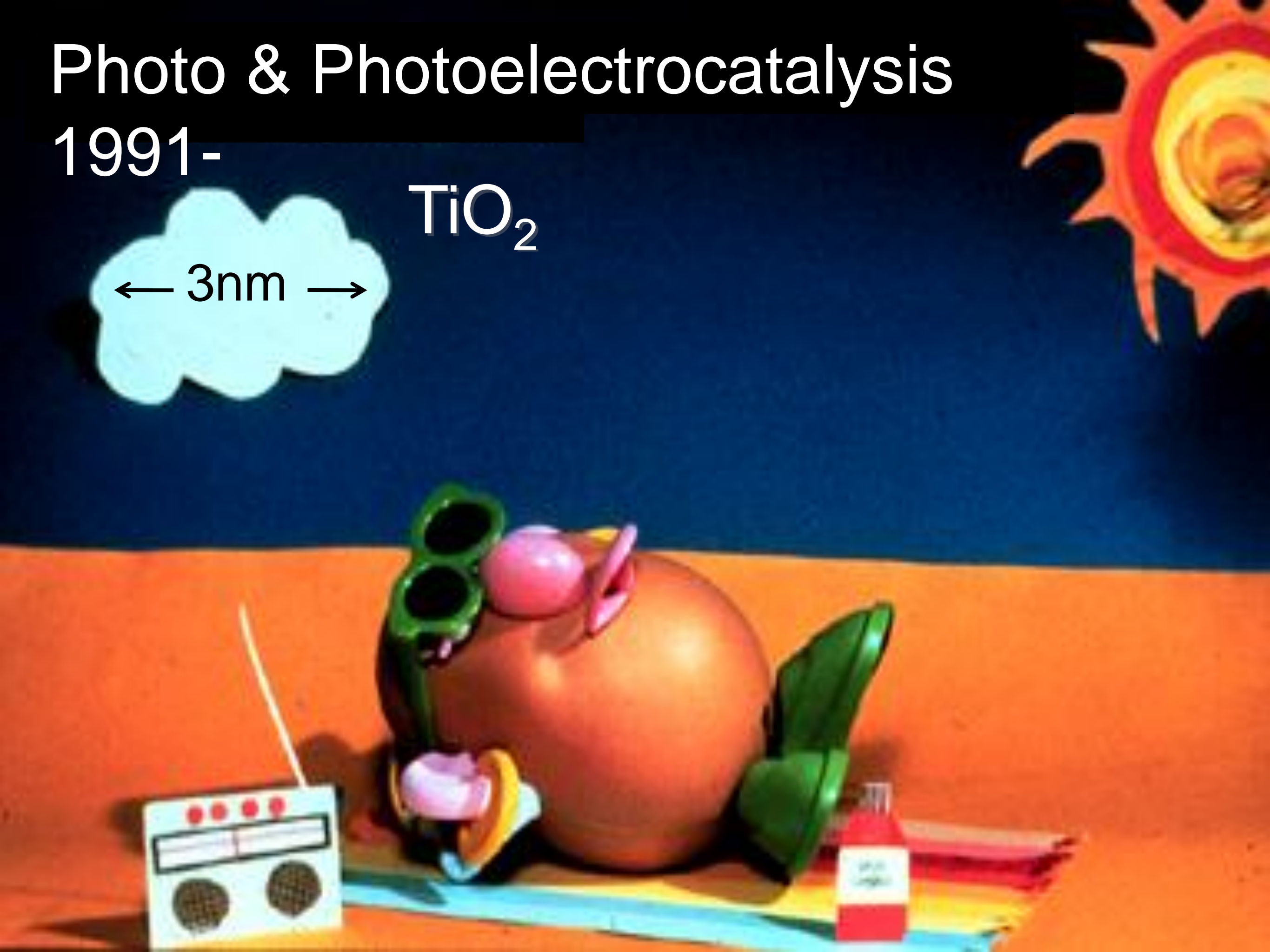


# Photo & Photoelectrocatalysis

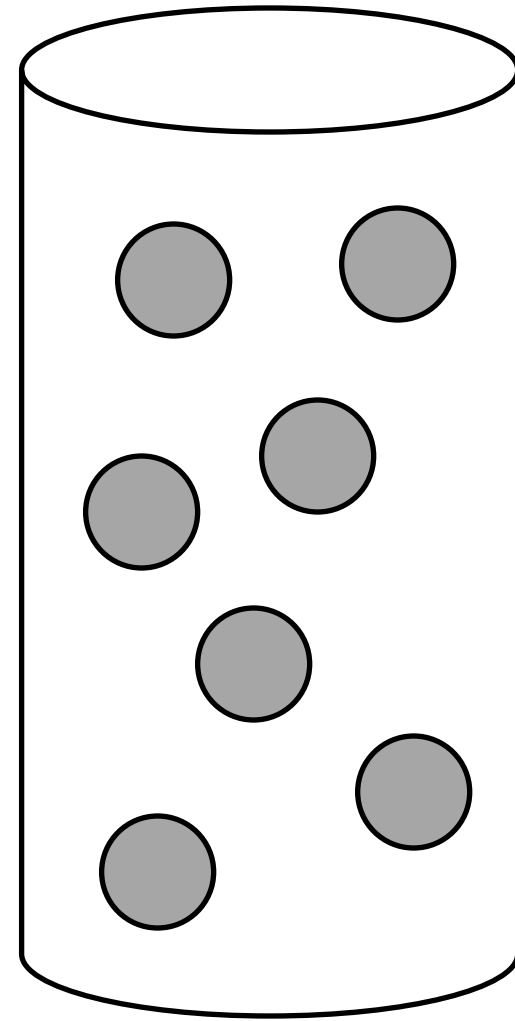
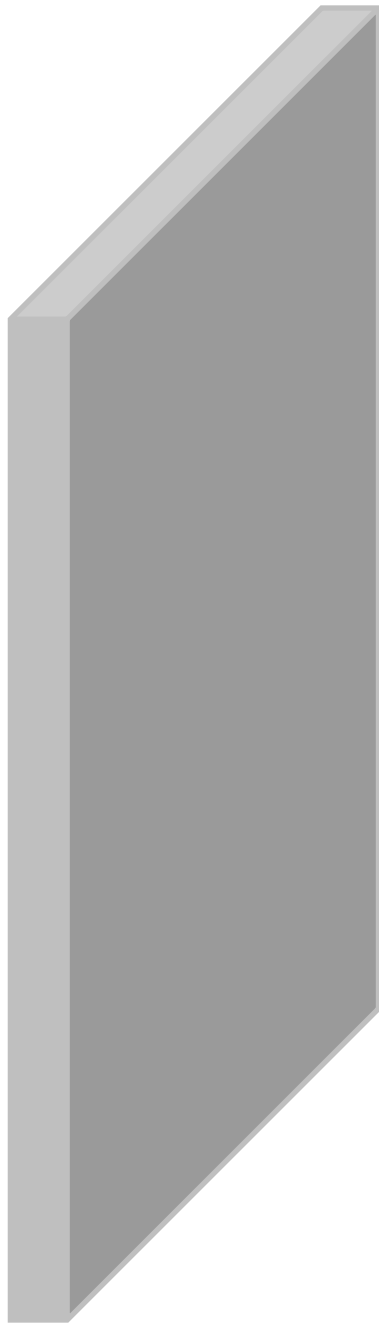
1991-

$\text{TiO}_2$

← 3nm →



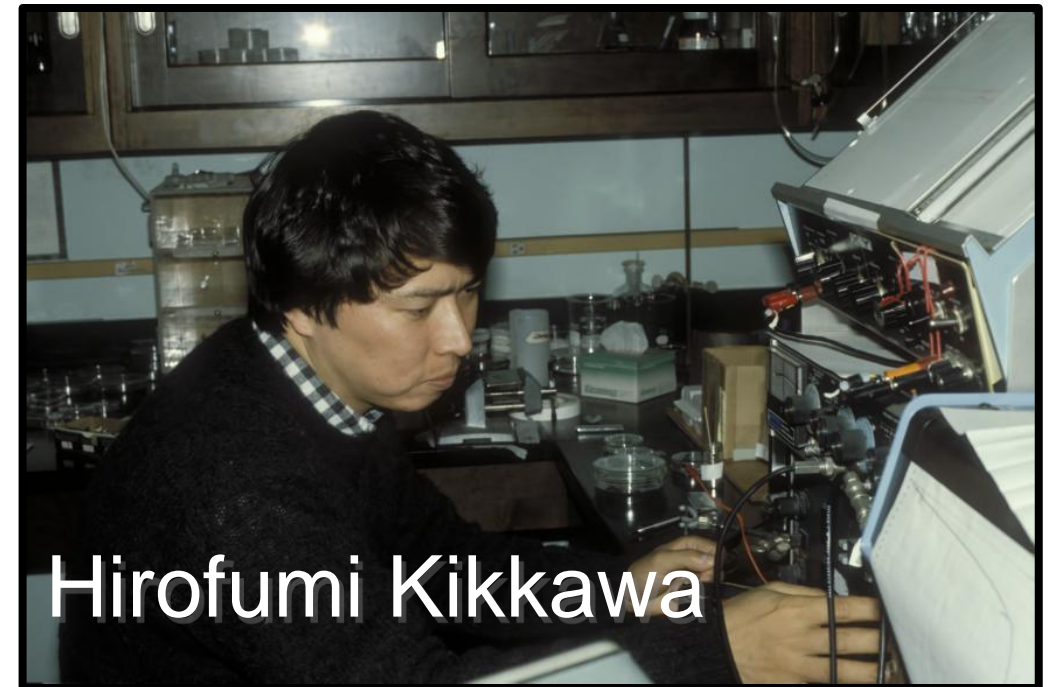
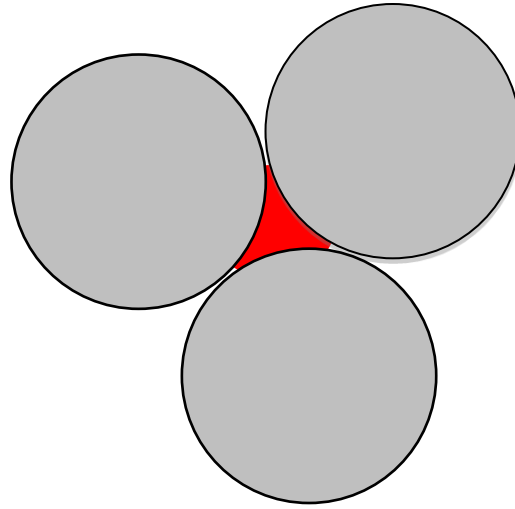
# Films vs Suspensions



*No Separation Needed  
Better Light Penetration  
Photoelectrodes*



# Transparent Semiconducting Thin-Films



- *Photoelectrochemist*
- *Grätzel Cells*
- *Porous Electrodes !*





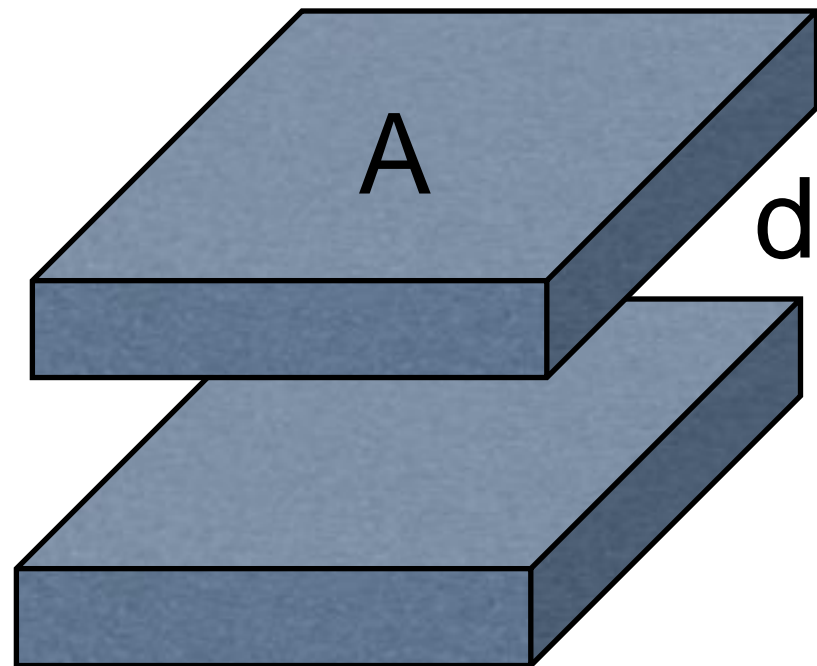
# Energy Storage

- *Batteries*
- *Capacitors*

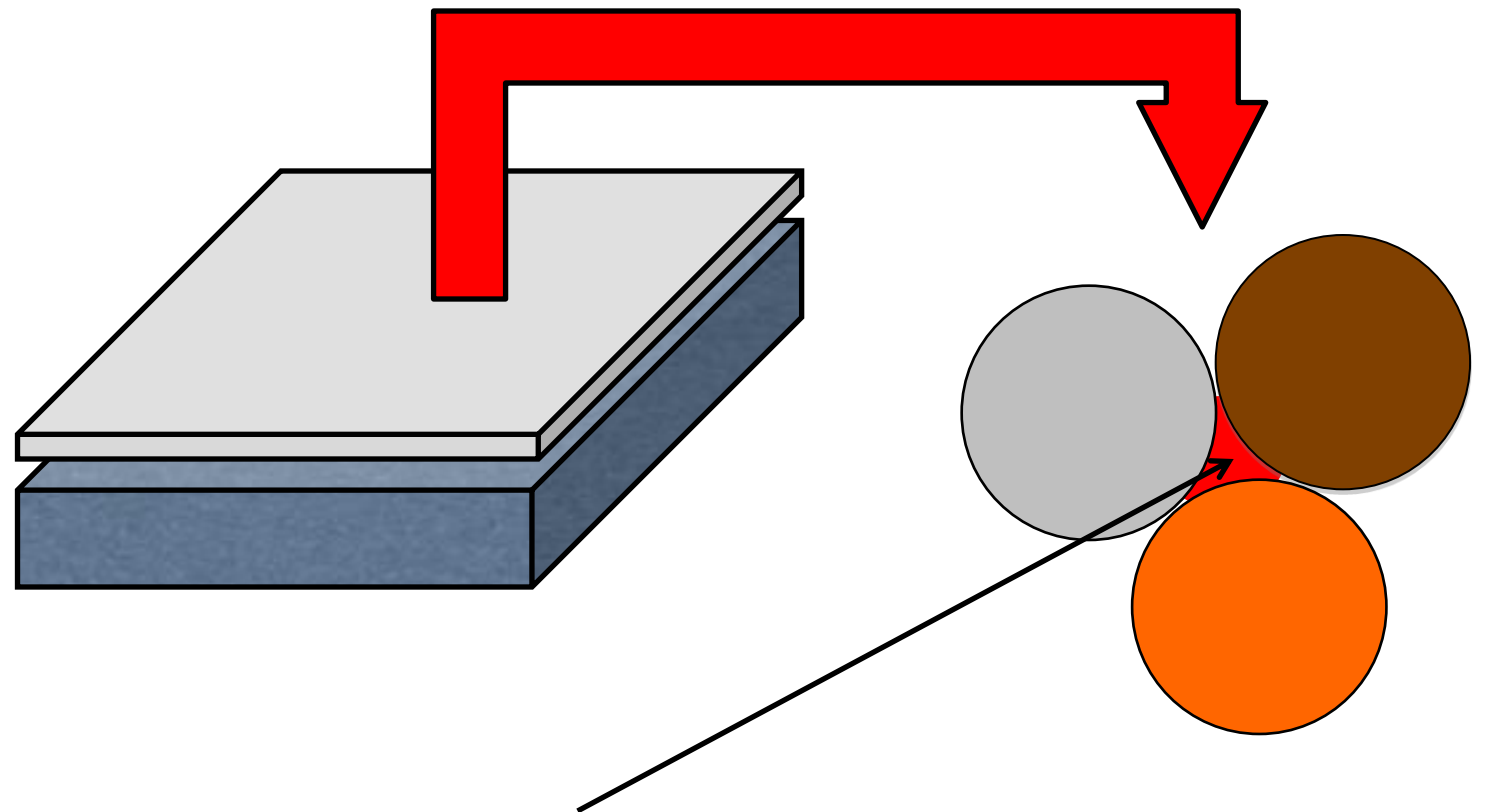


# Ultracapacitors

1994-



$$C = \epsilon \frac{A}{d}$$



Ion Distance to Surface = Angstroms

Energy Density ⇌

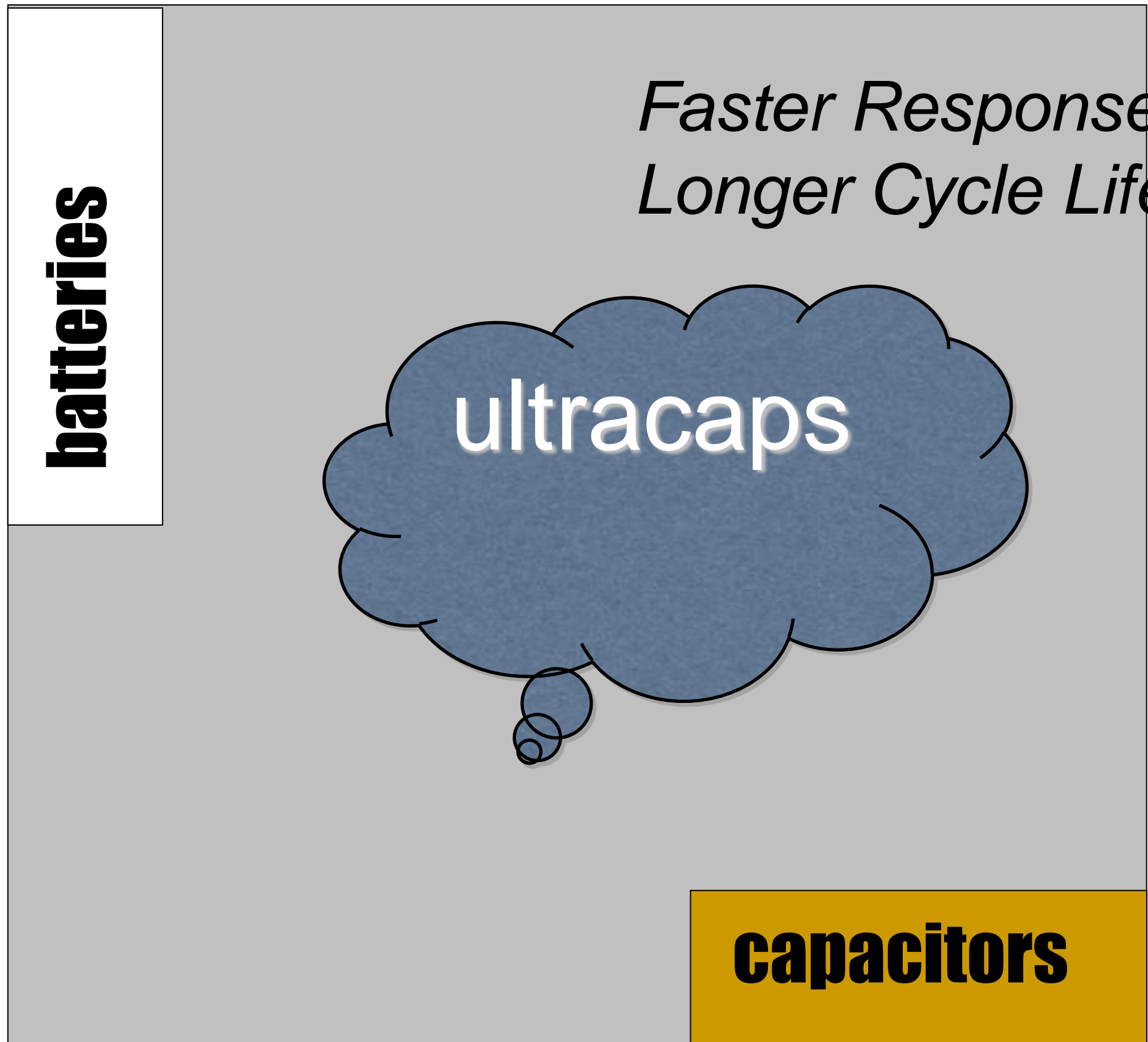
**batteries**

*Faster Response  
Longer Cycle Life*

ultracaps

**capacitors**

Power Density ⇌







# ***Load-Leveling***



***USA  
Alkaline  
Battery***



**WATER**

**ENERGY**



# Rhone River Plant- France

POWER PLANTS NEED WATER!





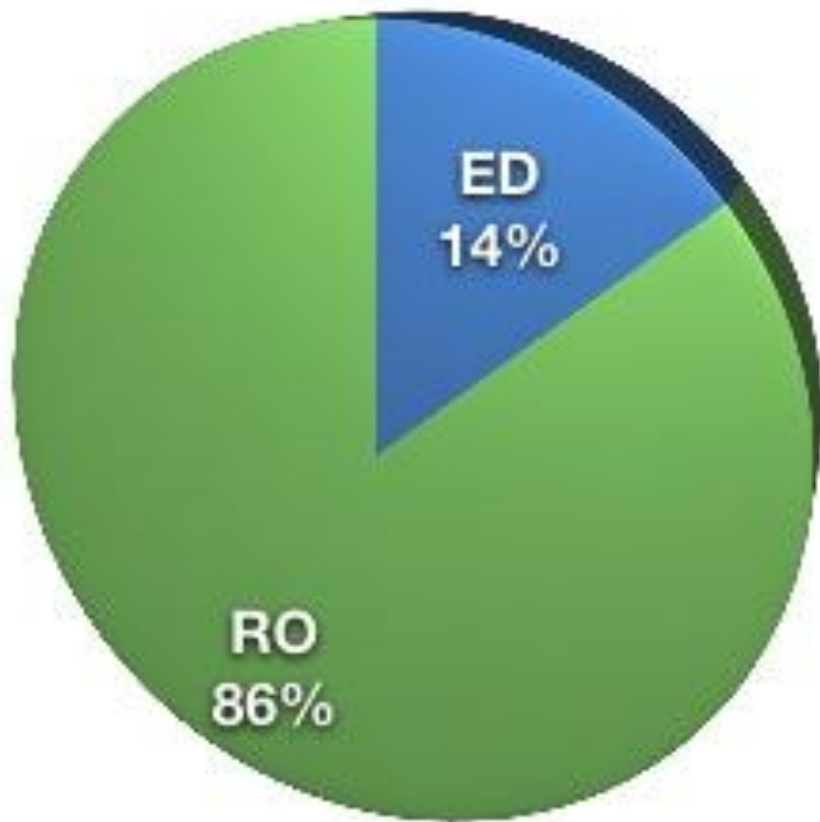
WATER PLANTS NEED ENERGY!



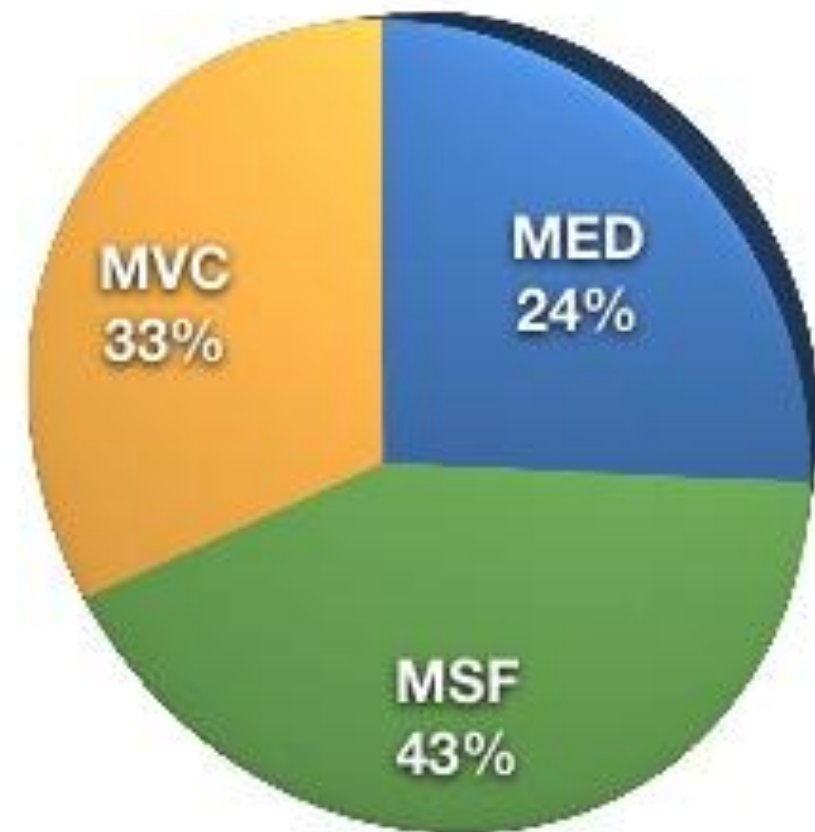
*Adelaide Australia*



## DESALINATION PLANTS USING GIVEN TECHNOLOGIES



**MEMBRANE PROCESSES**

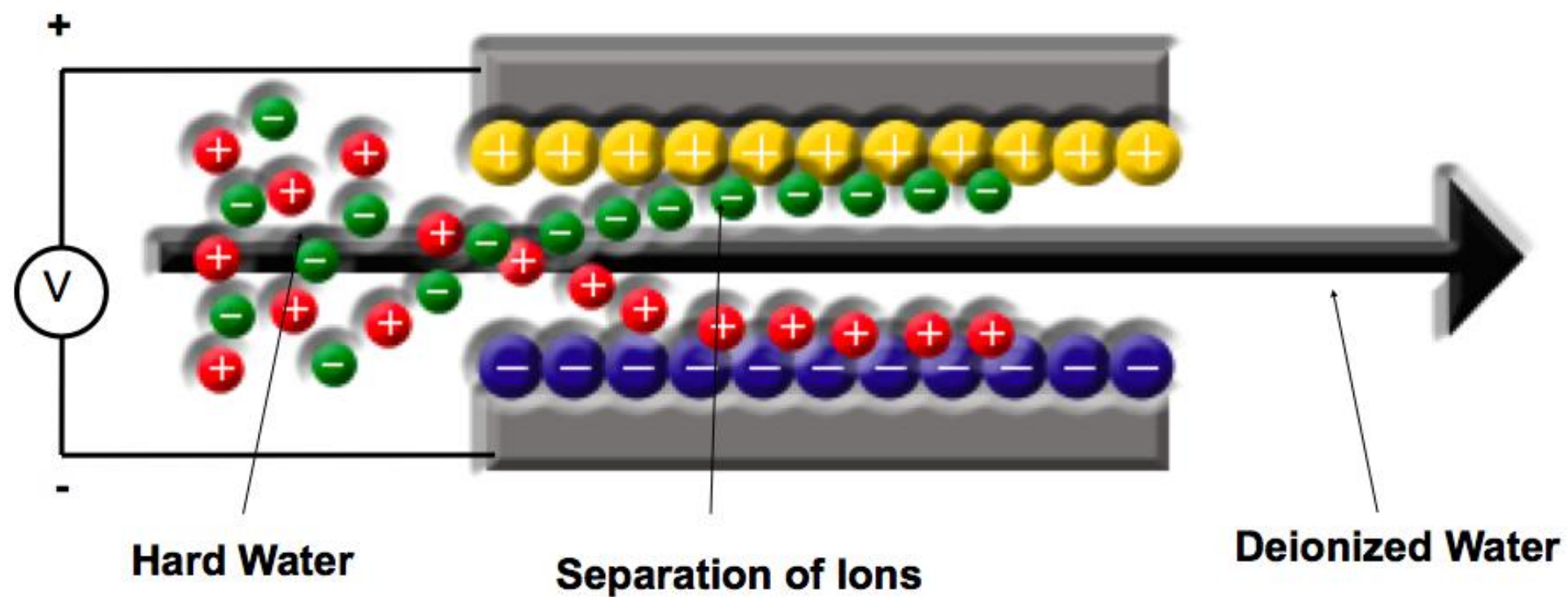


**THERMAL SYSTEMS**

DELIVER WATER  
&  
STORE ENERGY?



# CAPACITIVE DEIONIZATION!



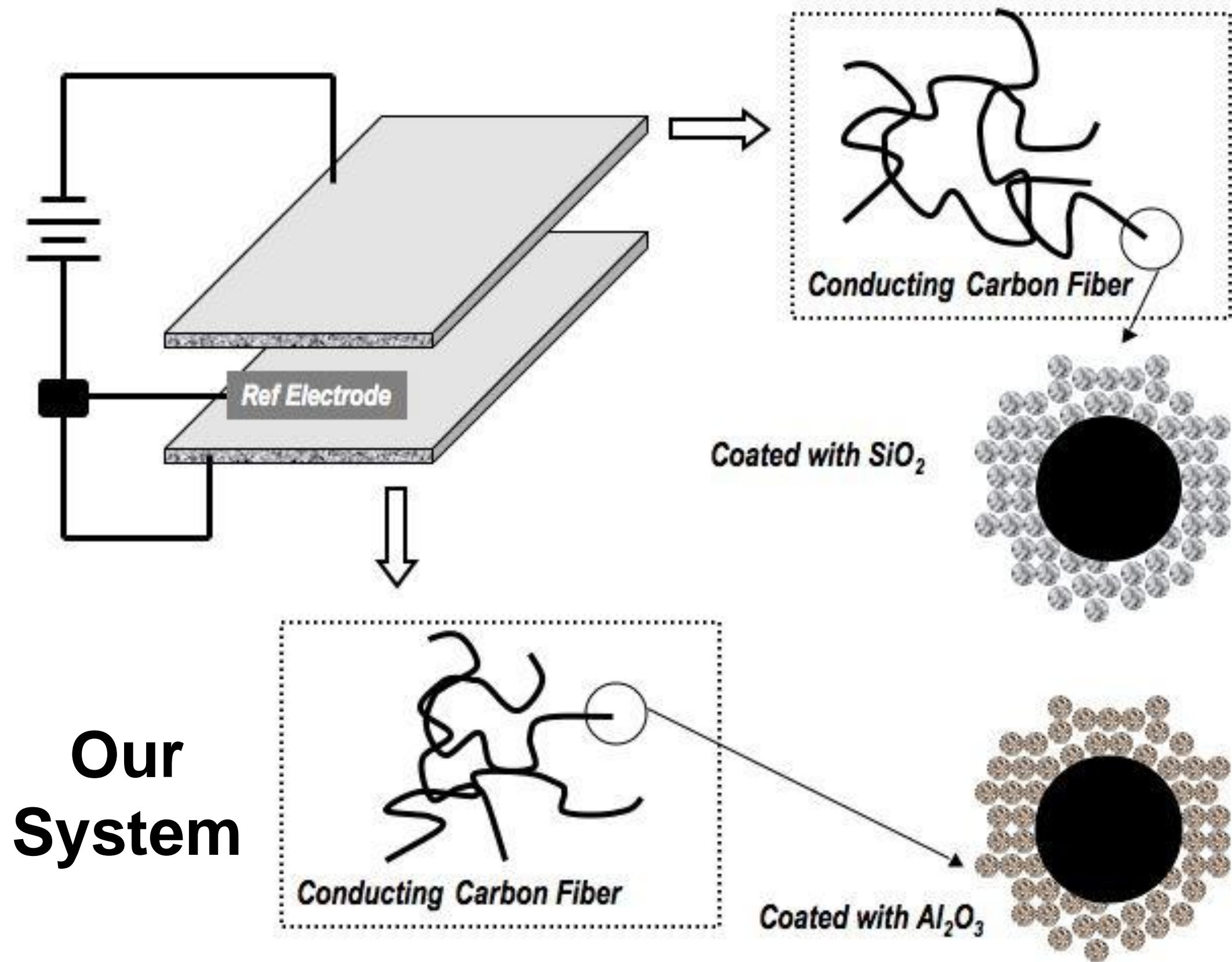
# History of CDI

Caudle et al 1960's

Oren et al 1970-1980's

Farmer et al 1990's

*FIFTY YEARS BUT NO COMMERCIAL SUCCESS ?*



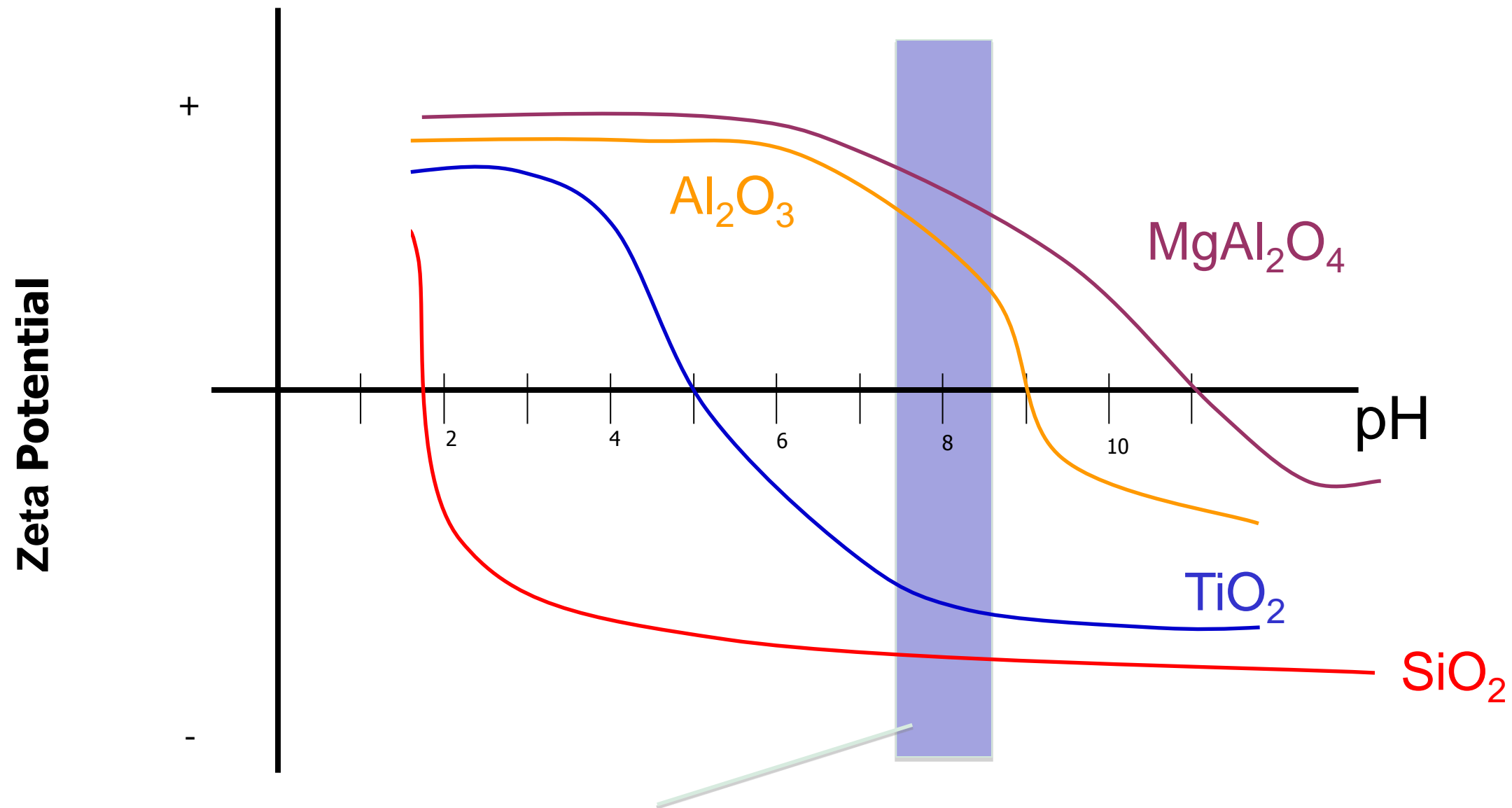


# Proton is a Potential Determining Ion



*THE PROTON HAS RETURNED!*

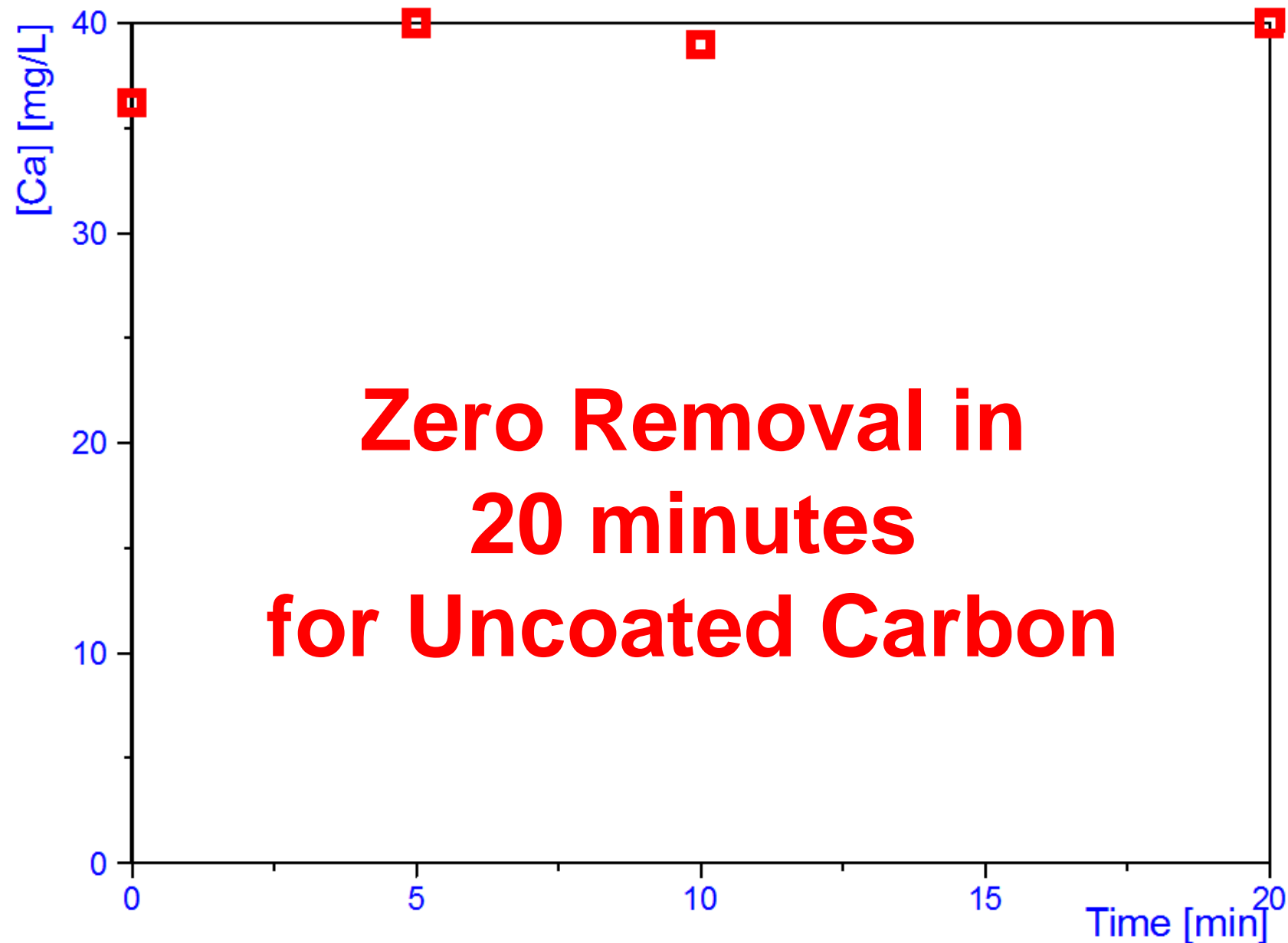
# Choosing Capacitor Materials



The pH range of Normal Waters.

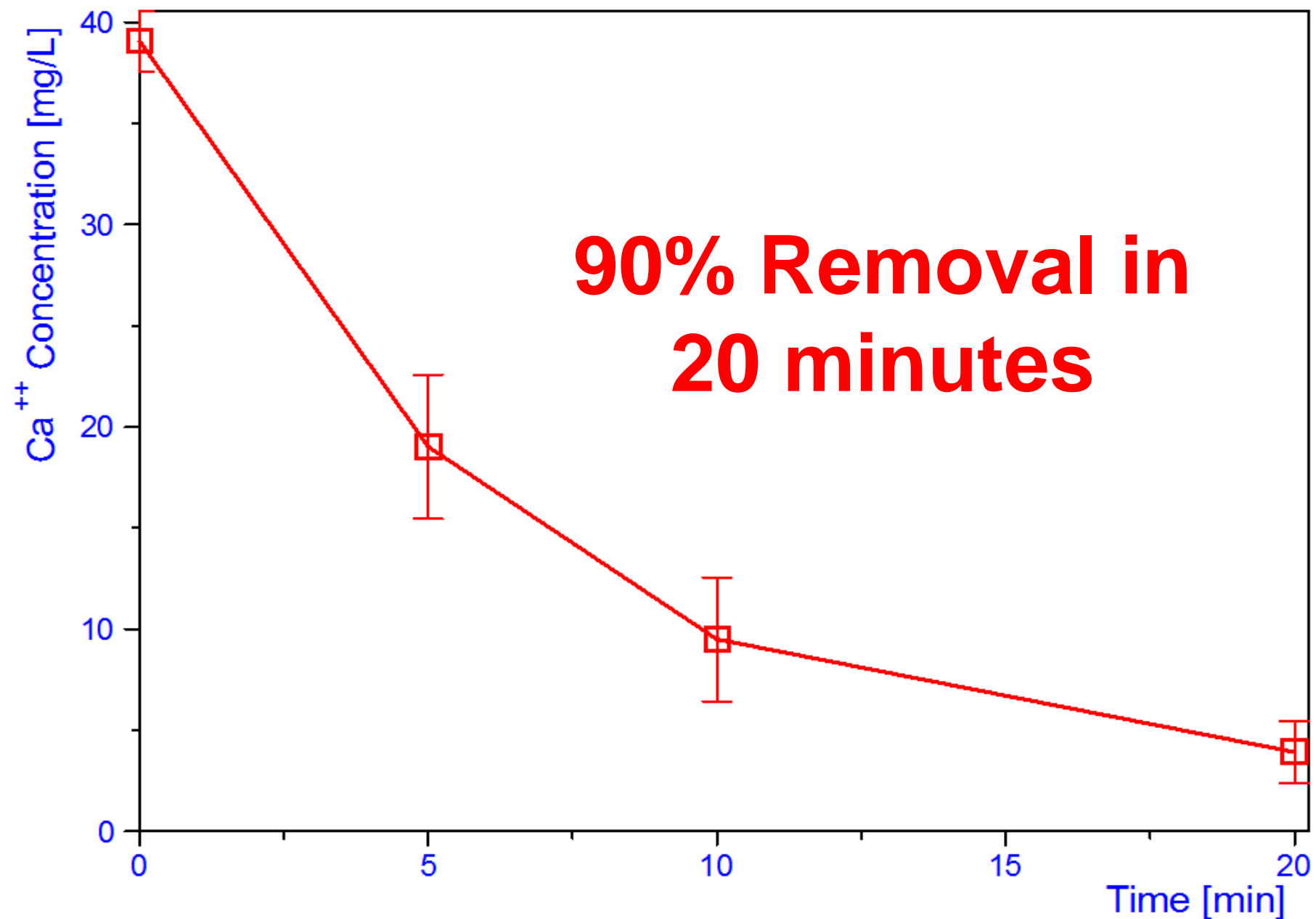
# CaCl<sub>2</sub> Removal

## How Effective is Coating?

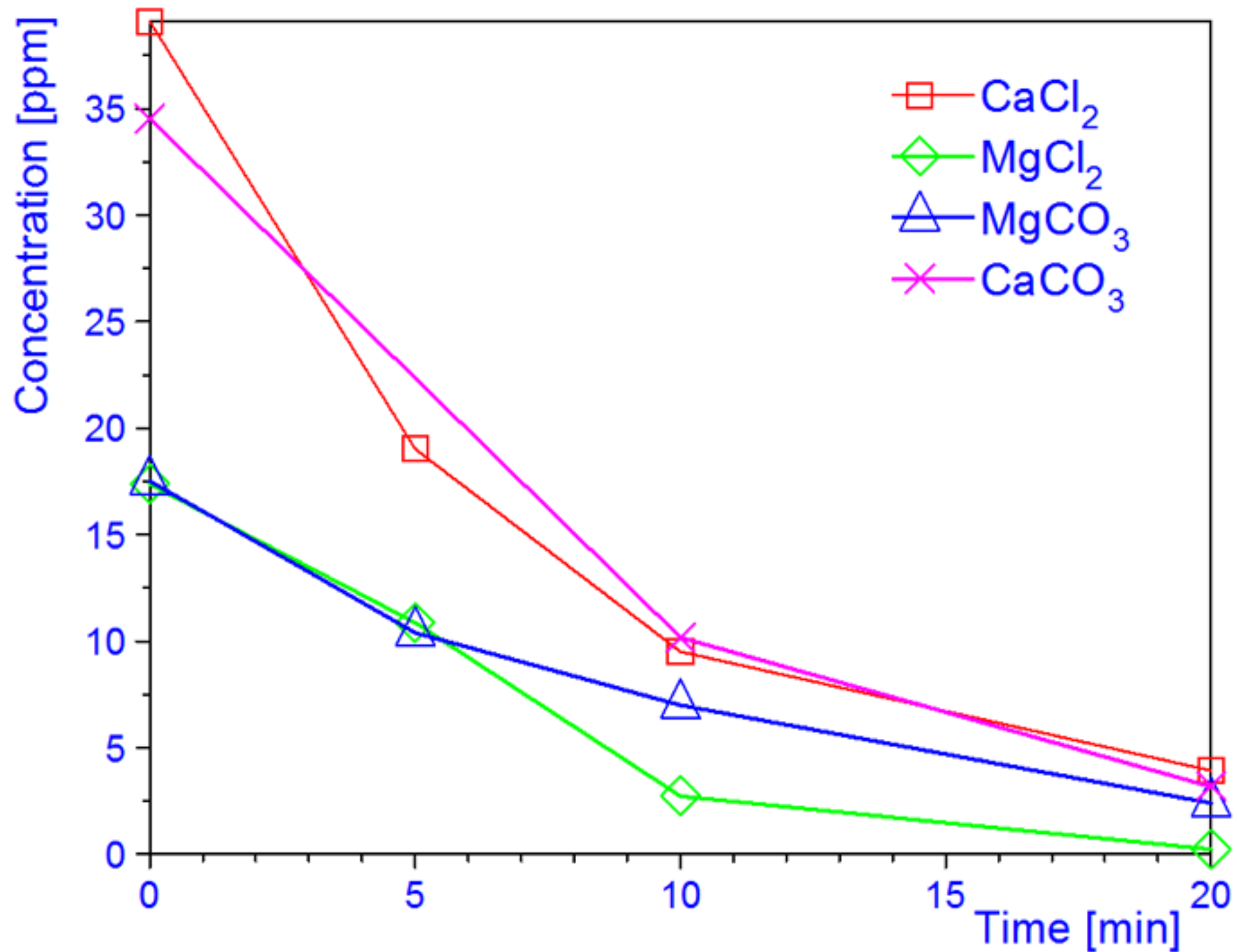




# CaCl<sub>2</sub> Removal with Coatings

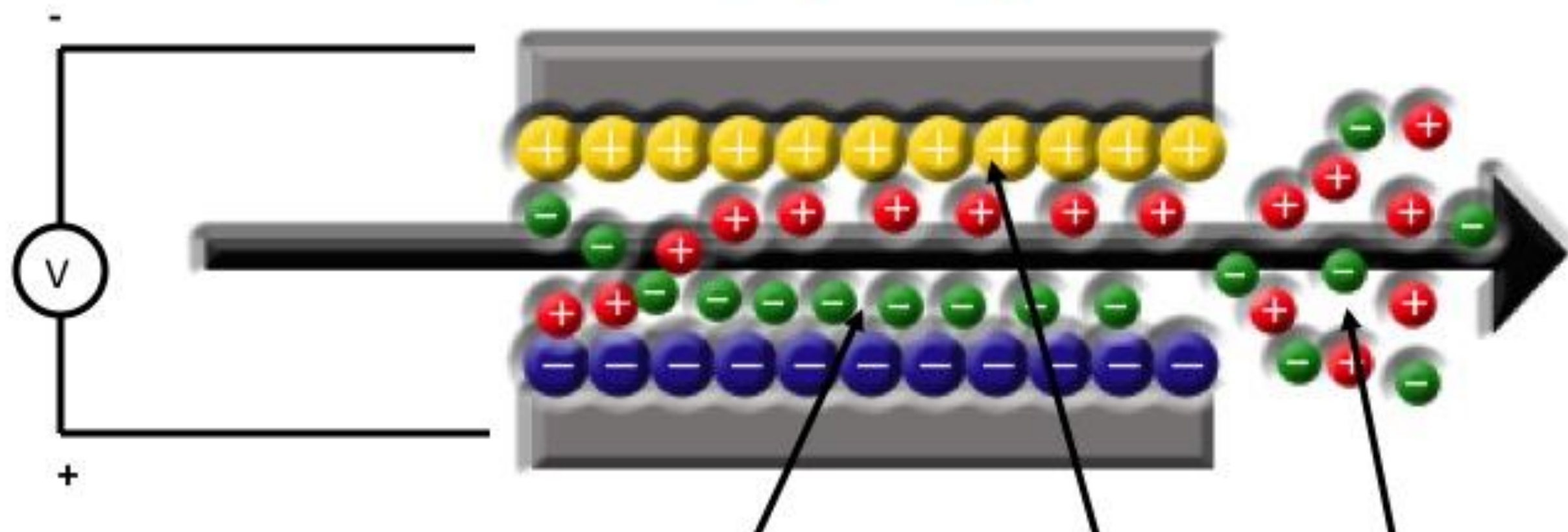


# Other Ion Removal



Note: Calcium is Difficult if Not Impossible to Remove with Carbon Aerogels Capacitive Systems!

Regeneration buy  
Reversing the Voltage!!

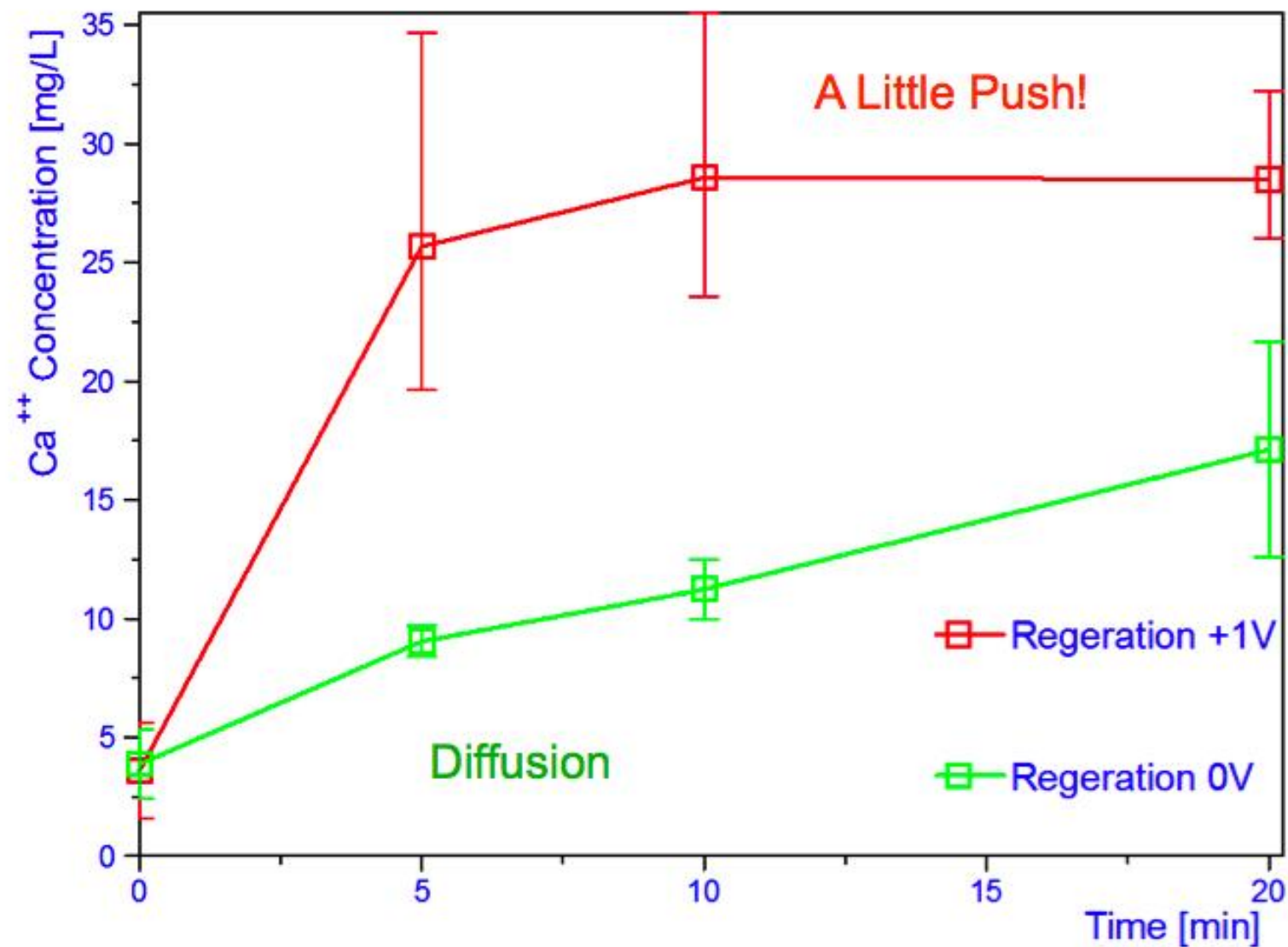


Repulsion Between Surface  
Charge and Ions

Flush Water



# CaCl<sub>2</sub> Regeneration



# CDI vs RO

*Reduced Energy (>30%)*

*Reduced Fouling (>60%)*

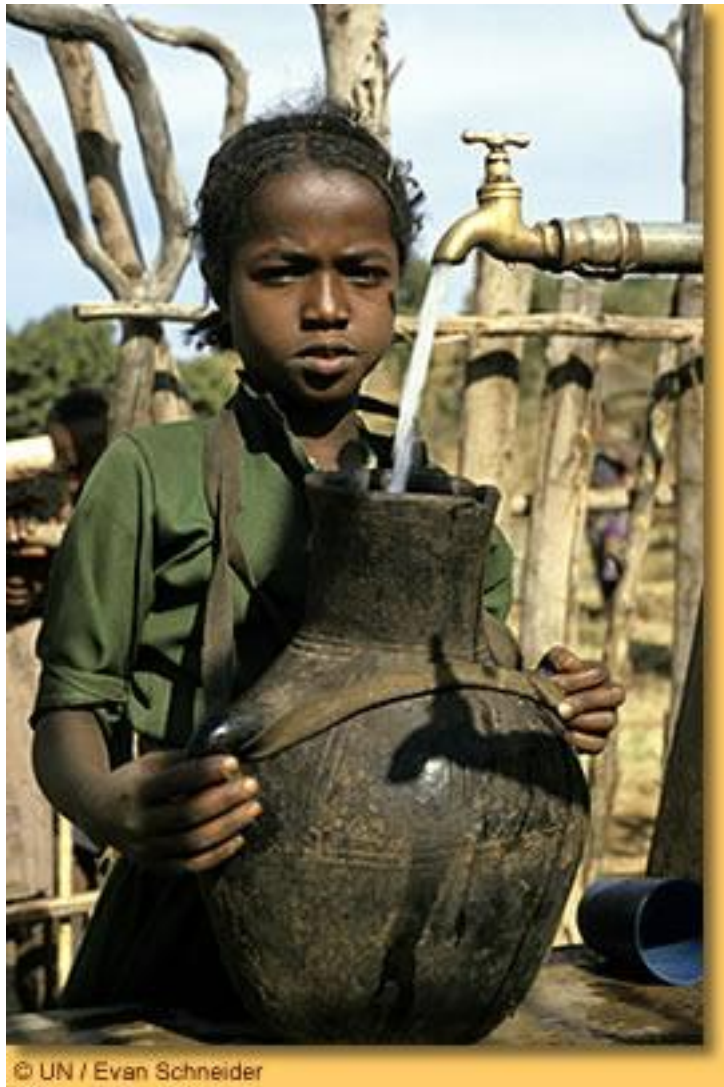
*Less Brine (>40%)*

*Low Maintenance Cost (>50%)*

*Higher Throughput (>70%)*

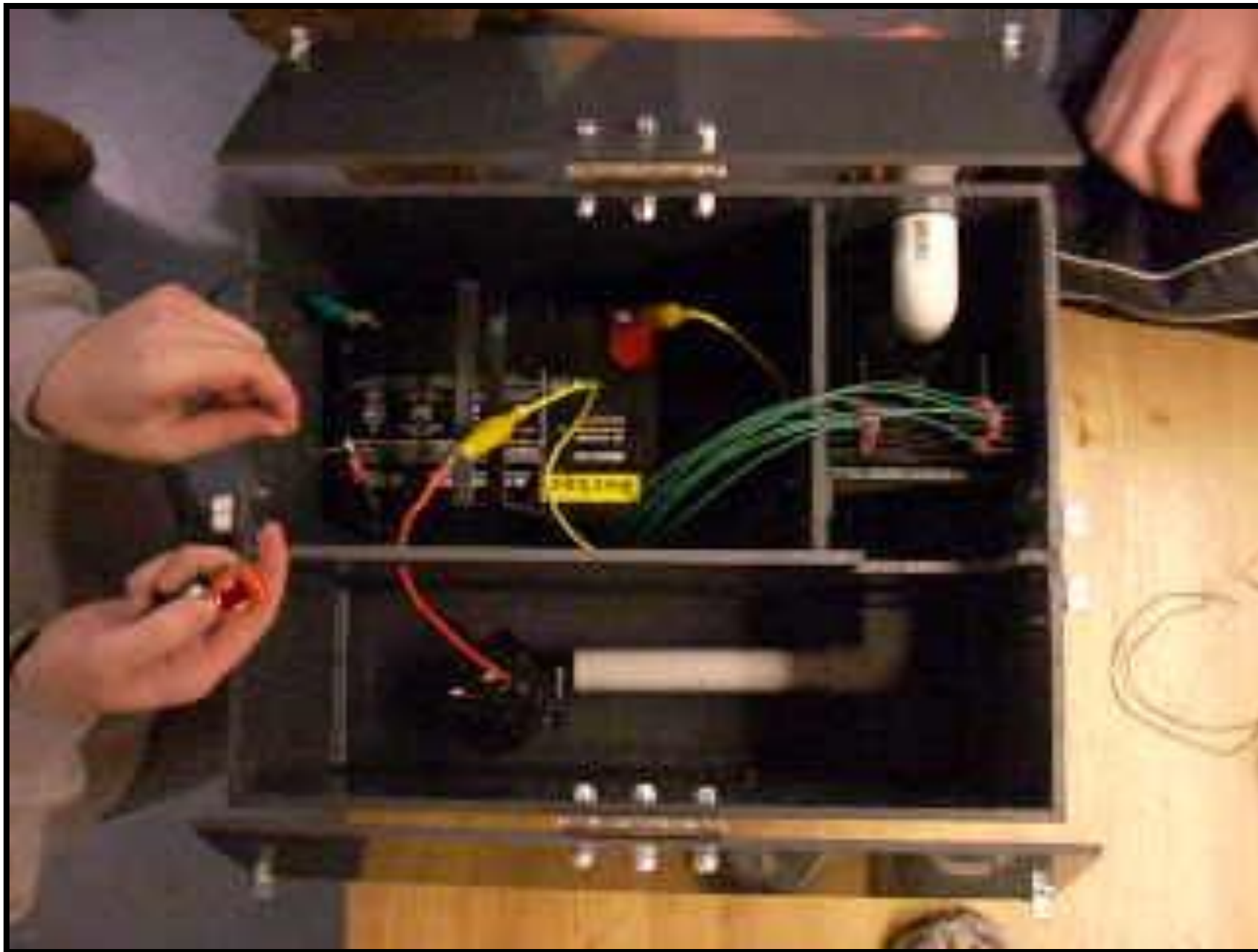
*Lower Capital Costs (>40%)*

# Third World Water





# Solar Powered CDI For A Family of Four





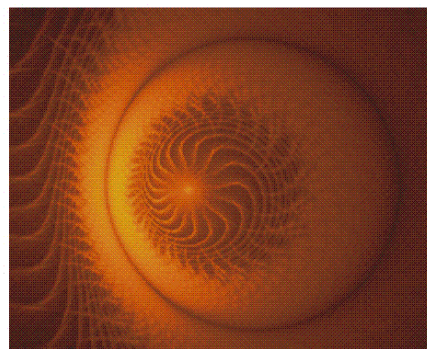
# Where Do We Go From Here?







THE UNIVERSITY  
of  
**WISCONSIN**  
MADISON



**imdea**  
energía



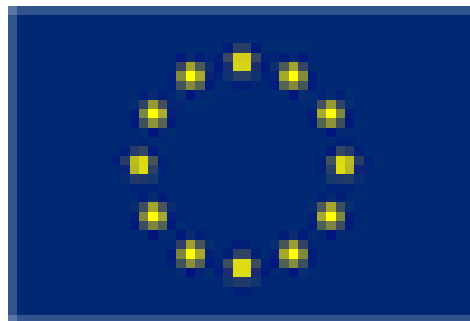
**PROINGESA**  
PROYECTOS, INGENIERÍA Y GESTIÓN S.A.







# Senior 5-Year Proposal





# To Be Continued . . .



*Marc A. Anderson*  
*Univ. of Wisconsin – Madison*  
*Imdea Energia - Madrid*  
**[www.marc-tech.com](http://www.marc-tech.com)**